Cognitive Development 28 (2013) 41–50

Contents lists available at SciVerse ScienceDirect

Cognitive Development

Perspective-taking ability in bilingual children: Extending advantages in executive control to spatial reasoning

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A R T I C L E I N F O

Keywords:
Bilingualism
Spatial cognition
Perspective-taking
Executive control

A B S T R A C T

Monolingual and bilingual 8-year-olds performed a computerized spatial perspective-taking task. Children were asked to decide how an observer saw a four-block array from one of three different positions (90°, 180°, and 270° counter-clockwise from the child's position) by selecting one of four responses – the correct response, the egocentric error, an incorrect choice in which the array was correct but in the wrong orientation for the viewer, and an incorrect choice in which the array included an internal spatial error. All children performed similarly on background measures, including fluid intelligence, but bilingual children were more accurate than monolingual children in calculating the observer's view across all three positions, with no differences in the pattern of errors committed by the two language groups. The results are discussed in terms of the effect of bilingualism on modifying performance in a complex spatial task that has implications for academic achievement.

Bilingual children have demonstrated advantages over their monolingual peers in dealing with conflict in nonverbal tasks, an advantage that has been interpreted as indicating precocious development of executive control (for meta-analysis see Adesope, Lavin, Thompson, & Ungerleider, 2010). This advantage has been found in studies that have ruled out the possibility of differences in culture (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010), immigration (Bialystok & Viswanathan, 2009), specific language pairs (Barac & Bialystok, 2012), and socioeconomic status (Engel de Abreu, Cruz-Santos, Tourinho, Martin, & Bialystok, 2012), confirming bilingualism as the relevant factor.

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http://dx.doi.org/10.1016/j.cogdev.2012.10.002

Why would bilinguals show an advantage in executive control? Central to the explanation is evidence from behavioral (Beauvillain & Grainger, 1987; Francis, 1999; Hernandez, Bates, & Avila, 1996; Kroll & De Groot, 1997) and imaging (Marian, Spivey, & Hirsch, 2003; Rodriguez-Fornells, Rotte, Heinze, Nösselt, & Münte, 2002; Wu & Thierry, 2010) studies that indicate both languages are jointly activated for bilinguals, even in strongly monolingual contexts. This joint activation creates the need for a mechanism to control attention to the target language and avoid interference from the competing language. In an influential model proposed by Green (1998), this selective attention is handled by recruiting a domain-general inhibitory control system.

A growing body of literature has documented the performance advantage for bilingual children on various tests of executive control. Most of the tasks used in these studies require that children ignore or inhibit a distracting stimulus feature to respond appropriately. For example, bilingual children outperform their monolingual peers on the dimensional change card sort task (Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008), Simon task (Martin-Rhee & Bialystok, 2008), and flanker task (Carlson & Meltzoff, 2008; Yang, Yang, & Lust, 2011), all of which include extraneous perceptual information that must be ignored. However, inhibition alone is not a sufficient explanation for these bilingual advantages. Some types of inhibition are not performed better by bilinguals than monolinguals (Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008), and executive control components in addition to inhibition (e.g., updating and shifting, Miyake et al., 2000) are also enhanced for bilinguals (Bialystok, 2010, 2011). Bilinguals have also shown an advantage in a task that requires considering abstract alternatives but not directly inhibition, a form of creativity (Adi-Japha, Berberich-Artzi, & Libnawi, 2010). Moreover, a bilingual advantage in executive control has been reported in preverbal infants (Kovács & Mehler, 2009) and toddlers (Bialystok, Barac, et al., 2010; Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011), where active inhibition of a competing language is not relevant. To capture these findings, Costa, Hernández, Costa-Faidella, and Sebastian-Galles (2009) have proposed that the bilingual advantage is in monitoring, a more inclusive description of executive control that focuses less on individual components than on effortful general attention.

If the cognitive benefits of bilingualism extend beyond the individual core components of executive functioning and affect executive functioning more broadly, it is possible that bilingualism may also influence performance on more integrative tasks that combine executive control with conceptual knowledge, such as problem solving in academic settings. Evidence for a bilingual effect on such tasks would have implications for the academic achievement of bilingual children. Executive control is a major predictor of academic success (Best, Miller, & Naglieri, 2011), and academic success predicts long-term health and well-being (Duncan, Ziol-Guest, & Kalil, 2010).

