CHILD DEVELOPMENT PERSPECTIVES

Bilingualism and the Development of Executive Function: The Role of Attention

Ellen Bialystok

York University

ABSTRACT—***In this article, I review research examining the effect of bilingualism on children's cognitive development and in particular, executive function. I describe studies reporting bilingual advantages in various tasks to identify the process or component of executive function that might be responsible for this bilingual advantage, discussing several possibilities, including inhibitory control. Finally, I propose attention is a fundamental process that initiates developmental differences in bilingual children from as early as infancy.***

KEYWORDS—*bilingualism; cognitive development; executive function; attention; infancy*

Until about 50 years ago, popular belief and so-called scientific evidence converged to conclude that exposing children to more than one language could be dangerous. The expectation was that children would display "mental confusion" (1, p. 38) and show signs of "mental retardation" (2, p. 39). This view was challenged by Peal and Lambert (3), who predicted that monolingual French children would perform similarly to bilingual French-English children on measures of nonverbal intelligence but that bilinguals would obtain lower scores on verbal measures (3). To their surprise, bilingual children outperformed their monolingual peers on almost all the tests, including those of nonverbal intelligence. In contrast to the earlier descriptions, Peal and Lambert concluded that bilingual children showed enhanced "mental flexibility" (p. 20), perhaps because they had to switch between languages. Thus was born the idea of a bilingual advantage, soon followed by research investigating the qualitative nature, limiting boundaries, and possible causes of such an advantage.

Many researchers have documented benefits of bilingualism for children's cognitive development, although some studies have not found such outcomes (4). These contradictory results may be due to such factors as differences in populations, criteria for bilingualism, or experimental tasks (see 5, for discussion); in fact, a range of outcomes is not surprising, given the variation across the studies and bilingual experiences. Therefore, a complete understanding of the effect of bilingualism on development requires clarifying the conditions necessary for these effects to emerge and understanding more precisely the mechanisms that enable them.

BILINGUAL EFFECTS ON COGNITIVE DEVELOPMENT

The language environment that children experience influences the quality of the cognitive systems they develop (6), so it should not be surprising that bilingualism is an important factor in developmental outcomes. The earliest evidence of a beneficial effect of bilingualism came from studies of children's metalinguistic awareness (7). Bilingual children generally outperformed monolinguals on tasks assessing their understanding of abstract language structure, but the implications of these findings became apparent when these metalinguistic advantages were determined to be largely confined to tasks that included conflict and required control to manage that conflict (8). Hence, the reported bilingual advantage in metalinguistic ability was less about language processing and more about cognitive ability.

The shift from examining the effect of bilingualism on language-related outcomes to looking at its effect on cognition led to research documenting tasks in which bilingual children outperformed their monolingual peers (see review in 9, meta-analysis in 10). Most of the tasks in which bilingual advantages are found are considered to be indicators of executive function (but

Ellen Bialystok, York University.

The research reported in this article was supported by Grant R01HD052523 from the U.S. National Institutes of Health and by Grant A2559 from the Natural Sciences and Engineering Research Council of Canada.

Correspondence concerning this article should be addressed to Ellen Bialystok, Department of Psychology, York University, 4700 Keele St., Toronto, ON M3J 1P3, Canada; e-mail: ellenb@yorku.ca.

DOI: 10.1111/cdep.12116

Child Development Perspectives

see discussion later). The usual explanation is that both languages are always active in bilinguals, so the domain-general executive function system is incorporated into language processing to direct attention to the target language and in so doing, becomes reorganized, fortified, or both (11). Thus, bilingualism *trains* executive function through its constant recruitment for language selection. An enhancement of executive function is not trivial: Executive function is a major predictor of academic success (12) and academic success predicts long-term health and well-being (13).

One well-accepted view of executive function is the tripartite model proposed by Miyake and colleagues, which consists of inhibition, updating (working memory), and shifting (14, 15). Following this model, if executive function is involved in language processing for bilinguals, it would be important to identify the precise component that is involved and possibly boosted through this experience. Several researchers have proposed candidates for this effect, the most common of which is inhibition based on the assumption that the nontarget language is suppressed to avoid interference. However, clear evidence endorsing any one of these components, including inhibition, has not emerged (16). Bilinguals perform more optimally than monolinguals on tasks (e.g., flanker task) and conditions (e.g., incongruent trials) that clearly require inhibition, but they often do so as well on other tasks or conditions for which no inhibition is required (e.g., congruent trials; 17) or on tasks that require some types of inhibition but not others (e.g., response inhibition vs. interference suppression; 18). Thus, little evidence supports the specificity of bilingual effects on inhibition. Instead, bilingual children typically (but not always) outperform monolinguals on a range of tasks.

