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Back to Basics: A Bilingual Advantage in Infant Visual Habituation

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Comparisons of cognitive processing in monolinguals and bilinguals have revealed a bilingual advantage in inhibitory control. Recent studies have demonstrated advantages associated with exposure to two languages in infancy. However, the domain specificity and scope of the infant bilingual advantage in infancy remains unclear. In the present study, 114 monolingual and bilingual infants were compared in a very basic task of information processing—visual habituation—at 6 months of age. Bilingual infants demonstrated greater efficiency in stimulus encoding as well as in improved recognition memory for familiar stimuli as compared to monolinguals. Findings reveal a generalized cognitive advantage in bilingual infants that is broad in scope, early to emerge, and not specific to language.

Infants raised in a bilingual environment frequently impress in their ability to master two native languages with remarkable efficiency and apparent ease. Nevertheless, the learning burden placed upon a bilingual infant is substantial: Bilingual infants must differentiate their languages, associate sounds from each language with their conceptual correspondences, and establish independent control of two systems that often interact unpredictably. Mastering independent systems and alternating between languages have been hypothesized to sharpen an important component of cognition in bilinguals known as executive functioning.

In a substantial body of empirical research, superior abilities to manage stimuli that compete for attention have been evinced in bilingual learners (e.g., Bialystok, 1999; Bialystok, Craik, & Luk, 2008; Bialystok & Martin, 2004), commonly termed the *bilingual advantage*. Researchers have linked superior

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performance in bilinguals to components of the executive system (Bialystok, 2009; Carlson & Meltzoff, 2008; Miyake et al., 2000). To the extent that the executive system can be functionally partitioned, one of the key components of this system that is reportedly privileged in bilinguals is inhibitory control (Carlson & Meltzoff, 2008). Theoretical links between bilingualism and inhibitory control are forged on the grounds that bilingualism entails coactivation of both languages yet only one language can be produced at a time (Guttentag, Haith, Goodman, & Hauch, 1984). The bilingual therefore has to suppress production of the nontarget language in order to avoid cross-language intrusion (Bialystok, 2001).

It was traditionally presumed that the bilingual advantage emerged from sustained productive experience with two languages. However, a suite of recent studies reporting a bilingual advantage in preverbal infants suggest that mere exposure to two languages may confer advantages in inhibitory control upon young infants raised in bilingual environments. In tasks designed to measure inhibitory control in infants, bilingual infants outperformed their monolingual peers in adapting to a new set of rules in a conditioned response paradigm (Kovács & Mehler, 2009a) and in mastering two conflicting grammatical structures within a single session (Kovács & Mehler, 2009b). These studies reflect precocity in infant inhibitory control previously reported in bilingual adults and children. More recently, an infant bilingual advantage was reported in two studies that did not directly measure inhibitory control. In a visual speech discrimination task, Sebastián-Gallés, Albareda-Castellot, Weikum, and Werker (2012) demonstrated a bilingual advantage in language discrimination using visual cues alone. Most recently Gervain and Werker (2013) reported a bilingual advantage in rapid integration of pitch and duration cues in discerning word order within an artificial language.

The very notion of an infant bilingual advantage is seemingly difficult to reconcile with documented links between dual language production and inhibitory control. Previous accounts of the bilingual advantage in inhibitory control have appealed to the "productive bottleneck" as a basis for the bilingual advantage (Bialystok, 2009). Specifically, while it is apparent that both languages are available and activated in bilinguals when only one language is in use (Chee, 2006; Hernandez, Bates, & Avila, 1996; Marian, Spivey, & Hirsch, 2003), one language must be suppressed in order to produce the other. It has therefore been suggested that the continued productive use of two languages may enhance inhibitory control in bilinguals relative to monolinguals and lead to a bilingual advantage (Bialystok, 2009). This argument rests in part on evidence that individuals who do not need to suppress production of one language, speech-sign bilinguals, do not show expected bilingual advantages (Emmorey, Luk, Pyers, & Bialystok, 2008). It is therefore surprising that young infants with little, if any, experience in dual language production demonstrate an advantage in inhibitory control as a result of bilingual input.

Unlike the adult bilingual advantage, which has been heavily centered around inhibitory control (Martin-Rhee & Bialystok, 2008), investigations thus far of the infant bilingual advantage have been more diffuse in nature. Studies by Kovács and Mehler (2009a, 2009b) employed inhibitory control tasks, which are infant analogs to tasks that have evinced bilingual advantages in adults. In a different vein, Sebastián-Gallés, Albareda-Castellot, Weikum, and Werker (2012) focused on perceptual discrimination abilities revealing more acute discrimination abilities in bilinguals. In a third direction, Gervain and Werker's (2013) focus was on the potential for multiple-cue integration in discerning grammatical structure, revealing a flexible learning apparatus that readily adapts to the complexity of bilingual input. These findings are not incongruent: It stands to reason that a need to differentiate languages and to master two systems in tandem may foster a broad range of advantages including enhanced language discrimination reported by Sebastián-Gallés et al. (2012), inhibitory control advantages reported by Kovács and Mehler (2009a, 2009b) and foster a learning apparatus that opportunistically avails of all leading cues as reported by Gervain and Werker (2013). However, the relative diversity of tasks that have elicited an infant bilingual advantage raises important questions about the scope and specificity of this effect. In particular, it remains unclear whether the infant bilingual advantage mirrors the adult advantage in scope and specificity, or whether early advantages are more basic in form than those ascribed to bilingual adults.