One such task that combines executive control with conceptual ability is theory of mind (ToM), the ability to ascribe mental states to others (Premack & Woodruff, 1978). Performance on ToM tasks involves coordinated executive control processes, reasoning, and conceptual skills (Carlson & Moses, 2001; Carlson, Moses, & Hix, 1998; Frye, Zelazo, & Palfai, 1995; Hala, Hug, & Henderson, 2003; Hala & Russell, 2001; Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Wellman, Cross, & Watson, 2001). In a recent fMRI study, van der Meer, Groenewold, Nolen, Pijnenborg, and Aleman (2011) showed partial overlapping neural activation in a ToM task that required ignoring one's own mental representation of a problem and a stop-signal task that required simple response inhibition. The results substantiate the presence of a common inhibitory or executive control mechanism for these very different tasks.

Performance on complex ToM problems may have implications for problem-solving performance outside the laboratory and for academic achievement more specifically. Astington and Pelletier (1996) argued that learning and problem solving in a classroom setting routinely involves ToM, a point elaborated by Wellman and Lagatutta (2004), who assigned ToM a central role in understanding psychological explanations of a person's actions or experiences in academic learning. More generally, understanding mental states of others is associated with improved problem solving in academic contexts. Chi, Bassock, Lewis, Reimann, and Glaser (1989) presented students text explanations in physics and then tested their understanding using conceptually similar problems. Students who explained the author's reasoning aloud outperformed those who did not engage in self-explanation, suggesting the importance of access to the author's mental state. Similarly, Siegler (1995) demonstrated that training 5-year-olds to explain the reasoning behind an experimenter's corrective feedback improved their performance on the Piagetian number conservation task, whereas children who received feedback with no explanation or who were required to explain the reasoning behind their own answers did not improve. These examples demonstrate the role of ToM in learning and academic problem solving where it is necessary to understand a problem from another person's perspective.

In support of the possibility that the bilingual advantage could extend to such tasks, several studies have shown that bilingual children outperform monolingual children on ToM problems, both in unexpected transfer problems (e.g., object moves to new location: Goetz, 2003; Kovács, 2009) and appearance-reality problems (e.g., sponge-rock: Bialystok & Senman, 2004; Goetz, 2003). Presumably the superior performance of bilingual children is at least in part attributable to their enhanced executive control. Rubio-Fernández and Glucksberg (2012) extended this finding to adults by using eye-tracking equipment and showed that bilingual participants were less distracted than monolinguals by the egocentric option on a ToM false-belief task.

Although ToM tasks provide promising evidence for bilingual advantages in problem solving, a limitation is their reliance on verbal ability (Astington & Jenkins, 1999; de Villiers, 2007; de Villiers & de Villiers, 2000; Happé, 1995; Tager-Flusberg & Sullivan, 1994). ToM development parallels language development (de Villiers, 2007), and training children in a linguistic construct (i.e., sentential complements) produced benefits in ToM performance that were equivalent to false-belief training (Hale & Tager-Flusberg, 2003). These verbal abilities remain involved with ToM performance into adulthood. Newton and de Villiers (2007) asked adults to complete a nonverbal false-belief task while performing either a verbal or nonverbal interference task and found that performing the verbal interference task impaired false-belief judgment. A problem is that bilingual children typically have reduced language ability relative to monolingual speakers of each language, a difference shown dramatically in the receptive vocabulary of a large sample of children (Bialystok, Luk, Peets, & Yang, 2010) and extended into adulthood (Bialystok & Luk, 2012). It is not known, therefore, how the linguistic and executive control demands of ToM tasks interact in determining performance of bilingual children. Ideally, the effect of bilingualism on such problem solving should be examined in a task that is structurally similar to ToM but without its reliance on language ability.

The purpose of the present study is to determine whether the advantage in executive control found for bilingual children in simple attention tasks extends to enhancement of problem solving in a complex task that is less dependent on language proficiency than is ToM. One such task is the well-documented spatial perspective-taking task (Piaget & Inhelder, 1967). Like ToM, it requires executive control to attend to relevant information and ignore salient distractions, but unlike ToM it does not require verbal proficiency. The child must determine how an observer sees a spatial display and avoid the egocentric error, in which the child believes that the display appears the same to an observer in a different location as it does to the child. Structurally, the reasoning is similar to that involved in the unexpected-transfer ToM task in which children must realize that the other child has different information about the location of the object. Therefore, performance on the spatial perspective-taking task provides a test of problem-solving skills with minimal reliance on verbal ability.

In their original research with the spatial perspective-taking task, Piaget and Inhelder (1967) claimed that children were egocentric, as they did not understand that the observer saw something different than they did. However, a large body of research has shown that young children do have some understanding that other observers' views differ from their own (Cox, 1978; Yaniv & Shatz, 1990). Piaget and Inhelder's task requires the further ability to interpret situations in multiple ways and integrate the various perspectives (Huttenlocher & Presson, 1973, 1979; Vasilyeva, 2002). Importantly, the solution requires the ability to resolve conflict among the perspectives and overrule the salient perceptual features (Gullo & Bersani, 1983), especially those associated with the egocentric view. These abilities are all part of executive functioning.