IDENTIFYING THE SOURCE OF BILINGUAL ADVANTAGE

To identify the components of executive function affected by bilingualism, several studies have used a version of the flanker task, with the most frequent choice being the children's Attentional Network Task (19). In this task, children see a line of five fish in which the central fish is designated as the target and the four flanking fish point in either the same (congruent trials) or opposite (incongruent trials) direction. Children are required to "feed" the target fish by indicating with a key press the direction it faces. Bilingual children generally respond faster or more accurately than their monolingual peers (20). However, as in studies of adults, both congruent and incongruent trials typically yield bilingual advantages in this task (21), even though no explicit inhibition is required on congruent trials because no misleading information is presented.

Therefore, instead of inhibition, some researchers have proposed that the source of the bilingual advantage is in monitoring (16, 22), a concept similar to shifting in Miyake's model but broader than any individual component. In some sense, inhibition is included in monitoring: In shifting across options, the irrelevant cue or response must be suppressed. One task that incorporates both inhibition and monitoring is the dimension change card sort task (DCCS; 23), in which a set of cards depicting bivalent stimuli (e.g., colored shapes) needs to be sorted by one dimension (color), then resorted by the other (shape). Young children find this task difficult and fail to reclassify the stimuli in the second sorting. Successful performance requires children to ignore the previous dimension (inhibition) and shift attention to the newly relevant dimension (monitoring). In several studies, bilingual children performed more successfully than their monolingual agemates on this task (24, 25), extending bilingual advantages to multiple components of executive function.

Monitoring also includes the notion of working memory in that successful monitoring requires holding a rule in mind over a set of procedures. Studies assessing differences in working memory in monolingual and bilingual children have produced mixed results, with some showing no difference between groups (26) and others showing that bilinguals outperform monolinguals (27). In studies with adults, language group differences in working memory are also inconsistent, although bilingual advantages are more likely when the working memory task is based on nonverbal materials than verbal stimuli (28). Thus, under some conditions working memory is also improved by bilingualism.

These studies investigating bilingual advantages in inhibition, monitoring, and working memory tend to use simple tasks based on specific aspects of processing, in part because the goal is to identify one component of executive function as uniquely responsible for developmental differences in bilingual children. Using this approach, no single component has emerged as decisive. However, another group of studies has taken a broader approach and used tasks that incorporate more integrated reasoning ability. These tasks are difficult to categorize in terms of individual components of executive function, although they require executive functioning for their solution. In general, bilinguals outperform monolinguals on tasks that are effortful and include perceptually conflicting information.

Included in this category are studies of theory of mind. Researchers debate the correct interpretation of theory of mind and the role of language proficiency, social awareness, and other factors in its development, but many accounts highlight the central role of executive functions in performing these complex tasks (29, but see 30, for a different view). The tasks are perceptually misleading as well: The appearance-reality task deliberately distorts the identity of an object by making it look like something else, and the false belief task alters the function of a known visual target in a brief narrative. But theoretical debate aside, most researchers agree on an established set of tasks that assess this complex ability. Research comparing performance of monolingual and bilingual children has generally reported more accurate performance by bilinguals (31, 32). In a false belief task adapted for adults that used eye tracking, bilingual adults

looked less at the incorrect option than monolinguals, paralleling error performance in children (33). To the extent that executive function is involved in theory of mind performance, its definition must be based on a more holistic conception than is conveyed by the components of inhibition, shifting, and working memory because none of these individual components is obviously primary.

In other conceptually complex visual tasks—such as creating novel drawings (34), resolving dual representation in ambiguous figures (35, 36), and calculating visual perspective (37)—bilingual children outperformed their monolingual peers. Although these tasks involve some form of monitoring and inhibiting, they are not considered traditional tests of executive function. Both the lack of consensus for the responsibility of a single component of executive function and evidence for bilingual advantages in tasks that are more integrative leave unsolved the precise link between bilingual experience and the reported cognitive advantages.

CONNECTION TO LANGUAGE USE

In research on adults, investigators assume that the bilingual advantage in nonverbal executive functioning can be traced to using that system to resolve conflict from jointly activated languages, making it more efficient across a range of tasks. Behavioral (38), eye-tracking (39), event-related potential (ERP; 40), and functional magnetic resonance imaging (41) studies support the claim of joint language activation. Two implications relate to the view that this management of language conflict is the primary mechanism for the bilingual effects on cognition.