Arguably, the most basic experimental test of information processing in infancy is visual habituation, which is widely exploited to assess generalized information encoding and retrieval in infants (Colombo, 1993). Visual habituation refers to the progressive reduction in an infant's response to a stimulus as a function of repeated presentation. The predictive validity of this paradigm has led to its rapid proliferation in infant cognition research (e.g., Bornstein & Ludemann, 1989; Bornstein, Pêcheux, & Lécuyer, 1988; Fagan & Singer, 1983). In spite of its apparent simplicity, infants' habituation patterns predict a number of long-term developmental outcomes, such as language comprehension and productive vocabulary in toddlers (Ruddy & Bornstein, 1982; Tamis-LeMonda & Bornstein, 1989), intelligence in early childhood (Bornstein & Sigman, 1986; Kavšek, 2004; McCall & Carriger, 1993; Rose, Slater, & Perry, 1986), and sophistication of play behavior in children (Tamis-LeMonda & Bornstein, 1989). Visual habituation has been shown to be a more powerful predictor of later intelligence than standardized tests such as the Bayley Scales of Infant Development (Colombo, 1993; McCall & Carriger, 1993; Slater, 1997). In the present study, bilingual and monolingual infants were compared in visual habituation in order to establish whether the efficiency of information encoding differs between monolingual and bilingual infants.

Method

Participants

The sample comprised 114 infants. The mean age of participants was 185 days (range = 173–189 days). There were 62 males and 52 female participants. There were 54 monolingual participants (27 males and 27 females) and 60 bilingual participants (35 males and 25 females). Participants were recruited as a part of the Growing Up in Singapore Today (GUSTO) birth cohort. Data from 10 additional infants were collected and discarded due to inattention during the test, resulting in the session having to be aborted prior to completion. Monolingualism was defined as having at least 90% exposure to a first language (English) and bilingualism was defined as having at least 25% exposure to a second language, as established in prior research (Pearson, Fernández, & Oller, 1993). Native languages for monolinguals and language pairings for bilinguals are listed in Table 1. All families were legally resident in the same city (Singapore) and all infants were Singaporean residents born in Singapore. Three ethnic groups (Chinese, Indian, and Malays) were each represented in the monolingual and bilingual samples (monolinguals: 32 Chinese, 10 Indian, and 12 Malay; bilinguals: 17 Chinese, 11 Indian, and 32 Malay). The mean proportion of second language exposure was 4% for monolinguals (range = 0%–10%) and 41% for bilinguals (range = 25%–50%). There were no significant differences between groups in terms of maternal income, $F(1, 108) = 1.3$, $p = .24$; household income, $F(1, 104) = 1.6$, $p = .2$; or maternal education, $F(1, 109) = .01$, $p = .91$ (see Table 2 for descriptive statistics). Groups were comparable in terms of city of residence, relevant demographic characteristics, and ethnic composition.

Table 1
Participants' Native Languages (Monolingual and Bilingual)

Monolingual native languages	
English	11
Mandarin	21
Malay	13
Tamil/Hindi	9
Bilingual language pairings	
English (L1)–Chinese (L2)	16
English (L1)–Tamil/Hindi/Bengali (L2)	12
English (L1)–Malay (L2)	32

Table 2
Maternal Education, Maternal Income, and Household Income for Monolingual and Bilingual Participants

	Years of postsecondary education (maternal; SEM)	Annual maternal income (SEM)	Annual household income (SEM)
Monolingual	2.64 (.13)	21,673 (2,243)	49,197 (2,445)
Bilingual	2.66 (.16)	25,295 (2,124)	45,238 (2,349)

Note. SEM = standard error of the mean.

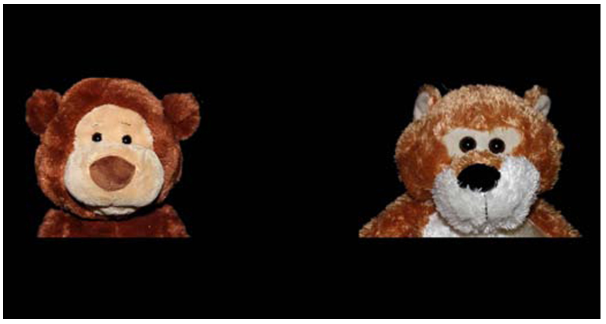

Figure 1. A photograph of the habituation stimuli.