Because of the task's reliance on executive control mechanisms, our hypothesis is that bilingual children will perform the perspective-taking task more accurately than comparable monolingual children. Such evidence would provide an important extension of the literature on developmental differences in bilingual children by employing a more integrative measure of cognitive processing that has implications for academic success. Unlike the tasks typically used, the perspective-taking problem involves high-level problem solving and manipulation of complex representations and, as such, more closely resembles the cognitive abilities required for academic achievement. Support for this claim comes from the high correlations observed between perspective-taking tasks and composite measures of intelligence (Humphreys & Parsons, 1979; Humphreys, Rich, & Davey, 1985), as well as the relation between spatial perspective taking and social/communicational abilities (Shelton, Clements-Stephens, Lam, Pak, & Murray, 2012), which are crucial in a cooperative learning environment such as in school. At the same time, perceptually salient information about the child's own perspective needs to be ignored or inhibited, making executive control central to the solution.

Some preliminary evidence supports the prediction that bilingual children will outperform monolinguals on a perspective-taking task. In a study of 37 monolingual and 50 bilingual 8-year-olds, children had to choose what an observer saw at one of three positions (90°, 180°, or 270°) around a wooden frame with four colored blocks placed in the cardinal positions (Bialystok, 2009). After the observer moved to the viewing position, the display was covered and the child was shown four smaller versions of the frame with the blocks representing one of four possibilities – the correct perspective of the observer, the egocentric error, an error in orientation that preserved the internal sequence of blocks, and a structural error in the display that placed two blocks in an incorrect relation to each other. The results were promising but inconclusive. Bilinguals produced significantly more correct responses than monolinguals on the 270° trials, which were the most difficult according to the accuracy scores, suggesting that the bilingual children were more advanced. However, the mechanical nature of the task, the imprecision of the administration, and the inclusion of a working memory component (i.e., covering the block array with a cloth prior to the presentation of response options) made it difficult to conclusively determine any specific advantages in perspective taking for bilingual children. The present study built on this research by using a more controlled task.

1. Method

1.1. Participants

Participants were 82 8-year-olds, 45 monolingual (24 girls) and 37 bilingual (24 girls), recruited from different schools in a middle-class urban neighborhood.

Parents completed a questionnaire inquiring about language use patterns in and outside the home and the child's competence in all relevant languages. There were 15 different languages represented in the bilingual group with the dominant languages being Spanish (30%), Italian (24%), and Portuguese (11%). The majority of the bilingual children learned their non-English language at home (89%) and spoke both English and the other language on a daily basis (62%). Parents indicated home language used in various situations on a 5-point scale (1 = always in English; 5 = always non-English language; 3 = equal use of both languages). For the monolingual children the average score was 1.1 (sd = 0.2) indicating an essentially English home environment, while for bilingual children the score was 2.1 (sd = 0.6), which is closer to the mean of 3 for equal use of two languages. The home language scores for the two groups were significantly different from each other, $t(79) = 9.54$, $p < .0001$.

1.2. Tasks

1.2.1. Peabody Picture Vocabulary Test-III

The Peabody Picture Vocabulary Test-III (PPVT-III Form A) is a standardized test of receptive English vocabulary (Dunn & Dunn, 1997). The test consists of a series of panels, each with four illustrations; the child must select the illustration that corresponds with the word spoken by the experimenter. Test items are divided into sets of 12 with the starting point determined by the child's age. The test items increase in difficulty and then terminate in the set in which eight or more errors are made. Raw scores are converted into standardized scores based on a mean of 100 and standard deviation of 15. The PPVT took approximately 10 min to administer.

1.2.2. The Kaufman Brief Intelligence Test-Matrices

The matrices subset test of the Kaufman Brief Intelligence Test (K-BIT MAT) is used to assess nonverbal fluid intelligence (Kaufman & Kaufman, 1990). The test consists of 46 items in which children select a picture from a set of six that completes a matrix analogy. The child's age determines the initial test item and testing proceeds following detailed instructions provided in the test manual. Raw scores

