

DOES BILINGUALISM CONFER PERSPECTIVE-TAKING ADVANTAGES IN
LANGUAGE USE?

BY

RACHEL A RYSKIN

THESIS

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Adviser:

Assistant Professor Sarah Brown-Schmidt

Abstract

The bilingual advantage hypothesis proposes that being bilingual leads to benefits in cognitive abilities that are mediated by superior executive control. Bilingual children demonstrate accelerated mastery of basic cognitive skills such as inhibition control (Carlson & Meltzoff, 2008) and are thought to have cognitive advantages in a variety of domains (Bialystok, Craik, & Luk, 2012), including insights into the perspective of others, i.e., theory of mind (Kovacs, 2009). However, little is known about the long-term impacts of bilingualism on cognition, including whether bilingual children's advantages in inhibitory control confer lasting advantages in adulthood, and whether these advantages extend to other domains. Here we examine the effects of bilingualism on adult cognition, focusing on perspective-taking in language processing, a domain which is thought to place particular demands on the executive control system. We conclude that the results of two experiments comparing perspective-taking abilities in monolingual and bilingual adults offer no support for the hypothesis that bilingualism improves the ability to appreciate the perspective of another person during language comprehension. In fact, bilinguals seem to have more difficulty interpreting spatial language.

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INTRODUCTION

In today's globalized world, the number of people who regularly use two or more different languages to communicate is significant and steadily increasing. In the US, approximately 20% of the population is bilingual, according to a 2009 American Community Survey (U.S. Census data, 2009), and this number continues to grow. While it is clear that there are many cultural advantages to speaking several languages (e.g., communicating with a more diverse group of people, travelling to other countries more comfortably, keeping in touch with older family members, etc.), it is not entirely clear the extent to which being bilingual confers cognitive benefits.

According to the bilingual advantage hypothesis, the bilingual experience recruits central executive functions as a result of switching between, and alternately inhibiting, the two languages (Bialystok, Craik, Green, & Gollan, 2009). These processes are thought to result in improvements to cognitive control that impact non-linguistic domains. On this hypothesis, bilingualism may have far-reaching, beneficial consequences for many aspects of cognition that have yet to be fully explored.

Evidence in support of the bilingual advantage hypothesis has been found primarily in young children and in older adults. This evidence includes findings that bilingual children demonstrate cognitive advantages in a variety of domains (Bialystok & Majumder, 1998; Bialystok, 2010; Bialystok & Viswanathan, 2009), including problem solving (Bialystok & Codd, 1997; Kessler & Quinn, 1980), understanding of quantity (Bialystok, 1999), knowledge of grammar (Bialystok, 1988), and insights into the perspective of others, i.e., theory of mind (Kovacs, 2009; Goetz, 2003). Among older adults, the evidence suggests that bilingualism diminishes cognitive declines associated with aging (Bialystok, Craik, Klein, & Viswanathan,

2004; Bialystok, Craik, & Freedman, 2007) and may even delay the onset of Alzheimer's (Schweizer, Ware, Fischer, Craik, & Bialystok, 2012; Chertkow, Whitehead, Phillips, Wolfson, Atherton, & Bergman, 2010). However, little is known about the impacts of bilingualism on cognition over the course of the lifespan, including whether bilingual children's accelerated mastery of basic cognitive skills such as inhibition control (Carlson & Meltzoff, 2008; Bialystok, 1999; Bialystok & Martin, 2004), confers lasting advantages in young adulthood. Limited results have shown the presence of a bilingual advantage in executive functioning in younger adults (Costa, Hernandez, & Sebastian-Galles, 2008; Bialystok, Craik, Klein, & Viswanathan, 2004; Prior & MacWhinney, 2010). These findings have been somewhat inconclusive (Kousaie & Phillips, 2012; Costa, Hernandez, Costa-Faidella, & Sebastian-Galles, 2009; see Hilchey & Klein, 2011) as they report overall faster response times for bilinguals on all conditions--in the Attentional Networks test and Simon task, for instance--not only the incongruent conditions designed to assess inhibitory control. In other words, the differences likely stem from a more general executive processing benefit for bilinguals, one that isn't specifically driven by inhibitory control. In particular, conflict monitoring, the ability to detect and signal a conflict during processing (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999), has been proposed as an alternative faculty at which bilinguals may excel due to their experience monitoring language changes.

Furthermore, in some cases the differences between monolinguals and bilinguals disappear over the course of the task (e.g., Bialystok et al., 2004; Costa et al., 2008), suggesting that the difference between groups may be related to task-strategies, the more successful of which monolinguals may learn over the course of the task (see discussion in Hilchey & Klein, 2011). Moreover, few, if any, attempts have been made to examine whether the scope of any

such advantages in young adulthood extend to other cognitive domains which are thought to make particular demands on executive functions such as inhibition control and conflict monitoring, which are hypothesized to be boosted by bilingualism.

Thus, one of the goals of the present research is to examine the effects of bilingualism on adult cognition and to what extent it may have an impact on the higher-order cognitive processes involved in everyday life. We focus on the domain of spatial perspective-taking because it is an ability that is frequently called upon, yet can be challenging for adults (Schober, 2009), and bilingual children are thought to have perspective-taking advantages (Kovacs, 2009). In what follows, we briefly introduce the cognitive challenges presented by perspective-taking, and then discuss in more detail the evidence that motivates the bilingual advantage hypothesis. We then present the results of two experiments that test whether the hypothesized bilingual cognitive advantage extends to the domain of perspective-taking in young adult language use.

Background on Perspective-Taking

Perspective-taking is an essential skill. It allows people to better understand each other and communicate more effectively. It has applications in realms as diverse as mathematics (e.g., in understanding the geometry of multi-dimensional figures) and language comprehension (by helping to resolve ambiguities). Yet, it is not something that always comes naturally. Children may lack the ability to explicitly reason about complex belief states until the age of 4 (Wimmer & Perner, 1983), despite the fact that many other cognitive skills are already developed by this age. On the other hand, evidence from implicit, non-verbal tasks demonstrates the ability to reason about false-belief by 15 months of age (Onishi & Baillargeon, 2005), suggesting that resource, rather than representational issues may be at play. Indeed, Carlson and Moses (2001) find that 3- and 4-year-old children with better inhibitory control also perform better on a theory

of mind task. This is further supported by the fact that in slightly older children (3 to 5 years old), inhibitory control skills play an important role in the child's ability to utilize another person's perspective in conversation (Nilsen & Graham, 2009).