Stimuli

The stimuli consisted of a colored image of a bear and a wolf, one of which served as the habituation stimulus and one as the novel stimulus (see Figure 1). The assignment of stimulus to familiarization versus novel stimuli was counterbalanced across participants.

Apparatus and Procedure

Parents sat in a chair placed in front of the monitor with their child on their lap and about 60 cm away from the monitor. During the habituation phase, infants were presented with successive presentations of a wolf or a bear. Trial length was based on infant's fixation to the stimulus. Fixation to the habituation stimulus was determined by the experimenter administering the session. Habituation trials ended when infants looked away for a minimum of 1 s. Fixation durations under 1 s resulted in a repetition of a trial. At the end of each trial, an attention getter was displayed to draw the infant's attention to the monitor. The attention getter was a beeping blue and white ball that expanded and contracted recursively, ranging in diameter between 4 and 23 cm (see Figure 1). There was a maximum of 20 habituation trials. Habituation was defined as the point at which fixation duration to the habituation stimulus of the last three trials decreased to less than 50% of the longest three consecutive trials, computed by HABIT X (Cohen, Atkinson, & Chaput, 2004). Following habituation, the test phase was initiated. Test trials consisted of two trials lasting 10 s each. In each test trial, the habituation and novel stimulus were presented side by side. Test trial data were coded offline and habituation phase data were obtained from the session record generated by HABIT X. Three experimenters independently coded the test phase, and interrater reliability was .94.

Language exposure of participants was determined via a Language Background Questionnaire (LBQ) administered to each parent comprising 16 detailed questions about children's language exposure. The LBQ comprised questions about the identity of the primary caregiver(s), the language(s) spoken by the parents and/or primary caregivers when addressing the child, as well as the proportion use of each language when addressing the child. The amount of time each caregiver spends with the child was also recorded.

Results

Experimental results were divided into the habituation and posthabituation (test) phases. All participants were included in the analysis of habituation phase data. However, only those who successfully habituated were included in test phase analyses. All descriptive statistics are reported in Table 3.

Table 3
Descriptive Statistics for Habituation and Test Phase

	Monolinguals (SEM)	Bilinguals (SEM)
Fixation time (habituation), s	74.29 (5.12)	76.89 (6.17)
Decrement (difference between first two and last two habituation trials), s	3.96 (.59)	6.49 (.66)
Slope (regression coefficient of habituation trajectory), s	−0.82 (.13)	−1.6 (.33)
Fixation to novel stimulus during test phase, s	6 (332)	7.4 (574)

Note. SEM = standard error of the mean; s = seconds.

Habituation Phase

During the habituation phase, monolingual infants fixated on the habituation stimulus for 74.3 s (SD = 37.64) and bilingual infants for 76.9 s (SD = 47.86). There were no differences in total fixation times for monolingual and bilingual infants, $t(112) = -.32$, $p = .75$. Ninety-five percent of the sample met the criteria for habituation within 20 trials. Further analyses were aimed at examining the nature of the habituation function in relation to language background. Variables typically employed to characterize the habituation function include slope (regression coefficient of the habituation trajectory), baseline (fixation times during the first two trials), and decrement in attention (decrease in attention between the first and last two habituation trials). Of these variables, the most common predictor of preschool developmental outcomes in visual habituation is amount of decrement in attention with larger decrements associated with more advanced performance in concept formation (Lewis, Goldberg, & Campbell, 1969), nonverbal cognitive outcomes (Miller et al., 1979), expressive language (Bornstein, 1985; Colombo, Shaddy, Richman, Maikranz, & Blaga, 2004), receptive language (Miller et al., 1979), standardized measures of IQ such as the Bayley Scales of Infant Intelligence (Colombo et al., 2004; Ruddy & Bornstein, 1982), and the Weschler Preschool and Primary Scale of Intelligence (Bornstein, 1985). In addition, the slope of the habituation function has been positively correlated with later performance on language and cognitive measures (e.g., Colombo & Mitchell, 1990; Gilmore & Thomas, 2002), although use of this measure as a predictor is less widespread than attentional decrement.

The dependent variables used for the habituation phase were decrement in attention and slope (regression coefficient of the habituation trajectory). A comparison of total decrement (fixation time to last two habituation trials subtracted from fixation to first two habituation trials) revealed an effect of language group on decrement with greater attentional decrement during the habituation phase observed in bilinguals compared to monolinguals, $t(112) = 2.86$, $p = .005$, Cohen's $d = .54$. In addition to decrement, the slope of the habituation function was compared for monolinguals and bilinguals, revealing larger negative values (steeper slopes) for bilinguals as compared to monolinguals, $t(112) = 2.1$, $p = .04$, Cohen's $d = .39$ (see Table 3 for descriptive statistics).