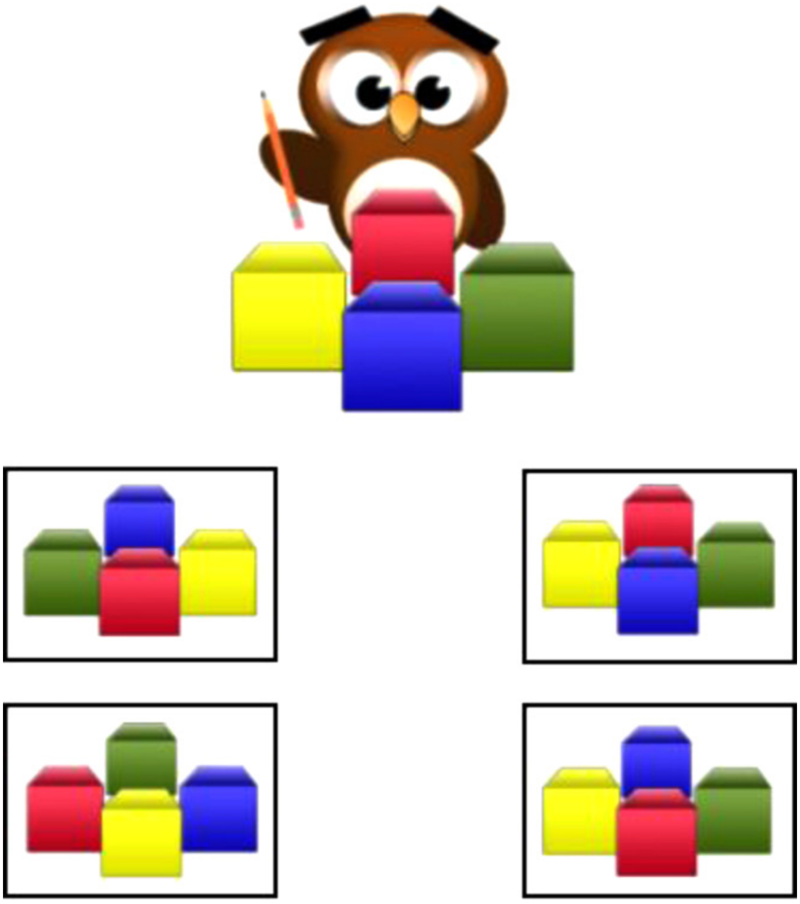

Fig. 1. Example of computerized four-block array with owl in 180° position. This figure is an approximation of what the child would see during the response component of a 180° trial. The target array and the owl appeared centered at the top of the screen and the four options appeared below. The options are: correct (top left), egocentric (top right), structured (bottom left), and oriented (bottom right).

are converted into standardized scores based on a mean score of 100 with a standard deviation of 15. The test took approximately 10 min to administer.

1.2.3. Computerized perspective-taking task

The perspective-taking task was programmed in E-Prime v.1.2 and administered on a Lenovo ThinkPad X60 laptop with a 12-in. touchscreen monitor. Each trial began with a four-block array consisting of a colored block in each of the cardinal positions of a square (see Fig. 1). The observer was a cartoon image of an owl. Children saw the display for 2000 ms and then the owl appeared in one of three positions around the array (90°, 180°, or 270°) counter-clockwise from the child. After 2000 ms, four choices appeared at the bottom of the screen, each one a smaller version of the display depicting four different configurations of the blocks. Children selected the display option that corresponded to the owl's view by touching that choice. The four options were constructed to represent specific responses: correct response (the owl's view of the array), egocentric error (the child's view of the array), oriented error (correct front–back relationship of blocks but with a left–right reversal), and structured view (correct internal structure of blocks but incorrect orientation relative to the owl's position). The target array, the response options, and the owl remained visible during the entire trial. There were 12 trials consisting of 4 trials for each of the three observer positions. The order of trials and position of alternative responses were randomized across children. There were no time limits for children to respond and the options remained on screen until the response was made, followed immediately by the next trial.

Prior to the actual task, the child was introduced to owl and was told that this character would move to different positions around another character, giraffe, and that the child had to determine what owl

Table 1
Mean scores (and standard deviations) for background measures by language group and age group.

Group	*n*	Age (months)	PPVT-III Std.	K-BIT	Mother's education	Father's education
Monolingual	45	100.7 (3.2)	98.3 (10.9)	99.4 (13.4)	3.3 (1.0)	3.0 (1.2)
Bilingual	37	101.1 (4.3)	96.7 (11.1)	100.9 (14.7)	3.6 (1.2)	3.2 (1.3)

saw. Two trials with giraffe were presented to familiarize the child with the task. Next, the block array was presented and the child was told that owl would move to various positions around this "toy" and that it was the child's job to figure out what owl saw. There were 3 practice trials with feedback that consisted of a happy (correct trial) or sad (incorrect trial) face. Following this practice, the 12 experimental trials were presented in a random order, with no feedback. The task took approximately 7 min to administer.

Children were tested individually in one of two fixed orders: PPVT, KBIT, Perspective, or KBIT, Perspective, PPVT. At the end of the session, children were thanked for their time and rewarded with a small toy and a certificate of participation.