While adults overwhelmingly are sensitive to perspective (Hanna, Tanenhaus, & Trueswell, 2003), adults do still show interference from their egocentric perspective (Keysar, Lin, & Barr, 2003; Birch & Bloom, 2007). Further, the degree to which adults appreciate perspective is modulated by basic cognitive functions including memory and inhibition (Brown-Schmidt, 2009; Lin, Keysar, & Epley, 2010; Grodner et al., 2012; also see Converse, Lin, Keysar, & Epley, 2008). In view of the literature suggesting that bilingualism provides certain cognitive advantages, a key question, then, is whether perspective-taking skills might also benefit from bilingualism in adulthood.

Neural evidence, in children and adults, suggests that bilinguals recruit separate, non-linguistic areas when engaging theory of mind in each language (Kobayashi, Glover, & Temple, 2006; Kobayashi, Glover, & Temple, 2007), suggesting that linguistic experience can have a profound influence on the processing of perspective. Moreover, Goetz (2003) found that 3- and 4-year-old Mandarin-English bilingual children performed better on several measures of perspective-taking ability than monolingual Mandarin- and English-speaking children. Similarly, Kovacs (2009) found that Romanian-Hungarian bilingual children (around age 3) outperform matched monolinguals on both a standard false-belief task and a modified version that mimics the type of language switch situation that early bilinguals may encounter in their daily life. According to Kovacs, this suggests that the childhood bilingual advantage in theory of mind is likely due to enhanced inhibitory control, rather than simply to a more developed awareness of the different mental states of others due to the experience of tailoring language to the listener.

Among adults, a study by Wu and Keysar (2007) showed that Chinese participants, who, as students at University of Chicago were likely to be bilingual, performed better than American adults (likely monolinguals) at appreciating the perspective of a speaker during an on-line language interpretation task. While Wu and Keysar interpreted this as a cultural advantage (see Oyserman & Lee, 2008; Gardner, Gabriel, & Lee, 1999), an alternative interpretation of this result is that there is a bilingual advantage in the domain of perspective-taking for language-processing in adulthood as well. Further, Rubio-Fernandez and Glucksberg (2012) claim that bilingual adults are less susceptible to an egocentric bias during a false belief task, than monolingual adults. However, the eye-tracking measures they report (first fixation locations and latencies to look at the target object) are somewhat challenging to interpret because of known delays in bilingual linguistic processing (Ransdell & Fischler, 1987). At the time when monolinguals were interpreting the critical test question that queried their understanding of false-belief, bilinguals may have been processing an earlier part of the sentence that mentioned the target object and *this* may have guided their eye fixations, rather than better understanding of false belief.

While a large and growing literature suggests a bilingual advantage in childhood for perspective-taking (Goetz, 2003; Kovacs, 2009) and other cognitive domains (Bialystok & Codd, 1997; Bialystok, 1999), there is little consensus on the source of this advantage. Nor is it immediately clear why learning multiple languages would extend to improved performance on largely unrelated cognitive tasks, considering limited evidence of transfer of general skills from training to testing in other domains (Owen, Hampshire, Grahn, Stenton, Dajani, Burns, Howard, et al., 2010; Dahlin, Neely, Larsson, Bäckman, & Nyberg, 2008; c.f. Hertzog, Kramer, Wilson, & Lindenberger, 2009). For example, while there is evidence that suggests that experienced

video game players have improved visual and attentional processes (Gopher, Weil, & Bareket, 1994; C. S. Green & Bavelier, 2003), it is unknown whether this benefit is the *result* of that experience or the functional *cause* of the experience—that is, that individuals with better executive function self-select as gamers (see Boot, Blakely, & Simons, 2011). Some research suggests that training on video games and other cognitive tasks does lead to improvements in separate cognitive domains (Chein & Morrison, 2010; Jaeggi, Buschkuhl, Jonides, & Perrig, 2008), particularly in children (Jaeggi, Buschkuhl, Jonides, & Shah, 2011) and older adults (Hertzog et al., 2009). However, the training effects seem to hinge on a subset of individuals (Jaeggi et al. 2011), such that most of the transfer is seen, unsurprisingly, among participants who quickly improve during the training phase. Finally, the training effects appear to be at most minimal.

The possibility that early experience with multiple languages could confer general cognitive advantages is compelling, given that, unlike video-game experience, or intensive training on a working memory task, the bilingual experience is likely to begin earlier and be more extensive than video-game or laboratory interventions, with bilingual children being repeatedly exposed to multiple languages throughout life. Further, with early bilinguals, who are often the focus of the present research, the exposure occurs early in development, potentially capitalizing on the young child's neuroplasticity (Stiles, 2000; Schlaug, Forgeard, Zhu, Norton, Norton, & Winner, 2009). There is indeed evidence that being bilingual has an impact on neural architectures and their activation even when both languages are not being used, for instance, on flanker and Simon tasks (Luk, Anderson, Craik, Grady, & Bialystok, 2010; Bialystok, Craik, Grady, Chau, Ishii, Gunji, & Pantev, 2005), in language processing (Kovelman, Baker, & Petitto, 2008), theory of mind (Kobayashi, Glover, & Temple, 2006), and non-verbal task-switching (Garbin et al., 2010).

According to one view, bilinguals frequently switch from one language to another, and it is this switching that tunes a general ability to selectively attend to relevant information and inhibit irrelevant information (Green, 1998). On another view, the role of executive function is less “active” (see Colzato et al., 2008) and the benefits seen in bilinguals are the result of superior monitoring ability. The former claims are consistent with findings that 5-year-old Chinese-English bilingual children have better inhibitory control than monolingual children from a geographically and socioeconomically close community (Bialystok & Martin, 2004), as measured by the dimensional card sort change task (Zelazo, Frye, & Rapus, 1996). Converging evidence for the bilingual inhibitory advantage hypothesis comes from findings of a bilingual advantage in executive functioning among older adults (Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Luk, 2008; Bialystok, Craik, & Ryan, 2006). However, several studies have failed to replicate any bilingual executive control advantage (see Hilchey & Klein, 2011) particularly in young adults. Findings that young bilingual adults (19 to 32 years) have better performance on the Attentional Networks Test than monolinguals (Costa et al., 2008), on the other hand, seem to support the latter hypothesis of an executive monitoring advantage because bilinguals’ RTs are faster overall (Costa et al., 2009).

While some findings suggest bilinguals may be at an advantage in general cognitive abilities, other evidence suggests that these advantages come with costs in the language domain. Adult bilinguals demonstrate delays and more errors, as compared to monolinguals, on verbal fluency tasks (Rosselli, Ardila, Araujo, Weekes, Caracciolo, Padilla, & Ostrosky-Solis, 2000; Gollan, Montoya, & Werner, 2002; Bialystok et al., 2008), as well as picture naming tasks (Kaplan, Goodglass, & Weintraub, 1983; Roberts, Garcia, DesRochers, & Hernandez, 2002; Gollan, Montoya, Fennema-Notestine, & Morris, 2005). This processing cost is evident even when

participants are tested in their dominant language (Sandoval, Gollan, Ferreira, & Salmon, 2010), suggesting these effects are not simply due to low proficiency.