The first implication follows from the interpretation that these effects are essentially caused by experience-dependent training and so requires evidence that the advantage increases with more bilingual experience. In a recent study, monolingual participants who undertook a yearlong university-level course in either introductory Spanish or introductory psychology were tested before and after the course on executive function tasks with ERP recordings (42). One task was a nonverbal go-no-go task for which two previous studies showed ERP waveform differences between monolinguals and bilinguals (but no behavioral differences), with bilingual electrophysiology consistent with more optimal performance (43, 44). In the first session, all participants performed equivalently on this measure, but in the second session, the ERP results for participants in the Spanish group shifted significantly toward those reported for bilinguals in the previous studies. Thus, even a small amount of experience learning a second language produced changes in these fundamental processes even without behavioral differences.

In other research with children, outcomes were also related to degree of bilingual experience (45). In these studies, children were learning a second language through immersion education. None of them was fully bilingual, but they had spent different lengths of time in the program and achieved different levels of proficiency in the second language. Language proficiency predicted performance on metalinguistic tasks, but the length of time spent in the immersion program predicted performance on nonverbal executive function tasks. Thus, for both adults and children, the bilingual advantage in nonverbal executive function emerges with more bilingual experience.

The second implication is that if bilingual advantages depend on managing linguistic conflict, then monolinguals and bilinguals should perform comparably until the individual has built up adequate linguistic representations to create competition between them and sufficient experience in managing them to affect the developing executive function system. The youngest children in the early studies reporting bilingual advantages were 3½ or 4 years old (e.g., studies on theory of mind or DCCS). By this age, children are reasonably verbal and bilingual children can communicate effectively in both languages. But would bilingual advantages be found in younger children? In the first study to investigate this question, children from 29 to 60 months performed simple tasks that involved different aspects of control (46), such as a tapping task (if the experimenter taps once, the child taps twice) and reverse categorization (put big animals in the bucket marked *baby* and little animals in the bucket marked *mommy*). Even at the youngest age, bilingual children outperformed monolingual children on most tasks.

However, more dramatically, differences in performance as a function of language environment can be seen in the 1st year of life. In one study, researchers recorded anticipatory eye movements to a reward that appeared on one side of a display following an auditory cue in 7-month-olds who were being raised in monolingual or bilingual homes (47). After a learning set, the position of the reward changed, so infants had to override their learned response and look to the opposite side. Only bilingual infants achieved this; monolingual infants continued to respond habitually even though no reward was present. In another study, of habituation and concept formation in 6-month-olds, infants being raised in bilingual homes outperformed monolingual infants on measures of stimulus encoding and recognition (48). In terms of executive function, the bilingual infants in these studies showed more flexibility and perhaps more inhibitory control over a simple behavior. Managing the conflict from jointly activated languages is a crucial part of the explanation, but studies of preverbal infants suggest that such conflict management alone cannot explain the emergence of nonverbal differences in executive function between monolinguals and bilinguals in early childhood.

IF NOT LANGUAGE, THEN WHAT?

Competition between languages is crucial for bilingual advantages to emerge in executive function, but two factors challenge that view as the exclusive mechanism. First, monolingual adults routinely experience conflict from competing representations,

even linguistic ones (e.g., cup vs. mug), but these conflicts are not thought to enhance executive functioning. Second, infants have only rudimentary representations of language, yet monolingual and bilingual infants differ by 7 months. What could trigger the processing differences that lead to enhanced executive function in bilinguals, including infants?

One possibility comes from studies of infants processing a stimulus that is salient in their environments: talking faces. In two studies, infants were shown a silent video of a face that read sentences in one language and, after the infants habituated, switched to a different language and continued reading (49, 50). Could the babies detect the language change from visual cues alone and regain interest in the video? In both studies, the bilingual infants noticed the language switch but the monolingual infants did not. This was the case both when the two languages were the same as those in the infants' environment (50) and when they were completely different from those heard by the bilingual infants (49). Whatever the babies used to make this discrimination was more general than the facial features associated with known languages.

These studies raise the possibility that bilingual experience changes the way attention is directed to the environment. For the infant, the presence of two languages that introduce two sets of sounds, cadences, structures, speakers, and facial configurations draws attention to the contrasts between the systems. Contrasts create novelty, attracting more attention and possibly more intense processing than similarity. Thus, bilingual babies may simply attend more carefully to subtle environmental differences. If so, these strategies improve attentional processing and lead to the creation of more complex representational structure that includes two languages. Once two representational structures are established, executive function is recruited to maintain attention to the target language. This account differs from the view that the nontarget language is inhibited: Infants are not resolving conflict between lexical features, but identifying organized systems that differ subtly and require attentional processing to discriminate.