2. Results

The mean scores and standard deviations for the background measures are reported in Table 1. A series of one-way between-subjects ANOVAs for language group showed no significant differences in age, KBIT, or PPVT, all Fs < 1. Independent sample t-tests for parents' education level, used as indication of SES, showed no language group differences for either mother's education level, $t(79) = 1.24$, n.s., or father's education level, $t(79) = 0.51$, n.s.

The correct responses for each position were calculated as proportion scores by dividing the number correct by the maximum of 4. The mean proportion correct (collapsed across gender) for language group and position are presented in Fig. 2. Because there were 4 alternatives, chance responding would produce a mean of 0.25, indicated in the figure by the dotted line. A three-way ANOVA for language group, gender, and observer position on these scores indicated no effect of gender, $F(1,78) = 1.04$, n.s., or position, $F < 1$, but a significant effect of language group, $F(1,78) = 9.52$, $MSE = .23$, $p < .003$, $d = .69$, 95% CI[.63, .75]. There were no significant interaction effects, but visual inspection of the graph suggests that the three positions were not equivalent for the two language groups. Therefore, we conducted a one-way analysis for language group separately for each position and found that bilinguals obtained significantly higher scores than monolinguals for the 180° position, $F(1,80) = 5.77$, $p < .01$, and 270°

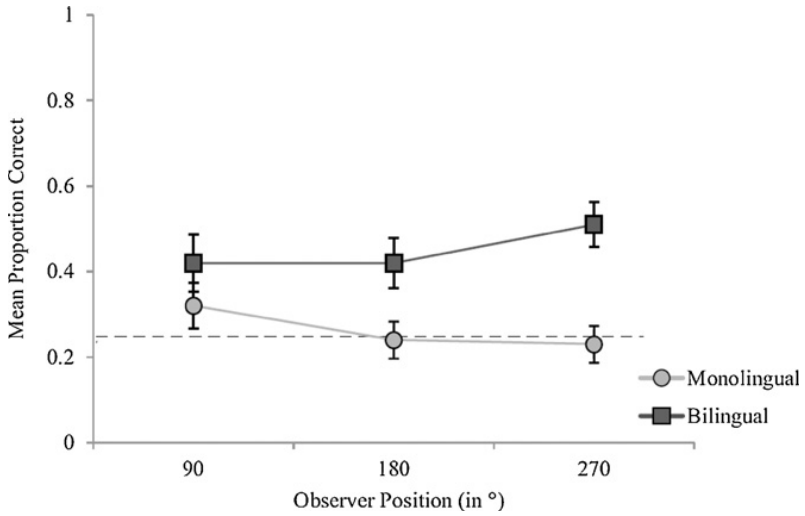

Fig. 2. Mean proportion correct responses (and standard error) for each observer position by language group in each age group. Dotted line represents chance level of responding.

Table 2
Percentage of children committing each error type in perspective-taking task by language group.

Group	Egocentric (%)	Oriented (%)	Structured (%)
Monolingual ($n = 45$)	58.78	33.33	0.04
Bilingual ($n = 37$)	43.24	24.32	0.03

position, $F(1,180) = 16.22$, $p < .0001$, but not for the 90° position, $F(1,80) = 1.44$, n.s. This pattern is similar to that found in the pilot study described above (Bialystok, 2009).

The total number of errors for each category was calculated across the three positions because the numbers were too small to analyze separately by position. These error scores were non-normally distributed (Egocentric: Skewness = 0.39, Kurtosis = −1.46; Oriented: Skewness = 0.80, Kurtosis = −0.40; Structured: Skewness = 3.62, Kurtosis = 13.97), so Pearson's chi-square test was used to examine language group differences for each error type. To create frequency data from the error scores, which ranged from 0 to 12 for each error type, scores between 0 and 3 were classified as not committing the error and scores between 4 and 12 were classified as committing the error. This cutoff was chosen to reflect the base probability that 3 choices reflected chance (since there were 12 trials and 4 possible options) so that a frequency greater than 3 was likely to indicate an intentional choice. Therefore, each child was classified as either committing or not committing each error type. Percentages of children committing each error type (number of children committing the error out of total number of children) by language group are reported in Table 2. There were no language group differences for egocentric errors, $\chi^2(1) = 1.70$, n.s., oriented errors, $\chi^2 < 1$, or structured errors, $\chi^2 \leq 1$.

Finally, a multiple regression analysis with correct responses as the dependent variable was conducted to examine the relation between the background measures and success on the perspective-taking task using a more nuanced approach than a between-groups comparison to determine the contribution of bilingualism to these results. PPVT, K-BIT, and language group were entered as predictor variables in that order. The model significantly predicted accuracy on the task, $F(2,77) = 8.97$, $p < .001$, and accounted for 25.9% of the variance. The parameter estimates are reported in Table 3 and show language group remained significant when entered in the last step.