Taken together, these findings suggest that whatever advantage bilingualism confers, it may not extend to all cognitive domains. One possible explanation for the bilingual linguistic disadvantage lies in the fact that bilinguals have much larger lexicons, composed of approximately twice as many words as those of monolinguals. As a result, a balanced bilingual (i.e., one who uses each language with equal frequency) most likely uses each individual word with less frequency than monolingual speakers, because his or her word usage is split between two languages. Some have suggested that this “frequency-lag” may be responsible for findings of a bilingual disadvantage in lexical access (Gollan, Slattery, Goldenberg, van Assche, Duyck, & Rayner, 2011). Another view suggests that the bilingual disadvantage stems from the need to actively inhibit whichever language is not in use at the time of lexical access (Meuter & Allport, 1999; Levy, McVeigh, Marful, & Anderson, 2007)—notably, this is the same inhibitory process implicated in the proposed general cognitive advantage for bilinguals.

The present research

The present research was designed to examine the reach of the hypothesized bilingual cognitive advantage into a domain—perspective-taking—which is thought to place high demands on, and receive support from the same frontal-cortex mediated executive control networks believed to underlie the bilingual cognitive advantage (Bialystok et al., 2005). We examine the relationship between perspective-taking and bilingualism in a series of two experiments in which monolingual and bilingual participants complete an interactive spatial perspective-taking task.

The tasks were designed to encourage participants to engage their verbal, spatial, and crucially, perspective-taking abilities. Analyses compare the performance of bilingual and monolingual participants and evaluate their ability to take the perspective of their interlocutor. Measures of individual differences, and comparisons across linguistic-experience-based groups speak to the underlying cognitive mechanisms that may be responsible for between-participant differences in perspective-taking ability.

We examined perspective-taking in a language task for two reasons. First, perspective-based representations are widely encoded in the languages of the world (Papafragou, 2002; Bloom, 2001; Clark & Brennan, 1991; Clark, 1996), as exemplified by perspective verbs (*chase* vs. *flee*), grammatical person (*I* vs. *you*), frames of reference for spatial terms (e.g., *left* vs. *right*), evidential morphology (as in Korean; Papafragou, Li, Choi, & Han, 2007), and utterance form (e.g., questions vs. statements; Brown-Schmidt, Gunlogson, & Tanenhaus, 2008; Gunlogson, 2001). Second, while previous findings of bilingual advantages in various cognitive control tasks speak to conferred advantages in domain-general abilities in adulthood (Costa et al., 2008; Bialystok et al., 2004; cf. Bialystok et al., 2008), these findings do not speak to whether these advantages have any benefit in the typical activities of daily living—that is whether bilingualism confers clear cognitive advantages in real world tasks. Thus, we selected a task—perspective-taking in conversational language use—which is thought to recruit the same executive functions hypothesized to be trained by the bilingual experience (Lin et al., 2010; Brown-Schmidt, 2009), and for which some evidence suggests young bilingual children might be at an advantage (Kovacs, 2009). If the bilingual experience provides advantages beyond basic cognitive tasks, and beyond childhood, we would expect to find evidence of, and be able to measure the extent of this advantage in a perspective-taking language task. A final goal of the present research is to use

a number of individual differences measures (inhibition, working memory, etc.) to more clearly specify the cognitive mechanisms underlying the bilingual advantage in adulthood, if one exists.

Experiment 1

Experiment 1 compares the performance of bilingual and monolingual adults on a modified route-finding task (e.g., Bard et al., 2000; Anderson et al., 1991) in which we manipulate the difficulty of adopting the appropriate spatial perspective. A speaker and listener can never view a scene from the exact same perspective at the same time (Schober, 1993). Thus, in order to communicate spatial information, the speaker must adjust his or her language to reflect the listener's perspective on the scene, or vice-versa. The present experiment examined the role of bilingualism and individual differences in executive function in the ability to adjust to the spatial perspective of another person.

Methods

Participants

Participants were 32 monolingual speakers of English (16 female) and 33 bilinguals (21 female) who spoke English and at least one other language fluently. The second languages reported included Spanish, Japanese, Polish, Chinese, Korean, Marathi, Assyrian, and Ukrainian, among others. All participants were from the University of Illinois at Urbana-Champaign student community and were between the ages of 18 and 50 ($M = 20.53$, $SD = 4.39$). They either received partial course credit for their participation or were paid \$8/ hr.

Table 1 shows participant characteristics obtained from a language background questionnaire. Monolinguals and bilinguals did not differ significantly in age, however, bilinguals did report less frequent weekly use of English, later first exposure to English, and earlier first exposure to a second language than monolinguals. Bilinguals also reported more frequent use of a second language, better speaking ability in a second language and longer exposure to a second language than monolinguals. Socio-economic status was measured using

the level of parental education (averaged across both parents for each participant), and did not differ across monolinguals and bilinguals. Two participants were excluded because they were not clearly bilingual, monolingual, or a native speaker of English. Exclusion criteria included age of first exposure to a language, self-described proficiency in languages, percent weekly use, and quality and duration of exposure.

	Bilinguals (<i>n</i> =33)		Monolinguals (<i>n</i> =32)		95% <i>CI</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Age	20.09	1.47	21	5.62	[-1.21 to 3.02]
Percent weekly use of English	83.83	16.04	98.77	5.42	[8.96 to 20.91]
Age of first exposure to English (in years)	2.84	3.77	(at birth)	-	[-4.30 to -1.38]
Age of first exposure to second language (non-English)	2.38	3.48	13.14	2.89	[8.36 to 13.17]
Percent weekly use of non-English language	18.09	17.81	1.955	5.49	[-22.72 to -9.55]
Self-rated speaking ability in non-English language (0-beginner to 3- near native)	2.62	0.62	0.67	0.73	[-2.23 to -1.59]
Years of exposure to non-English language	11.86	5.78	3.84	2.02	[-10.35 to -5.67]
Parental education	-0.15	1.06	0.16	0.81	[-0.78 to 0.16]

Table 1. Average, standard deviation, and 95% confidence intervals of difference of the means of participant characteristics.

Three of the language questionnaire responses (proficiency in non-English second language, percent weekly use of non-English second language, and duration of second language exposure) were used to compute a continuous measure of bilingualism using an un-weighted average of the standardized scores. These three questions were used because they have been commonly used to assess bilingual experience (e.g., Unsworth, 2011; Jia, Aaronson, & Wu, 2002; Paradis, 2011). In addition, the remaining questions on the questionnaire contained many blank values or were highly correlated with these three. This bilingualism quotient provided each participant with an individual measure of their bilingual experience. Hereafter, we use the terms “monolingual” and “bilingual” to refer to participant groups created based on the median split of this quotient (i.e.,

the “bilingual” group had higher quotient scores)¹. Three participants were re-categorized based on this split (e.g., they were recruited as bilingual but their quotient score turned out to be below the median), leading to a sample of 32 bilinguals and 33 monolinguals.