Older children and adults do not need to infer the presence of two language systems through bottom-up attentional processing because they know that the languages are distinct. However, just as infants direct attention to contrasts between the environmental languages, children and adults are drawn to the contrasting features of the jointly activated languages. Therefore, not only are the two languages jointly activated, but bilinguals *attend* to both languages, creating the need for a general selection mechanism such as executive function to be recruited into language processing to avoid interference. Put this way, the bilingual advantage is not in inhibition; rather it is the *failure* of bilinguals to inhibit attention to the nontarget language that leads to the involvement of executive function and the eventual consequences for its development and function. No particular component of executive function has been identified as responsible for this selection; instead, a more *unified* conception of effortful processing (cf., 14) apparently operates. Researchers are investigating the cognitive and neural dimensions of this unified executive function.

Peal and Lambert's demonstration of cognitive advantages for bilingual children (3) changed assumptions about how this normal experience affected children's development. Although gaps in our knowledge still exist, it is a sign of the success of this research that these assumptions have changed. Current studies that report no difference between groups present themselves as a challenge to claims of bilingual advantages rather than to claims of bilingual disadvantages, although both interpretations are statistically equivalent outcomes of a null result. We have come a long way from the time when the prevailing belief was that children could be harmed by the languages people speak to them.

REFERENCES

1. Saer, D. J. (1923). The effects of bilingualism on intelligence. *British Journal of Psychology*, *14*, 25–38.
2. Goodenough, F. L. (1926). Racial differences in the intelligence of school children. *Journal of Experimental Psychology*, *9*, 388–397.
3. Peal, E., & Lambert, W. (1962). The relation of bilingualism to intelligence. *Psychological Monographs*, *76*, 1–23.
4. Dunabeitia, J. A., Hernandez, J. A., Anton, E., Macizo, P., Estevez, A., Fuentes, L. J., & Carreiras, M. (2014). The inhibitory advantage in bilingual children revisited: Myth or reality? *Experimental Psychology*, *61*, 234–251.
5. Kroll, J. F., & Bialystok, E. (2013). Understanding the consequences of bilingualism for language processing and cognition. *Journal of Cognitive Psychology*, *25*, 497–514.
6. Goldin-Meadow, S., Levine, S. C., Hedges, L. V., Huttenlocher, J., Raudenbush, S. W., & Small, S. L. (2014). New evidence about language and cognitive development based on a longitudinal study: Hypotheses for intervention. *American Psychologist*, *69*, 588–599.
7. Galambos, S. J., & Hakuta, K. (1988). Subject-specific and task-specific characteristics of metalinguistic awareness in bilingual children. *Applied Psycholinguistics*, *9*, 141–162.
8. Bialystok, E. (1986). Factors in the growth of linguistic awareness. *Child Development*, *57*, 498–510.
9. Barac, R., Bialystok, E., Castro, D. C., & Sanchez, M. (2014). The cognitive development of young dual language learners: A critical review. *Early Childhood Research Quarterly*, *29*, 699–714.
10. Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research*, *80*, 207–245.
11. Kroll, J. F., Bobb, S. C., & Hoshino, N. (2014). Two languages in mind: Bilingualism as a tool to investigate language, cognition, and the brain. *Current Directions in Psychological Science*, *23*, 159–163.
12. Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences*, *21*, 327–336.
13. Duncan, G. J., Ziol-Guest, K. M., & Kalil, A. (2010). Early childhood poverty and adult attainment, behavior, and health. *Child Development*, *81*, 306–325.
14. Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science*, *21*, 8–14.

15. Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (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.
16. Hilchey, M. D., & Klein, R. M. (2011). Are there bilingual advantages on nonlinguistic interference tasks? Implications for the plasticity of executive control processes. *Psychonomic Bulletin and Review*, *18*, 625–658.
17. Bialystok, E. (2010). Global-local and trail-making tasks by monolingual and bilingual children: Beyond inhibition. *Developmental Psychology*, *46*, 93–105.
18. Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*, 282–298.
19. Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia*, *42*, 1029–1040.
20. Kapa, L. L., & Colombo, J. (2013). Attentional control in early and later bilingual children. *Cognitive Development*, *28*, 233–246.
21. Costa, A., Hernandez, M., & Sebastian-Galles, N. (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition*, *106*, 59–86.
22. Costa, A., Hernandez, A., Costa-Faidella, J., & Sebastian-Galles, N. (2009). On the bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition*, *113*, 135–149.
23. Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development*, *11*, 37–63.
24. Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development*, *70*, 636–644.
25. Okanda, M., Moriguchi, Y., & Itakura, S. (2010). Language and cognitive shifting: Evidence from young monolingual and bilingual children. *Psychological Reports*, *107*, 68–78.
26. Engel de Abreu, P. M. (2011). Working memory in multilingual children: Is there a bilingual effect? *Memory*, *19*, 529–537.
27. Blom, E., Kuntay, A. C., Messer, M., Verhagen, J., & Leseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish-Dutch children. *Journal of Experimental Child Psychology*, *128C*, 105–119.
28. Bialystok, E., Poarch, G., Luo, L., & Craik, F. I. M. (2014). Effects of bilingualism and aging on executive function and working memory. *Psychology and Aging*, *29*, 696–705.
29. Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, *72*, 1032–1053.
30. Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory-of-mind development: The truth about false belief. *Child Development*, *72*, 655–684.
31. Goetz, P. (2003). The effects of bilingualism on theory of mind development. *Bilingualism: Language and Cognition*, *6*, 1–15.
32. Kovacs, A. M. (2009). Early bilingualism enhances mechanisms of false-belief reasoning. *Developmental Science*, *12*, 48–54.
33. Rubio-Fernandez, P., & Glucksberg, S. (2012). Reasoning about other people's beliefs: Bilinguals have an advantage. *Journal of Experimental Psychology: Learning Memory and Cognition*, *38*, 211–217.
34. Adi-Japha, E., Berberich-Artzi, J., & Libnawi, A. (2010). Cognitive flexibility in drawings of bilingual children. *Child Development*, *81*, 1356–1366.
35. Bialystok, E., & Shapero, D. (2005). Ambiguous benefits: The effect of bilingualism on reversing ambiguous figures. *Developmental Science*, *8*, 595–604.
36. Wimmer, M. C., & Marx, C. (2014). Inhibitory processes in visual perception: A bilingual advantage. *Journal of Experimental Child Psychology*, *126*, 412–419.
37. Greenberg, A., Bellana, B., & Bialystok, E. (2013). Perspective-taking ability in bilingual children: Extending advantages in executive control to spatial reasoning. *Cognitive Development*, *28*, 41–50.
38. Beauvillain, C., & Grainger, J. (1987). Accessing interlexical homographs: Some limitations of a language-selective access. *Journal of Memory and Language*, *26*, 658–672.
39. 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.
40. Martin, C. D., Dering, B., Thomas, E. M., & Thierry, G. (2009). Brain potentials reveal semantic priming in both the "active" and the "non-attended" language of early bilinguals. *NeuroImage*, *47*, 326–333.
41. Rodriguez-Fornells, A., Rotte, M., Heinze, H.-J., Nosselt, T. M., & Munte, T. F. (2002). Brain potential and functional MRI evidence for how to handle two languages with one brain. *Nature*, *415*, 1026–1029.
42. Sullivan, M. D., Janus, M., Moreno, S., Astheimer, L. B., & Bialystok, E. (2014). Early stage second-language learning improves executive control: Evidence from ERP. *Brain and Language*, *139*, 84–98.
43. Fernandez, M., Tartar, J. L., Padron, D., & Acosta, J. (2013). Neurophysiological marker of inhibition distinguishes language groups on a non-linguistic executive function test. *Brain and Cognition*, *83*, 330–336.
44. Moreno, S., Wodniecka, Z., Tays, W., Alain, C., & Bialystok, E. (2014). Inhibitory control in bilinguals and musicians: Event related potential (ERP) evidence for experience-specific effects. *PLoS ONE*, *9*, e94169.
45. Bialystok, E., & Barac, R. (2012). Emerging bilingualism: Dissociating advantages for metalinguistic awareness and executive control. *Cognition*, *122*, 67–73.
46. Bialystok, E., Barac, R., Blaye, A., & Poulin-Dubois, D. (2010). Word mapping and executive functioning in young monolingual and bilingual children. *Journal of Cognition and Development*, *11*, 485–508.
47. Kovacs, A. M., & Mehler, J. (2009). Cognitive gains in 7-month-old bilingual infants. *Proceedings of the National Academy of Sciences of the United States of America*, *106*, 6556–6560.
48. Singh, L., Fu, C. S., Rahman, A. A., Hameed, W. B., Sanmugam, S., Agarwal, P., . . . the GUSTO Research Team. (2015). Back to basics: A bilingual advantage in visual habituation. *Child Development*, *86*, 294–302.
49. Sebastian-Galles, 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.
50. Weikum, W. M., Vouloumanos, A., Navarra, J., Soto-Faraco, S., Sebastian-Galles, N., & Werker, J. F. (2007). Visual language discrimination in infancy. *Science*, *316*, 1159.