3. Discussion

The spatial perspective-taking problem shares features with academic performance and assessment tasks. It requires coordinated executive functions (inhibit the egocentric option, attend to the relation between the display and observer) and complex conceptual representations (represent the internal structure of the display, calculate the distance traveled by the observer) to compute the way that the observer sees the display. In a computerized version of the task, bilingual children who were equivalent to monolingual children in fluid intelligence and verbal ability outperformed monolingual children on the task. In addition, bilingualism significantly predicted accuracy in a regression model after all other factors had been entered.

The computerized task provided clearer results than did an earlier pilot study (Bialystok, 2009) using wooden materials and a moving figure as the observer. The manual presentation in the pilot study made it difficult to control viewing angle for different children and distances between observer and display, for example, were not well controlled. More importantly, the pilot study included a working memory component by covering the array with a cloth before presenting the response options,

Table 3
Parameter estimates for multiple regression analysis with perspective taking accuracy as dependent variable.

Source	B	SE B	β	ΔR^2	t
PPVT	0.06	0.03	0.19	0.04	1.88
K-BIT	0.08	0.03	0.33	0.12	3.28**
Language group	2.19	0.69	0.31	0.10	3.19**

** $p < .01$.

adding an additional effortful component to the problem. Thus, the present task provided a more direct measure of performance on the perspective task without potential confounds from other task requirements.

Although there was no significant interaction effect for observer position in the present study, there was a greater disparity between the language groups for the 180° and 270° observer positions than the 90° position (Fig. 2). In fact, monolingual children were performing near chance level at the two more difficult observer positions. This finding is similar to results from the pilot study in which bilingual children outperformed monolingual children on the 270° observer position. It is not clear why bilinguals would show specific advantages on these two positions. The 180° position is typically the most difficult, as reported in previous mental rotation research, and bilinguals may be using a different strategy than monolinguals for solving this problem. For example, the "opposite" relations strategy, rather than computing the actual rotation, simplifies this problem (Wraga, Creem, & Proffitt, 2000). Similarly, the 270° position was the most difficult in the pilot study and showed the lowest mean scores for monolinguals in the present study. Again, bilinguals may be using an alternate strategy to succeed at this observer position. Overall, these results imply that bilinguals are succeeding at the more difficult aspects of the perspective-taking task developmentally earlier than their monolingual peers.

The results of the present study provide evidence for a bilingual advantage in a task involving complex spatial reasoning. The perspective-taking task has been used to examine children's ability to perform mental manipulations (Huttenlocher & Presson, 1973, 1979; Vasilyeva, 2002), reason about the mental states of others (similar to ToM reasoning; Carlson & Moses, 2001; Carlson et al., 1998), and mark the developmental milestones through which all of these abilities are engaged (Cox, 1978). The present results demonstrate that this task is also better solved by bilingual children, thus extending the evidence showing executive control advantages for bilingual children to a task that partly relies on executive control but also incorporates demands for spatial representation and manipulation in the context of selective attention to relevant perceptual information.

Importantly, performance on a spatial perspective-taking has been used as an indicator of academic success. A study by Tarshis and Shore (1991) showed that preschoolers with exceptionally high IQ scores outperformed preschoolers with slightly above average IQ scores on a modified version of the spatial perspective-taking task as indicated by higher correct scores and fewer egocentric errors. These authors suggest that the perspective-taking task can be used in an educational setting to identify children with high academic potential at an early stage. Thus, the advantage in executive control, a component of this task, may boost the ability of bilingual children to perform these crucial problem-solving tasks.

The results of the present study extend research on the cognitive effects of bilingualism in an important new direction. In previous research, bilingual children outperformed monolingual children in executive control tasks that were designed to isolate simple components of executive control such as inhibition. Although these executive control abilities are clearly relevant for problem solving, there has been little evidence to date that the precocious development of executive abilities by bilingual children also support superior performance in complex reasoning tasks. Evidence for bilingual advantages in ToM provided a basis for the predictions, but the demonstration of these reasoning abilities in a difficult nonverbal task is an important advance in understanding how bilingualism shapes the developing mind. The spatial perspective-taking task involves complex relations between a layout of constant physical objects and arbitrary viewpoints that are continuously changing. The ability to accurately compute these complex relations for a specific vantage point requires a higher-level problem solving ability and, moreover, one that is fundamental to success in an academic environment.

Acknowledgements

This research was funded by grant R01HD052523 from the US National Institutes of Health to EB. We are grateful to Vered Latman and Angela Massey-Garrison for their assistance in conducting this research.