Materials and Procedure

Following completion of the language background questionnaire, participants completed a series of individual differences tasks selected to measure several aspects of executive function, and then completed an interactive perspective-taking task.

Individual Difference measures. Individual differences tasks were selected to measure the constructs of perceptual speed, working memory, and inhibition control. The perceptual speed tasks consisted of a letter comparison and a pattern comparison task; both were computerized versions of tasks used by Salthouse and Babcock (1991). In the letter comparison task, participants viewed a pair of consonants and were instructed to make a speeded judgment as to whether the two letters were the same or not. The task consisted of six blocks of trials, each lasting 20 seconds. The complexity of the display increased with every new block. The pattern comparison task was identical except that participants viewed simple line patterns instead of letters. Scores were calculated by summing the numbers of hits and correct rejections. An overall perceptual speed score was calculated by averaging the scores from the letter comparison task and the pattern comparison task. Participants with a high score were presumed to have superior perceptual speed skills than those whose scores were lower.

Four computerized working memory tasks were used to assess working memory ability: an alphabet span task, a reading span task, a listening span task, and a minus 2 span task. In the

¹ Note that the quotient is used as a continuous measure in the main analysis. Preliminary analyses indicated the median split provided a better fit to the data than grouping participants based on their categorical self-report bilingualism status.

² A measure of reliability calculated using a correlation of the even and odd trials for both Stroop tasks

alphabet span task, participants saw a list of words and then were asked to recall them in alphabetical order. In the reading span task, participants read sentences aloud and made “true/false” judgments about them. After each set of sentences, they were instructed to recall the last word from each sentence, with the restriction that the first recalled word could not be from the last sentence. The listening span task was identical to the reading span task, except that participants listened to the sentences instead of reading them. Finally, the minus 2 span task required participants to recall, in order, a list of numbers they had just viewed and subtract 2 from each number. Each span task included 2 short practice blocks, followed by 12 test blocks of varying difficulty (determined by the number of items to be remembered in each block). The score was determined by summing the proportions of items recalled correctly in each block (e.g., if the participant recalled 4 items from the block of 6 correctly, that block would receive a score of 4/6). The maximum possible score on each span task was 12. An overall working memory score was obtained by averaging scores across the four span tasks; higher scores indicated better working memory, and the top score overall was 12.

Inhibition was assessed using two versions of the Stroop task. In the first Stroop task, participants first viewed a series of color patches (either red, orange, yellow, green, blue or purple), and were instructed to say the color of the patch as quickly as possible and then press a key on the keyboard. Participants were then presented with a series of color words from the same set of colors as the color patches (e.g., “red”, “orange”, etc.), presented in an inconsistent ink color from the same set of colors (100% of trials were incongruent). Participants were instructed to say the color of the font that the word was displayed in as quickly as possible and then press a key on the keyboard. The timing of the key presses was used to determine how quickly the participants said the color (of the patch or the font) after seeing the display. The color patch

naming and font color naming tasks each consisted of 100 trials. The overall score was a measure of the amount of interference that the participant experienced from the incongruent color word. This score was obtained by subtracting the average reaction time (button press RT) for color patch naming from the RT for the font color naming. Thus, a lower score signified better inhibitory control.

In the second Stroop task, participants saw a series of color words presented in a font color that did not match the meaning of the word (e.g. the word “blue” in green font). During a first block consisting of 30 trials, participants read the color words (e.g., “blue”) out loud. The colors were the same as in the first Stroop task. In the second block of 30 trials, participants were told to say the color of the font that the word was presented in (e.g., green). All responses were recorded and the audio files were coded manually. The accuracy score was the number of trials on which a given participant said the correct color without any disfluencies (e.g., “*pur..uh...green*”). In this version, a higher score signified better performance.

Perspective-taking task. Following completion of the individual differences measures, participants completed an interactive perspective-taking task with the experimenter. In the first part of the task, participants followed the experimenter’s verbal instructions to trace a course through a simple map of objects. In the second part of the task, participants gave the experimenter instructions on the same task. At the beginning of the task, the participant was given a packet of 11 maps with images of simple objects. The experimenter sat across the table from the participant (see Figure 1). A barrier in the center of the table prevented any non-verbal communication. The need to take the experimenter’s spatial perspective was manipulated between-subjects: In the no Perspective-taking (nPT) condition, the experimenter’s maps were identical to the participant’s (Figure 2a), except that the experimenter saw a path drawn on the

map (Figure 2b). In the Perspective-taking (PT) condition, the experimenter's maps showed the opposite visual perspective from the participant (Figure 2c). The experimenter then proceeded to give the participant directions on how to draw a path through each map with a pen marker. The first trial was a practice trial, and it was followed by 10 critical trials.