Follow-up analyses were designed to investigate effects of language background on habituation behavior within the monolingual and bilingual groups. Within the monolingual group, participants were either exposed exclusively to English ($n = 11$), Mandarin ($n = 21$), Malay ($n = 13$), or an Indian language ($n = 9$). There was no effect of native language on decrement, $F(3, 50) = .52$, $p = .67$, or slope, $F(3, 50) = .52$, $p = .67$, of the habituation function. Within the bilingual group, participants were learning either English and Mandarin ($n = 16$), English and an Indian language ($n = 12$), or English and Malay ($n = 32$). There were no effects of language pairings on attentional decrement, $F(2, 57) = .46$, $p = .63$, or slope, $F(2, 57) = .47$, $p = .63$ (see Figure 2).

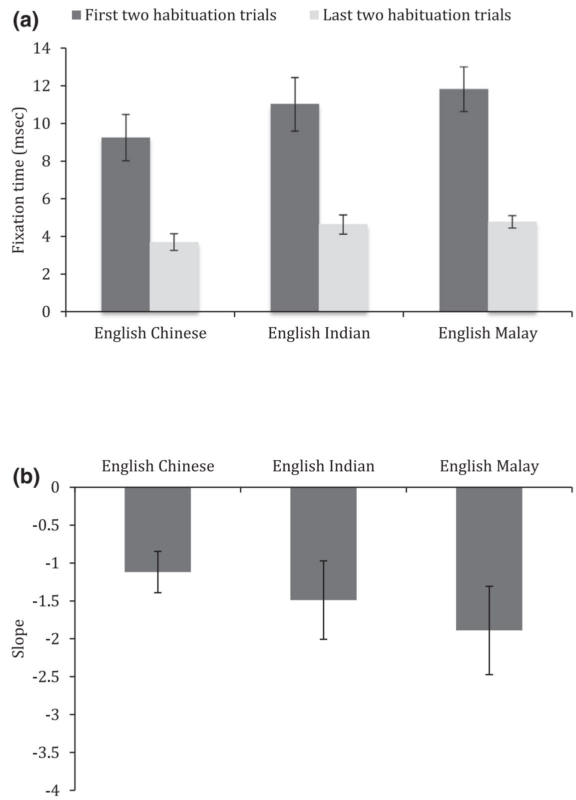

Figure 2. (a) Fixation times for first and last two habituation trials for each language pairing (error bars: standard error of the mean). (b) Slope of the habituation function for each language pairing (error bars: standard error of the mean).

Test Phase

Data from infants who did not habituate within the 20-trial maximum were excluded from test phase analyses (5% of the sample). Analyses from the test phase were computed for the remaining 95% of the sample and focus on recognition memory for the habituation stimulus. This is typically reflected in a novelty preference, which has been associated with improved performance on later IQ and vocabulary measures during the preschool and school-aged years (Lewis & Brooks-Gunn, 1981; Rose, Feldman, Wallace, & Cohen, 1991). Novelty preference scores were calculated by examining the proportion of the test phase spent fixating to the novel stimulus. Bilingual infants fixated to the novel stimulus for an average of 7.4 s ($SD = 4.4$ s), which was 37% of the total duration of the test phase (maximum fixation time = 20 s). Monolinguals fixated the novel stimulus for an average of 6 s ($SD = 2.4$ s), which was 30% of the total duration of the test phase. An independent sample t test confirmed that bilingual infants fixated to the novel stimulus during the test phase for a greater proportion of the test phase than monolingual infants, $t(112) = -2.09$, $p = .04$, Cohen's $d = -.39$.

Discussion

The aim of the present study was to determine whether the bilingual infants demonstrate basic information-processing advantages as compared to monolingual infants. Visual habituation has long been heralded as the prevailing measure of the capacity for simple learning in infants (Fantz, 1964). The present set of findings demonstrates that bilingual infants outperform their monolingual peers in the efficiency with which they habituate to a stimulus and in visual recognition memory of the habituation stimulus.

The current set of findings advance our understanding of bilingualism in two important ways. First, this study demonstrates an infant bilingual advantage in basic processing of nonlinguistic visual information. Each of the previous reports of an infant bilingual advantage employed tasks thought to link directly to the demands of learning two languages (Gervain & Werker, 2013; Kovács & Mehler, 2009a, 2009b; Sebastián-Gallés et al., 2012). Specifically, studies by Kovács and Mehler (2009a, 2009b) employed statistical learning paradigms widely exploited to understand how infants extract grammatical and phonological adjacencies from the input in the service of language learning (e.g., Saffran, 2003). Sebastián-Gallés et al. (2012) and Gervain and Werker (2013) investigated infants' abilities to visually differentiate two languages and to learn dual grammatical structures, respectively. From the visual habituation employed here, it appears that bilingual infants possess an advanced capacity to rapidly form internal memory representations of a novel visual stimulus. In addition, recognition memory of a novel stimulus was enhanced in bilingual infants relative to monolingual infants.