References

Adi-Japha, E., Berberich-Artzi, J., & Libnawi, A. (2010). Cognitive flexibility in drawings of bilingual children. *Child Development*, *81*, 1356–2136.

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.

Astington, J. W., & Jenkins, J. M. (1999). A longitudinal study of the relation between language and theory-of-mind development. *Developmental Psychology*, *35*, 1311–1320.

Astington, J. W., & Pelletier, J. (1996). The language of mind: Its role in learning and teaching. In D. R. Olson, & N. Torrance (Eds.), *The handbook of education and human development: New models of learning, teaching and schooling* (pp. 593–619). Cambridge, MA: Blackwell.

Barac, R., & Bialystok, E. (2012). Bilingual effects on cognitive and linguistic development: Role of language, cultural background, and education. *Child Development*, *83*(2), 413–422.

Beauvillain, C., & Grainger, J. (1987). Accessing interlexical homographs: Some limitations of a language-selective access. *Journal of Memory and Language*, *26*, 658–672.

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.

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development*, *70*, 636–644.

Bialystok, E. (2009). *Spatial relations from a different point of view: The perspective from bilingualism*. Paper presented in symposium, Cognitive effects of bilingualism: A look at executive function and theory of mind, biennial meeting of the society for research in child development.

Bialystok, E. (2010). Global–local and trail-making tasks by monolingual and bilingual children: Beyond inhibition. *Developmental Psychology*, *46*, 93–105.

Bialystok, E. (2011). Coordination of executive functions in monolingual and bilingual children. *Journal of Experimental Child Psychology*, *110*, 461–468.

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.

Bialystok, E., & Luk, G. (2012). Receptive vocabulary differences in monolingual and bilingual adults. *Bilingualism: Language and Cognition*, *15*, 397–401.

Bialystok, E., Luk, G., Peets, K. F., & Yang, S. (2010). Receptive vocabulary differences in monolingual and bilingual children. *Bilingualism: Language and Cognition*, *13*, 525–531.

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.

Bialystok, E., & Senman, L. (2004). Executive processes in appearance-reality tasks: The role of inhibition of attention and symbolic representation. *Child Development*, *75*, 562–579.

Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition*, *112*, 494–500.

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science*, *11*, 279–295.

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, *72*, 1032–1053.

Carlson, S. M., Moses, L. J., & Hix, H. R. (1998). The role of inhibitory control in young children's difficulties with deception and false belief. *Child Development*, *69*, 672–691.

Chi, M. T. H., Bassock, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, *13*, 145–182.

Costa, A., Hernández, M., 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.

Cox, M. V. (1978). The development of perspective-taking ability in children. *International Journal of Behavioral Development*, *1*, 247–254.

de Villiers, J. (2007). The interface of language and theory of mind. *Lingua*, *117*, 1858–1878.

de Villiers, J. G., & de Villiers, P. A. (2000). Linguistic determination and the understanding of false beliefs. In P. Mitchell, & K. J. Riggs (Eds.), *Children's reasoning and the mind* (pp. 191–228). Ease Sussex, England: Psychology Press.

Duncan, G. J., Ziol-Guest, K. M., & Kalil, A. (2010). Early childhood poverty and adult attainment, behaviour, and health. *Child Development*, *81*, 306–325.

Dunn, L. M., & Dunn, L. M. (1997). *Peabody Picture Vocabulary Test* (3rd ed.). Circle Pines, MN: American Guidance Service.

Engel de Abreu, P. M. J., Cruz-Santos, A., Tourinho, C. J., Martin, R., & Bialystok, E. (2012). Bilingualism enriches the poor: Enhanced cognitive control in low-income minority children. *Psychological Science*, http://dx.doi.org/10.1177/0956797612443836

Francis, W. S. (1999). Analogical transfer of problem solutions within and between languages in Spanish–English bilinguals. *Journal of Memory and Language*, *40*, 301–329.

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development*, *10*, 483–527.

Goetz, P. J. (2003). The effects of bilingualism on theory of mind development. *Bilingualism: Language and Cognition*, *6*, 1–15.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition*, *1*, 67–81.

Gullo, D. F., & Bersani, C. (1983). Effects of three experimental conditions on preschool children's ability to coordinate visual perspectives. *Perceptual and Motor Skills*, *56*, 675–678.

Hala, S., Hug, S., & Henderson, A. (2003). Executive function and false-belief understanding in preschool children: Two tasks are harder than one. *Cognition and Development*, *4*, 275–298.

Hala, S., & Russell, J. (2001). Executive control with strategic deception: A window on early cognitive development? *Journal of Experimental Child Psychology*, *80*, 112–141.

Hale, C. M., & Tager-Flusberg, H. (2003). The influence of language on theory of mind: A training study. *Developmental Science*, *6*, 346–359.