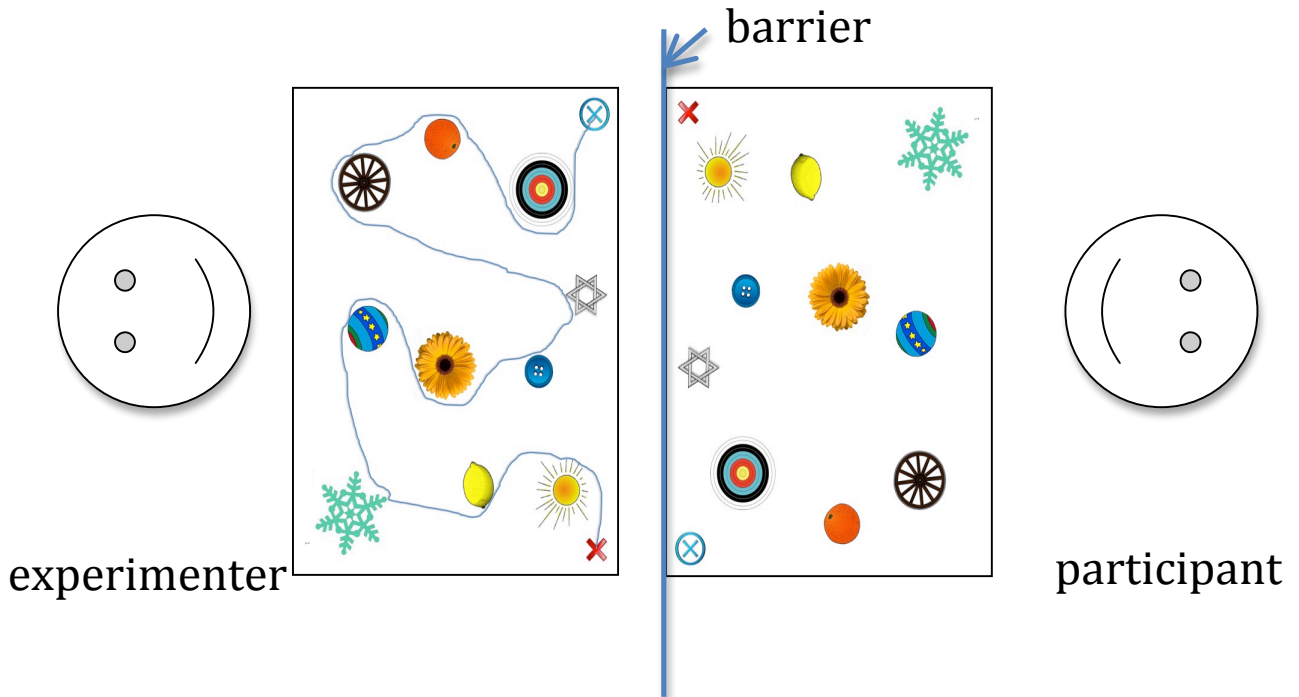
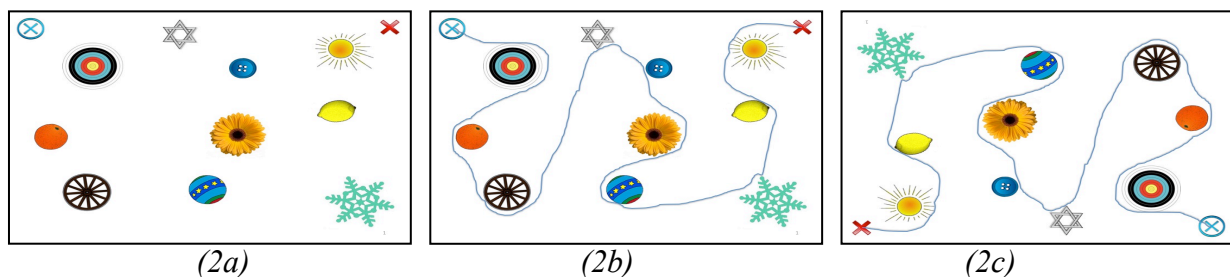


Figure 1. Schematic of the experimental setup (nPT condition).



Figures 2a-c. Example maps for participant (2a) and experimenter in the nPT condition (2b) and the PT condition (2c). Note the starting point for each map is the red X. In the nPT condition, the objects on the experimenter's right are the same as the objects on the participant's right, whereas in the PT condition, the objects on the experimenter's right are the same as the objects on the participant's left.

Linguistic stimuli

In the nPT condition, the experimenter gave directions from the perspective of the participant. In other words, if the participant heard “go left to the ball,” he or she would have had to draw a line to the left. In the PT condition, the experimenter gave directions from her own perspective, which was the opposite of the participant’s. In other words, if the participant heard “go left to the ball,” the participant would have had to draw a line to the right. The instructions were categorized into three types based on their format:

Type 1:

From the [object] go [direction term] and [second direction term] to the [second object].

From the ball go left and down to the button.

Type 2:

From the [object] go [direction term] to the [second object].

From the ball go down to the button.

Type 3:

Go around the [object] on the [direction term].

Go around the orange on the bottom.

Every map included instructions of all 3 types. The 10 map trials and the training trial were video-recorded. Participants’ errors were coded by comparing the paths that the participants drew to the directions given by the experimenter. Any directional deviation from an instruction given by the experimenter was considered one error. For instance, if the instruction was “Go around the ball on the left,” (in the nPT condition) a path drawn around the right side of the ball was counted as one error. Small variability in paths were not treated as errors. For example, if the

participant drew the line slightly closer to one object than the experimenter, this was treated as correct.

The audio and video footage was also coded to obtain timing data for each participant. A preliminary analysis of these data indicated that the relationship between the onset of the final word in each instruction (e.g., *button/ button/ bottom* in the examples above), and the onset and offset of the participant's pen movements were most informative about the task difficulty (as revealed by a comparison of the nPT and PT conditions). As a result, the final data analysis included measurements of the onset (in milliseconds) of the last word in each instruction spoken by the experimenter, as well as the onset and offset times of the participant's pen movement relative to the last word in the instruction. For instance, if the experimenter said "*From the ball go left to the star*", the onset and offset of the participant's pen movement relative to "star" were used to measure latency (how long it took for the participant to start the movement after hearing the instruction) and duration (how long it took for the participant to complete that movement) for each individual instruction.

Predictions

According to the bilingual advantage hypothesis (Bialystok et al., 2009), bilingual participants should perform better on executive function tasks, which should be observable in the individual differences measures. Further, if advanced perspective-taking skills in bilinguals (Kovacs, 2009) extend to adulthood, we would expect to see a clear bilingual advantage in our task. However, according to both the frequency-lag hypothesis (Gollan et al., 2011) and the lexical-inhibition hypothesis (Meuter & Allport, 1999; Levy et al., 2007), bilinguals' performance is likely to be strained due to the linguistic nature of the task. Thus, a bilingual advantage, if one were to occur, might manifest in bilingual's ability to overcome difficult perspective-taking situations in spite

of linguistic challenges. If bilingual children's improved perspective-taking abilities (Kovacs, 2009) are mediated by accelerated inhibition control (Carlson & Meltzoff, 2008), the demand the perspective-taking task places on inhibition (Brown-Schmidt, 2009) in conjunction with the executive demands of a spatial task (e.g., Baddeley, 1986) might suggest that individual differences in executive function should mediate these effects.

Results

We first present the analysis of performance on the individual differences measures for the 65 participants, comparing monolingual and bilingual participants directly. Then, we turn to an analysis of performance on the spatial perspective task which was evaluated using three separate measures: number of errors, latency of movement, and duration of movement.

Individual Differences

Analyses of the individual differences measures of perceptual speed, working memory, and inhibition scores revealed no significant differences between language (bilingual vs. monolingual) groups, contrary to previous findings of a bilingual advantage in inhibition (Costa et al., 2008; Bialystok et al., 2008), and working memory (Bialystok et al., 2004), among adults. The group means are presented in Table 2². While we did not observe significant group differences, individual differences in these measures may predict task performance; we return to this possibility below in the analyses of errors and reaction times.

	Monolingual		Bilingual		95% CI
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Perceptual speed	77.20	11.61	79.08	10.90	[-3.74 to 7.51]

Table 2. Group means, standard deviations, and 95% confidence intervals for difference of the means for individual difference measures.