These findings point to a fundamental cognitive advantage in bilingual infants that indicates precocity in a basic capacity to learn in addition to previously reported advantages in executive function, language discrimination based on visual cues, and grammatical acquisition using prosodic cues. Although previous studies demonstrating an infant bilingual advantage trained their spotlight on the inhibitory control advantages commonly attested in adults (Kovács & Mehler, 2009a, 2009b) or on processing of linguistic stimuli (Gervain & Werker, 2013; Sebastián-Gallés et al., 2012), the current study provides evidence for an earlier bilingual advantage that is more task and construct general than previously suggested. In toddlers, there has been evidence for a bilingual advantage in memory for nonlinguistic events reported by Brito and Barr (2012), where the authors demonstrated enhanced memory capacity in bilinguals using a deferred imitation task. A fundamental advantage in information uptake and encoding in bilingual infants at 6 months suggests that the scope of the infant bilingual advantage may be much broader than originally construed.

An important question to arise from the current findings is why bilingualism may lend itself to information-processing advantages. Here, we address three possibilities. First, it is possible that dual language processing mandates and therefore enhances information-processing efficiency to a greater extent than single-language processing. In considering the learning burden placed on the bilingual infant, Werker (2012) identifies two important unique aspects of bilingual acquisition, the first of which has been widely addressed yet the second has received relatively little attention. First, bilingual learners must distinguish languages and minimize interference across languages. The consequences of managing attention across dual streams of information has been extensively researched in bilingualism and associated with a bilingual advantage in inhibitory control (Bialystok, 2001; Kovács & Mehler, 2009a, 2009b). However, a second point raised by Werker (2012) and several others (e.g., Genesee, 2001; Meisel, 2001; Nicoladis & Genesee, 1997; Paradis & Genesee, 1996) is that bilingual learners receive reduced exposure to each language, yet are equipped with the same cognitive machinery. They are faced with the same eventual expectations of language proficiency, at least in the dominant language. Longitudinal studies attest to the fact that monolingual and bilingual children attain single-language gross linguistic milestones (e.g., first word, first phrase) at similar time points in spite of this reduction in the quantum of single-language input (Pearson et al., 1993; Werker, 2012). The combination of reduced input within each language and an equivalent learning window may enhance the efficiency with which information is encoded and processed within the bilingual learner, analogous to the ways in which effects of dual-language exposure have been hypothesized to improve executive function.

Second, it is possible that linguistic diversity is enhanced in bilingual input and that this may enhance the detection of novelty. Bilingual input necessarily encompasses two distinct linguistic systems. It is therefore likely that linguistic diversity within bilingual input exceeds that of monolingual input such that bilingual infants may encounter more novel linguistic information than monolingual peers. Certainly, productive differences in lexical diversity have been reported in bilinguals versus monolinguals, with bilinguals reported to possess more diverse lexica—a greater number of different words—than monolinguals (Oller & Pearson, 2002; Pearson et al., 1993). Although speculative, it is also possible that the broader sociocultural environment of the bilingual child may encompass more novelty than that of the monolingual child. Increased exposure to novelty, broadly construed, may enhance the efficiency with which new information is handled in the bilingual child. Just as advantages in infant inhibitory control are associated with alternating between two languages (Kovács & Mehler, 2009a) and bilingual infants' ability to spontaneously attend to and encode a greater diversity of cues has been linked to the increased structural complexity of bilingual input (Gervain & Werker, 2013), it is possible that the efficiency with which information is encoded is a reflection of the increased amount of new information typically confronting the bilingual infant.

Finally, it is possible that an information-processing advantage in bilingualism is rooted in individual differences in inhibitory control, previously linked to the demands of bilingual acquisition. It is acknowledged that there are principal components of the habituation cycle (orienting response, attentional engagement, termination of attention; Richards & Casey, 1991) and that the last phase, termination of attention, may be dependent on the capacity to inhibit attention to the focal point and to direct it elsewhere (Colombo, 1993; McCall, 1994). Inhibitory control of attention has been implicated as a strong basis for continuity between visual habituation and adult measures of intelligence (McCall, 1994). It is possible that an early emergent capacity for inhibitory control is evident in infant bilinguals and these early advantages are observed for visual as well as linguistic stimuli. In comparison to previous demonstrations of advanced inhibitory control in infant bilinguals, the current study suggests that such advantages may be evident upon the first encounter with a stimulus in addition to when a previously learned stimulus needs to be "unlearned" (e.g., Kovács & Mehler, 2009a, 2009b). Whether the relation between bilingual exposure and information processing is a direct one or mediated by inhibitory control cannot be ascertained from the current study due to the fact that a direct relation between language exposure and visual fixation patterns cannot be presumed. However, previous efforts to "parse" the habituation cycle into its constituent phases have successfully yoked distinct heart-rate correlates to the intermediate phase (attentional engagement) thought to reflect stimulus encoding. By contrast, processing in the final phase—termination of attention—is thought to reflect the inhibition of attention (Colombo, Richman, Shaddy, Follmer Greenhoot, & Maikranz, 2001; Colombo et al., 2004). A targeted examination of the stage at which heart-rate proxies of stimulus encoding and inhibition of attention differ between monolinguals and bilinguals may help to identify the locus of the infant bilingual advantage in visual habituation and specifically, whether it implicates an information-processing advantage or an inhibitory control advantage or both.