Happé, F. G. (1995). The role of age and verbal ability in the theory of mind task performance of subjects with autism. *Child Development*, *66*, 843–855.
Hernandez, A. E., Bates, E. A., & 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.
Humphreys, L. G., & Parsons, C. K. (1979). Piagetian tasks measure intelligence and tests assess cognitive development: A reanalysis. *Intelligence*, *3*, 369–382.
Humphreys, L. G., Rich, S. A., & Davey, T. C. (1985). A Piagetian test of general intelligence. *Developmental Psychology*, *21*, 872–877.
Huttenlocher, J., & Presson, C. C. (1973). Mental rotation and the perspective problem. *Cognitive Psychology*, *4*, 277–299.
Huttenlocher, J., & Presson, C. C. (1979). The coding and transformation of spatial information. *Cognitive Psychology*, *11*, 375–394.
Kaufman, A. S., & Kaufman, N. L. (1990). *Kaufman Brief Intelligence Test*. Circle Pines, MI: American Guidance Service.
Kovács, A. M. (2009). Early bilingualism enhances mechanisms of false-belief reasoning. *Developmental Science*, *12*, 48–54.
Kovács, 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.
Kroll, J. F., & De Groot, A. M. B. (1997). Lexical and conceptual memory in the bilingual: Mapping form to meaning in two languages. In A. M. B. de Groot, & J. F. Kroll (Eds.), *Tutorials in bilingualism: Psycholinguistic perspectives* (pp. 169–199). Mahwah, NJ: Erlbaum.
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.
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.
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.
Newton, A. M., & de Villiers, J. G. (2007). Thinking while talking: Adults fail nonverbal false-belief reasoning. *Psychological Science*, *18*, 574–579.
Piaget, J., & Inhelder, B. (1967). *The child's conception of space*. London: Routledge & Kegan Paul.
Poulin-Dubois, D., Blaye, A., Coutya, J., & Bialystok, E. (2011). The effects of bilingualism on toddlers' executive functioning. *Journal of Experimental Child Psychology*, *108*, 567–579.
Premack, D., & Woodruff, G. (1978). Does the chimpanzee have theory of mind? *Behavioural and Brain Sciences*, *1*(4), 515–526.
Rodriguez-Fornells, A., Rotte, M., Heinze, H.-J., Nösselt, T., & Münte, T. F. (2002). Brain potential and functional MRI evidence for how to handle two languages with one brain. *Nature*, *415*, 1026–1029.
Rubio-Fernández, 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.
Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind: A comparison of Chinese and U.S. preschoolers. *Psychological Science*, *17*, 74–81.
Shelton, A. L., Clements-Stephens, A. M., Lam, W. Y., Pak, D. M., & Murray, A. J. (2012). Should social savvy equal good spatial skills? The interaction of social skills with spatial perspective taking. *Journal of Experimental Psychology: General*, *141*(2), 199–205.
Siegler, R. S. (1995). How does change occur: A microgenetic study of number conservation. *Cognitive Development*, *28*, 225–273.
Tager-Flusberg, H., & Sullivan, K. (1994). Predicting and explaining behaviour: A comparison of autistic, mentally retarded and normal children. *Journal of Child Psychology and Psychiatry*, *35*, 1059–1075.
Tarshis, E., & Shore, B. M. (1991). Differences in perspective taking between high and above average IQ preschool children. *European Journal for High Ability*, *2*, 201–211.
van der Meer, L., Groenewold, N. A., Nolen, W. A., Pijnenborg, M., & Aleman, A. (2011). Inhibit yourself and understand the other: Neural basis of distinct processes underlying theory of mind. *Neuroimage*, *56*, 2364–2374.
Vasilyeva, M. (2002). Solving spatial tasks with unaligned layouts: The difficulty of dealing with conflicting information. *Journal of Experimental Child Psychology*, *83*, 291–303.
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.
Wellman, H. M., & Lagatutta, K. H. (2004). Theory of mind for learning and teaching: The nature and role of explanation. *Cognitive Development*, *19*, 479–497.
Wraga, M., Creem, S. H., & Proffitt, D. R. (2000). Updating displays after imagined object and viewer rotations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 151–168.
Wu, Y. J., & Thierry, G. (2010). Chinese–English bilinguals reading English hear Chinese. *Journal of Neuroscience*, *30*, 7646–7651.
Yang, S., Yang, H., & Lust, B. (2011). Early childhood bilingualism leads to advances in executive attention: Dissociating culture and language. *Bilingualism: Language and Cognition*, *14*, 412–422.
Yaniv, I., & Shatz, M. (1990). Heuristics of reasoning and analogy in children's perspective-taking. *Child Development*, *61*, 1491–1501.