² A measure of reliability calculated using a correlation of the even and odd trials for both Stroop tasks was high: Stroop 1 ($R=0.83$) and Stroop 2 ($R=0.87$). Due to task complexity, the same procedure was not possible for the other individual differences measures.

Working memory	8.25	1.04	8.03	0.99	[-0.72 to 0.29]
Inhibition (Stroop 1)	0.23	0.13	0.17	0.20	[-0.15 to 0.02]
Inhibition (Stroop 2)	48.28	8.46	46.59	6.72	[-5.51 to 2.14]

Table 2. (continued)

Errors

Each participant drew a line from one object to another in response to approximately 17 instructions for each of the ten maps, resulting in 174 data points for each participant. Below we plot the average number of total errors per participant for monolinguals and bilinguals (Figure 3).

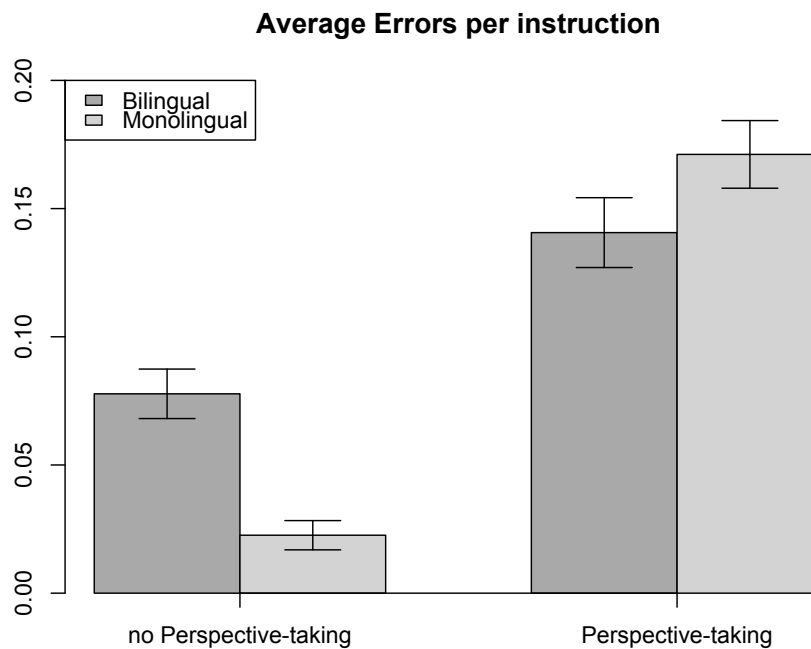


Figure 3. The proportion of errors (based on a total of 174 possible errors per participant) by language group and condition with by-subject standard error of the mean bars.

Performance was overall better in the nPT condition, suggesting that we were successful at creating a difficult perspective-taking task. However, language experience modulated how participants reacted to the pressures of the perspective-taking task. Overall, participants were only making an average of 18 errors out of 174 (10.5% error rate).

The data were analyzed in a mixed effects logistic regression using the *lme4* software package in R (Bates, 2007) with both subjects and items as random intercepts. Because the dependent measure was binary, models were fit using Laplace approximation. Perspective condition (nPT vs. PT) was contrast coded. A perspective by bilingualism interaction was entered as a fixed effect, with by-item random slopes for the interaction and the main effects of bilingualism and perspective condition (Table 3)³. Models with perceptual speed, working memory, and inhibition as mean-centered factors were attempted but those factors did not contribute significantly to the model based on evaluation of the t-statistic (see Appendix A). The model revealed a significant effect of condition due to more errors, for all participants, in the PT condition. A significant effect of language was due to more errors by bilinguals compared to monolinguals. The significant interaction of perspective condition and bilingualism was due to the fact that bilinguals made significantly more errors in the nPT condition ($p < 0.005$) and numerically fewer errors in the PT condition ($p = 0.813$)⁴.

<i>Fixed Effects</i>	Estimate	Std. Error	z value	p value
(Intercept)	-2.9035	0.1723	-16.847	< 2e-16
Perspective	1.7045	0.3134	5.439	5.36e-08
Bilingualism	0.563	0.1993	2.825	0.00472
Perspective x bilingualism	-1.0224	0.3981	-2.568	0.01022
<i>Random Effects</i>	Name	Variance	Std. Dev.	

Table 3. Effects of condition and language on interpretation errors in spatial perspective task.

³ An identical analysis was performed using language group as a categorical predictor. The results were the same as for the continuous bilingualism quotient, though the perspective by bilingualism interaction did not reach significance, likely due to lower statistical power.

⁴ A post-hoc analysis that included participant gender as a factor indicated that there was a significant perspective by gender interaction ($p < 0.005$) such that males made fewer errors in the nPT condition and females made fewer errors in the PT condition. This is consistent with evidence that males have superior spatial skills (Voyer, Voyer, & Bryden, 1995; Voyer, Nolan, & Voyer, 2000) and females have superior theory of mind abilities (Baron-Cohen & Hammer, 1997; Baron-Cohen, O’Riordan, Stone, Jones, & Plaisted, 1999; Baron-Cohen, 2003; Baron-Cohen, Knickmeyer, & Belmonte, 2005). Gender did not interact in any way with language group.

Subject	(Intercept)	1.30E+00	1.1399912	
Trial	(Intercept)	5.76E-02	0.2400284	
	Perspective	2.44E-02	0.1560523	
	Bilingualism	2.37E-03	0.0487101	
	Perspective x Bilingualism	1.86E-05	0.0043122	
Number of observations: 11203, Subjects, 65 ; Trials, 10				

Table 3. (continued)

Latency and Duration

The latency analysis examined the time it took for each subject to begin a pen movement in response to an instruction. Both trials on which the participants made errors and trials on which they responded correctly were included. Data points that were over three standard deviations above or below the mean were excluded. Latency data for the last instruction on each trial was also excluded as the last instruction was always of the form “From [object], go to the FINISH.” The “Finish” was always the only object left on the map, so participants typically began that movement prior to the final instruction. In total, 826 data points were excluded (<0.1%).

The latency data were analyzed in a mixed effects model with bilingualism and perspective, and their interaction, as fixed effects. Subjects and items were entered as random intercepts and the maximal random slope structure was used. The coefficients are summarized in Table 4. There was a significant effect of perspective condition, such that all participants were slower to begin drawing the response when the perspectives were misaligned. Although the effect of bilingualism did not reach significance, there was a significant interaction of bilingualism by perspective. Further analyses revealed that the effect of bilingualism was significant in the PT condition ($t=-2.168, p=0.035$), but not in the nPT condition ($t= 0.734, p=0.466$). This indicates that the bilinguals were faster than the monolinguals to initiate a pen movement when the perspectives were misaligned.