A second contribution of this study is that infants exposed to two languages recognize the familiar object with greater accuracy than infants exposed to single language input, as indexed by a novelty preference for the unfamiliar object. Like habituation, recognition memory in a visual paired comparison procedure is construed as a basic information-processing skill and a well-established predictor of later intelligence (Fagan, 1990, 2000; Fagan, Holland, & Wheeler, 2007; Thompson, Fagan, & Fulker, 1991). It remains a matter of theoretical debate whether habituation and novelty preference are related or independent constructs. Empirically, there is sparse evidence for a correlation between the two (Kavšek, 2004). Theoretically, many researchers have defined habituation behavior and novelty preference as measures of two distinct latent functions, resulting in a two-factor model of visual habituation (Colombo, 1993). In the current data set, there was no association between habituation measures and novelty preference, suggesting independent contributions of each measure to the infant bilingual advantage. When evaluating cognitive processes that underlie a novelty preference, it has been suggested that a novelty preference for an unfamiliar stimulus is an outgrowth of inhibition of attention toward the familiarized stimulus more so than processing of the novel stimulus (McCall, 1994). As such, the bilingual advantage observed during the test phase may be directly related to previously reported advantages in inhibitory control or its precursors (e.g., Kovács & Mehler, 2009a, 2009b; Sebastián-Gallés et al., 2012) in contrast to the bilingual advantage observed here during habituation.

The current study suggests that the infant bilingual advantage may assume a more basic form than prior studies would suggest. As noted by Colombo and Mitchell (2009), infant visual habituation is not a primary or fundamental component of mature intelligence but rather a building block for learning upon which the potential for higher order intelligence may rest. As a result, habituation may predict facility with inhibitory control tasks, as suggested by longitudinal relations observed between infant visual habituation and executive function abilities in young adulthood (Sigman, Cohen, & Beckwith, 1997). Therefore, the bilingual advantage in infant visual habituation may reflect precocity in simple learning that potentiates growth in other cognitive domains. Unlike previous reports of an infant bilingual advantage, the current task does not link directly to the demands of language processing and engages fundamental cognitive processes using a nonlinguistic mode of presentation. In conclusion, early bilingual exposure may exercise generalized cognitive primitives that may prove useful in a multiplicity of emergent abilities, including the successful acquisition of two languages.

References

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development*, *70*, 636–644. doi:10.1111/1467-8624.00046

Bialystok, E. (2001). Metalinguistic aspects of bilingual processing. *Annual Review of Applied Linguistics*, *21*, 169–181. doi:10.1017/S0267190501000101

Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and Cognition*, *12*, 3–11. doi:10.1017/S1366728908003477

Bialystok, E., Craik, F. I. M., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*, 859–873. doi:10.1037/0278-7393.34.4.859

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental Science*, *7*, 325–339. doi:10.1111/j.1467-7687.2004.00351.x

Bornstein, M. H. (1985). Habituation of attention as a measure of visual information processing in human infants: Summary, systematization, and synthesis. In G. Gottlieb & N. A. Krasnegor (Eds.), *Measurement of vision and audition in the first year of life* (pp. 253–301). Norwood, NJ: Ablex.

Bornstein, M. H., & Ludemann, P. L. (1989). Habituation at home. *Infant Behavior and Development*, *12*, 525–529. doi:10.1016/0163-6383(89)90031-3

Bornstein, M. H., Pêcheux, M.-G., & Lécuyer, R. (1988). Visual habituation in human infants: Development and rearing circumstances. *Psychological Research*, *50*, 130–133. doi:10.1007/BF00309213

Bornstein, M. H., & Sigman, M. S. (1986). Continuity in mental development from infancy. *Child Development*, *57*, 251–274. doi:10.2307/1130581

Brito, N., & Barr, R. (2012). Influence of bilingualism on memory generalization during infancy. *Developmental Science*, *15*, 812–816. doi:10.1111/j.1467-7687.2012.1184.x

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*, 282–298. doi:10.1111/j.1467-7687.2008.00675.x

Chee, M. W. L. (2006). Dissociating language and word meaning in the bilingual brain. *Trends in Cognitive Science*, *10*, 527–529. doi:10.1016/j.tics.2006.09.009

Cohen, L. B., Atkinson, D. J., & Chaput, H. H. (2004). *Habit X: A new program for obtaining and organizing data in infant perception and cognition studies (Version 1.0)*. Austin: University of Texas.