<i>Fixed effects</i>	Estimate	Std. Error	t-value	p-value
(Intercept)	520.64	52.38	9.939	0.000
Perspective	394.22	93.32	4.224	0.000
Bilingualism	-73.04	60.97	-1.198	0.236
Perspective x Bilingualism	-257.06	121.63	-2.113	0.039
<i>Random effects</i>	Groups	Name	Variance	
Subject	(Intercept)	1.04E+05	321.8524	
Trial	(Intercept)	5.69E+03	75.4229	
	Perspective	2.57E+01	5.0647	
	Bilingualism	6.01E+01	7.7529	
Residual	1.56E+06	1249.93		
Number of observations: 7883; Subjects, 54; Trials: 10				

Table 4. Effects of perspective and bilingualism on latency of response on spatial perspective-taking task.

A model with perceptual speed, working memory, and inhibition as mean-centered factors (Appendix B) revealed that the first measure of inhibition control (Stroop 1) predicted latency, $t=2.703$, $p=0.009$, such that participants who showed less interference on the Stroop were faster to respond. However, inhibition did not interact significantly with perspective, $t=-1.512$, $p=0.137$, and the interaction of perspective and bilingualism was only marginal, $t=1.835$, $p=0.072$. These findings, along with the *lack* of a significant difference between monolinguals and bilinguals on any of the individual differences measures suggest that the faster RTs by bilinguals in the perspective-taking condition cannot be fully explained by inhibitory control.

The duration of each pen movement was analyzed in the same way as latency, but none of the factors of interest significantly predicted duration, so they will not be discussed further. This null result is likely due to high variability in the speed with which these movements were executed.

Discussion

In Experiment 1, we did not find evidence for a bilingual advantage in executive function or in perspective-taking ability. In fact bilinguals performed equivalently on all four measures of

executive function, and made significantly more errors in the spatial perspective task. Bilinguals were faster to initiate a response than monolinguals, which is consistent with general findings of faster processing among bilinguals (Costa et al., 2009). The lack of a similar effect in the nPT condition may simply be due to ceiling performance in that condition.

One possible reason for the lack of executive function advantage for bilinguals is that the measures of individual differences (span tasks and Stroop) were mostly verbal in nature. If so, the differences in verbal fluency between bilinguals and monolinguals may have hindered bilinguals' performance on these tasks despite potentially superior processing abilities. A complication of this argument, however, is that other findings in the literature of a bilingual advantage in a similar color Stroop task (Bialystok et al., 2008) have been attributed to the bilingual participant's better cognitive control. Further, the present lack of a bilingual advantage in the Stroop task is consistent with other findings of a lack of a bilingual advantage in the Stroop task (Rosselli et al., 2002; Kousaie & Phillips, 2012), as well as a lack of advantage for video gamers in the Stroop task, despite their hypothesized improved cognitive skills (Bailey, West, & Anderson, 2010). Fluency may have contributed to bilinguals' increased error rates on the perspective-taking task, in particular because not all of the bilinguals had learned English as their first language (though all had learned it before puberty and used it as their primary language throughout their daily lives). However, fluency is unlikely to be the only factor. Gorrell (1987) reports a lack of benefit in bilingual children on a non-linguistic spatial reasoning task, where language deficits may play less of a role.

In Experiment 2, we address these concerns through the use of exclusively native English speaking bilingual participants, non-linguistic measures of executive function, and a perspective-taking task that taps both non-verbal and verbal spatial perspective-taking.

Experiment 2

The goals of Experiment 2 were threefold: The first goal was to examine the effects of bilingualism on perspective-taking ability using a more sensitive dependent measure.

Accordingly, we used an eye-tracking task that required on-line interpretation of linguistic perspective in order to interpret temporarily ambiguous spatial terms. Second, we manipulated perspective in three ways in order to provide more opportunities for creating a challenging perspective test that could tap potential bilingual advantages in perspective-taking. These three manipulations tested the on-line understanding of spatial perspective language (the primary manipulation), the ability to ignore potential competitors in the scene that were seen only by the participant, and the ability to flexibly switch perspectives. Third, in order to avoid confounds due to bilinguals' different experience with English, we used a large number of non-linguistic individual differences measures to evaluate claims of a bilingual executive function benefit, and the degree to which said benefit might modulate perspective-taking in the language task. We also collected a measure of verbal ability and, in this experiment, all participants learned English as their first language.

Methods

Participants

Participants were 21 native monolingual speakers of English (15 female) and 20 bilinguals (16 female) who spoke English as their native language and at least one other language fluently. The second languages included Spanish, Korean, Cantonese, Mandarin, Hindi, Kannada, Polish, and Gujarati. Participants were from the University of Illinois at Urbana-Champaign student community, were between the ages of 18 and 23 ($M= 19.22$, $SD= 1.26$), and all had normal hearing and normal or corrected-to-normal vision. Participants either received

partial course credit for their participation or were paid \$8/ hr for up to two hours of participation. Nine participants' data were not coded or included in the analysis due to experimenter error. Seven more participants' data were not included due to technical problems related to the eye-tracker, leaving a total of 41 participants for the main analysis.

All participants completed a language background questionnaire prior to the main experiment (Table 5). Important for the present experiment, all participants were native speakers of English, and both bilinguals and monolinguals reported high English proficiency and high rates of daily use of English. Bilinguals were exposed to their second, non-English, language early in life (on average, before age 1), whereas monolinguals were not exposed to any other languages until about 11. Whereas bilinguals used their second language much less often than English, bilinguals used a second language substantially more often than monolinguals. Socio-economic status was measured using the level of parental education (averaged across both parents for each subject), and did not differ between monolinguals and bilinguals.

	Bilinguals (<i>n</i> =20)		Monolinguals (<i>n</i> =21)		95% Confidence Interval of the diff.
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
Age	19.8	1.4	18.7	0.80	[0.40 to 1.86]
Percent weekly use of English	76.65	16.89	99	5.4	[-30.12 to -13.73]
Age of first exposure to second (non-English) language (in years)	0.74	1.56	10.89	4.54	[-12.44 to -7.87]
Percent weekly use of second language	20.85	15.95	0.52	1.21	[12.85 to 27.81]
Self-rated speaking ability in English (0-beginner to 3 near-native)	2.95	0.22	3	0	[-0.15 to 0.05]
Self-rated speaking ability in second language (0-beginner to 3-near-native)	2.7	0.57	0.44	0.51	[1.90 to 2.61]
Parental education	-0.26	0.91	0.25	0.77	[-1.05 to 0.04]

Table 5. Average and standard deviation of participant language characteristics, plus 95% confidence intervals of the difference between the means.