Colombo, J. (1993). *Infant cognition: Predicting later intellectual functioning*. Newbury Park, CA: Sage.

Colombo, J., & Mitchell, D. W. (1990). Individual differences in early visual attention: Fixation time and information processing. In J. Colombo & J. W. Fagen (Eds.), *Individual differences in infancy: Reliability, stability, prediction* (pp. 193–227). Hillsdale, NJ: Erlbaum.

Colombo, J., & Mitchell, D. W. (2009). Infant visual habituation. *Neurobiology of Learning and Memory*, *92*, 225–234. doi:10.1016/j.nlm.2008.06.002

Colombo, J., Richman, W. A., Shaddy, D. J., Follmer Greenhoot, A., & Maikranz, J. M. (2001). Heart rate-defined phases of attention, look duration, and infant performance in the paired-comparison paradigm. *Child Development*, *72*, 1605–1616. doi:10.1111/1467-8624.00368

Colombo, J., Shaddy, D. J., Richman, W. A., Maikranz, J. M., & Blaga, O. (2004). Developmental course of visual habituation and preschool cognitive and language outcome. *Infancy*, *5*, 1–38. doi:10.1207/s15327078in0501_1

Emmorey, K., Luk, G., Pyers, J. E., & Bialystok, E. (2008). The source of enhanced cognitive control in bilinguals: Evidence from bimodal bilinguals. *Psychological Science*, *19*, 1201–1206. doi:10.1111/j.1467-9280.2008.02224.x

Fagan, J. F. (1990). The paired-comparison paradigm and infant intelligence. In A. Diamond (Ed.), *Annals of the New York Academy of Sciences: Vol. 68. The development and neural bases of higher cognitive functions* (pp. 337–364). New York: New York Academy of Sciences. doi:10.1111/j.1749-6632.1990.tb48902.x

Fagan, J. F. (2000). A theory of intelligence as processing: Implications for society. *Psychology, Public Policy, and Law*, *6*, 168–179. doi:10.1037/1076-8971.6.1.168

Fagan, J. F., Holland, C. R., & Wheeler, K. (2007). The prediction, from infancy, of adult IQ and achievement. *Intelligence*, *35*, 225–231. doi:10.1016/j.intell.2006.07.007

Fagan, J. F., & Singer, L. T. (1983). Infant recognition memory as a measure of intelligence. In L. P. Lipsitt (Ed.), *Advances in infancy research* (Vol. 2, pp. 31–78). Norwood, NJ: Ablex.

Fantz, R. L. (1964). Visual experience in infants: Decreased attention to familiar patterns relative to novel ones. *Science*, *146*, 668–670. doi:10.1126/science.146.3644.668

Genesee, F. (2001). Bilingual first language acquisition: Exploring the limits of the language faculty. In M. McGroarty (Ed.), *21st annual review of applied linguistics* (pp. 153–168). Cambridge, UK: Cambridge University Press.

Gervain, J., & Werker, J. F. (2013). Prosody cues word order in 7-month-old bilingual infants. *Nature Communications*, *4*, Article 1490. doi:10.1038/ncomms2430

Gilmore, R. O., & Thomas, H. (2002). Examining individual differences in infants' habituation patterns using objective quantitative techniques. *Infant Behavior & Development*, *25*, 399–412. doi:10.1016/S0163-6383(02)00142-X

Guttentag, R. E., Haith, M. M., Goodman, G. S., & Hauch, J. (1984). Semantic processing of unattended words by bilinguals: A test of the input switch mechanism. *Journal of Verbal Learning and Verbal Behavior*, *23*, 178–188. doi:10.1016/S0022-5371(84)90126-9

Hernandez, A. E., Bates, E., & Avila, L. X. (1996). Processing across the language boundary: A cross-modal priming study of Spanish-English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *22*, 846–864. doi:10.1037/0278-7393.22.4.846

Kavšek, M. (2004). Predicting later IQ from infant visual habituation and dishabituation: A meta-analysis. *Journal of Applied Developmental Psychology*, *25*, 369–393. doi:10.1016/j.appdev.2004.04.006

Kovács, Á. M., & Mehler, J. (2009a). Flexible learning of multiple speech structures in bilingual infants. *Science*, *325*, 611–612. doi:10.1126/science.1173947

Kovács, Á. M., & Mehler, J. (2009b). Cognitive gains in 7-month-old bilingual infants. *Proceedings of the National Academy of Sciences of the United States of America*, *106*, 6556–6560. doi:10.1073/pnas.0811323106

Lewis, M., & Brooks-Gunn, J. (1981). Visual attention at three months as a predictor of cognitive functioning at two years of age. *Intelligence*, *5*, 131–140. doi:10.1016/0160-2896(81)90003-9

Lewis, M., Goldberg, S., & Campbell, H. (1969). A developmental study of information processing within the first three years of life: Response decrement to a redundant signal. *Monographs of the Society for Research in Child Development*, *34*(9, Serial No. 133). doi:10.2307/1165696

Marian, V., Spivey, M., & Hirsch, J. (2003). Shared and separate systems in bilingual language processing: Converging evidence from eyetracking and brain imaging. *Brain and Language*, *86*, 70–82. doi:10.1016/S0093-934X(02)00535-7

Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition*, *11*, 81–93. doi:10.1017/S1366728907003227

McCall, R. B. (1994). What process mediates predictions of childhood IQ from infant habituation and recognition memory? Speculations on the roles of inhibition and rate of information processing. *Intelligence*, *18*, 107–125. doi:10.1016/0160-2896(94)90022-1

McCall, R. B., & Carriger, M. S. (1993). A meta-analysis of infant habituation and recognition memory performance as predictors of later IQ. *Child Development*, *64*, 57–79. doi:10.1111/j.1467-8624.1993.tb02895.x

Meisel, J. M. (2001). The simultaneous acquisition of two-first languages: Early differentiation and subsequent development of grammars. In J. Cenoz & F. Genesee (Eds.), *Trends in bilingual acquisition* (pp. 11–41). Amsterdam, Netherlands: Benjamins.

Miller, D. J., Ryan, E. B., Aberger, E., McGuire, M. D., Short, E. J., & Kenny, D. A. (1979). Relationships between assessments of habituation and cognitive performance in the early years of life. *International Journal of Behavioral Development*, *2*, 159–170. doi:10.1177/016502547900200204

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100. doi:10.1006/cogp.1999.0734

Nicoladis, E., & Genesee, F. (1997). Language development in preschool bilingual children. *Journal of Speech-Language Pathology and Audiology*, *21*, 258–270.

Oller, D. K., & Pearson, B. Z. (2002). Assessing the effects of bilingualism: A background. In D. K. Oller & R. E. Eilers (Eds.), *Language and literacy in bilingual children* (pp. 3–21). Clevedon, UK: Multilingual Matters.

Paradis, J., & Genesee, F. (1996). Syntactic acquisition in bilingual children: Autonomous or interdependent? *Studies in Second Language Acquisition*, *18*, 1–25. doi:10.1017/S0272263100014662

Pearson, B. Z., Fernández, S. C., & Oller, D. K. (1993). Lexical development in bilingual infants and toddlers: Comparison to monolingual norms. *Language Learning*, *43*, 93–120. doi:10.1111/j.1467-1770.1993.tb00174.x

Richards, J. E., & Casey, B. J. (1991). Heart rate variability during attention phases in young infants. *Psychophysiology*, *28*, 43–53. doi:10.1111/j.1469-8986.1991.tb03385.x

Rose, D., Slater, A., & Perry, H. (1986). Prediction of childhood intelligence from habituation in early infancy. *Intelligence*, *10*, 251–263. doi:10.1016/0160-2896(86)90019-X

Rose, S. A., Feldman, J. F., Wallace, I. F., & Cohen, P. (1991). Language: A partial link between infant attention and later intelligence. *Developmental Psychology*, *27*, 798–805. doi:10.1037/0012-1649.27.5.798

Ruddy, M. G., & Bornstein, M. H. (1982). Cognitive correlates of infant attention and maternal stimulation over the first year of life. *Child Development*, *53*, 183–188. doi:10.2307/1129651

Saffran, J. R. (2003). Statistical language learning: Mechanisms and constraints. *Current Directions in Psychological Science*, *12*, 110–114. doi:10.1111/1467-8721.01243

Sebastián-Gallés, N., Albareda-Castellot, B., Weikum, W. M., & Werker, J. F. (2012). A bilingual advantage in visual language discrimination in infancy. *Psychological Science*. *23*, 994–999. doi:10.1177/0956797612436817

Sigman, M. D., Cohen, S. E., & Beckwith, L. (1997). Why does infant attention predict adolescent intelligence? *Infant Behavior and Development*, *20*, 133–140. doi:10.1016/S0163-6383(97)90016-3

Slater, A. (1997). Can measures of infant habituation predict later intellectual ability? *Archives of Disease in Childhood*, *76*, 474–476. doi:10.1136/adc.77.6.474

Tamis-LeMonda, C. S., & Bornstein, M. H. (1989). Habituation and maternal encouragement of attention in infancy as predictors of toddler language, play, and representational competence. *Child Development*, *60*, 738–751. doi:10.2307/1130739

Thompson, L. A., Fagan, J. F., & Fulker, D. W. (1991). Longitudinal prediction of specific cognitive abilities from infant novelty preference. *Child Development*, *62*, 530–538. doi:10.1111/j.1467-8624.1991.tb01549.x

Werker, J. (2012). Perceptual foundations of bilingual acquisition in infancy. *Annals of the New York Academy of Sciences: The Year in Cognitive Neuroscience*, *1251*, 50–61. doi:10.1111/j.1749-6632.2012.06484.x