Three of the language questionnaire responses (proficiency in non-English second language, percent weekly use of non-English second language, and age of first second language exposure) were used to compute a continuous measure of bilingualism using an un-weighted average of the standardized scores. These three questions were used because they have been commonly used to assess bilingual experience (e.g., Unsworth, 2011; Jia, Aaronson, & Wu, 2002; Paradis, 2011). In addition, the remaining questions on the questionnaire contained many blank values or were highly correlated with these three. This bilingualism quotient provided each participant with an individual measure of their bilingual experience. The bilingualism scores for all of the participants were consistent with their original category (monolingual or bilingual).

Materials and Procedure

Following completion of the language background questionnaire, participants performed a series of computer-based non-linguistic individual differences tasks, which lasted about 1 hour. Participants then switched rooms and started the interactive dialog task with an experimenter, which lasted about 40 minutes.

Individual Differences. The battery of individual differences tasks was selected to evaluate executive function using non-linguistic tasks, and included the Attentional Networks Test, a spatial working memory task, and an anti-saccade task. In addition, English fluency was assessed using a picture-naming test, and general intelligence was measured using Raven's Progressive Matrices.

The first individual difference measure was the Attentional Networks Test (Fan, McCandliss, Sommer, Raz, & Posner, 2002). It is designed to measure the processing efficiency of three uncorrelated networks thought to be involved in attention: alerting, orienting, and executive function. The Java version of the ANT was downloaded from Dr. Jin Fan's

professional website⁵ and used to collect data. The test instructs participants to click either the left or right mouse button, as fast as possible, to indicate whether an arrow presented in an immediately preceding screen was facing left or right, respectively (Figure 4A). The arrow was presented above or below the centered fixation cross and was surrounded by either two flanker arrows on either side pointing in the same direction as the center arrow (congruent condition), two arrows on either side pointing in the opposite direction (incongruent condition), or two dashes on either side (neutral condition). These conditions were fully crossed with four cue conditions. The cue, in the form of an asterisk, preceded the presentation of the target arrow by ~400 milliseconds and was visible for ~100 milliseconds. In the Center cue condition, the cue took the place of the fixation cross. In the Double cue condition, there were two cues, one above and one below the fixation cross. In the Spatial cue condition, the cue was either above or below the cross, indicating the location where the target arrow would soon appear. Finally, in the No cue condition, no cue appeared before the arrow.

⁵ (<http://www.sacklerinstitute.org/users/jin.fan/>)

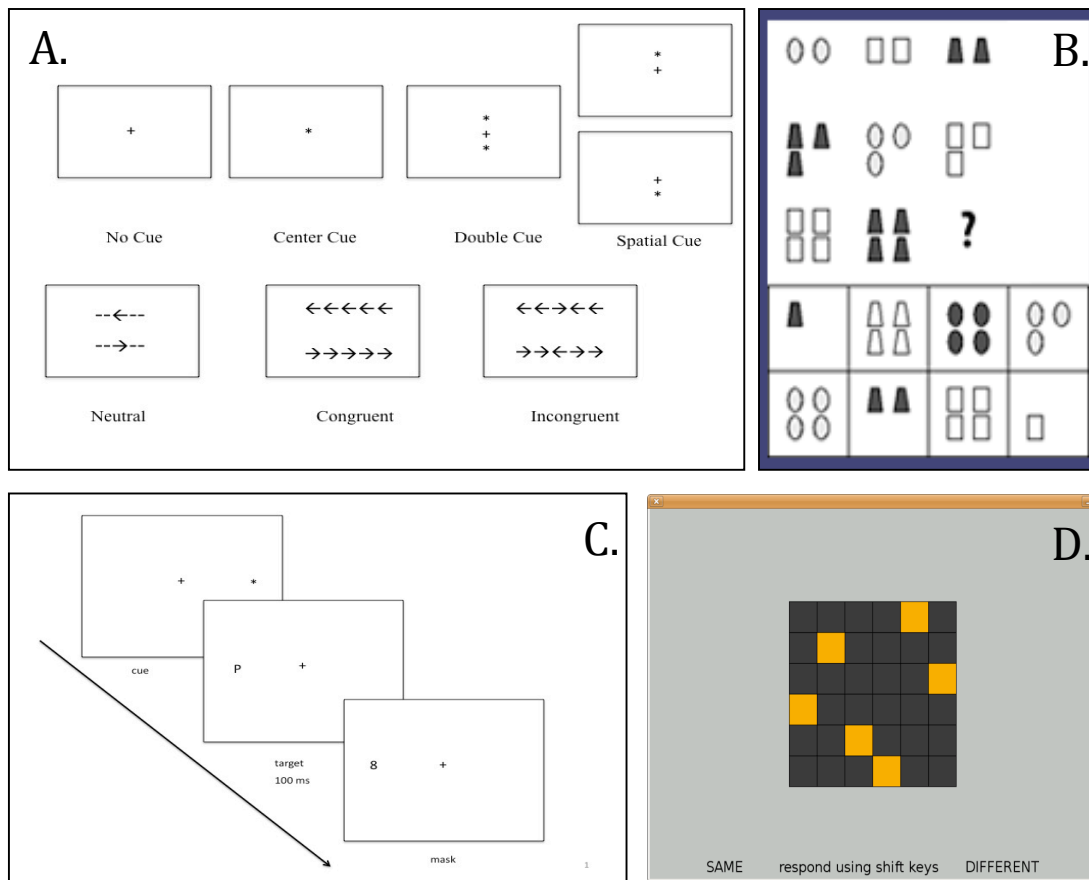


Figure 4. Illustrations of individual difference measures

The orienting score was calculated by comparing reaction times during the Spatial cue condition to the other conditions which do not help orient the participant to the appropriate location on the screen. The executive control score was calculated by comparing the reaction times in the Neutral, Congruent, and Incongruent flanker conditions. The alerting score was determined by comparing reaction times for conditions where a cue is present to those where no cue is present. This provided each participant with 3 individual scores. The ANT program was not able to calculate scores for 6 participants due to technical difficulties.

The second individual difference measure was a spatial working memory task that involved matrix rotation. This task is implemented in PEBL, the Psychology Experiment

Building Language (Mueller, 2009). During the task, participants saw a 6x6 matrix (Figure 4D), with a specific arrangement of grey and yellow cells. Participants were instructed to study the spatial layout of the matrix then press a key to see a second matrix, which was either the exact same matrix rotated to the right or left or a matrix with a completely different spatial layout. The participant's task was to identify the second matrix as same or different (by pressing either the left or right shift key, respectively) as fast as possible. Reaction times and accuracy were recorded.

The third measure was an anti-saccade task (Kane, Bleckley, Conway, & Engle, 2001). A flashing cue was displayed either to the left or right of the fixation cross. Then a target letter appeared on the opposite side of the screen for 100 milliseconds, followed by a mask (Figure 4C). Participants were instructed to identify which letter had been displayed, out of three possible letters (P,Q,R). The anti-saccade test is thought to measure executive control as, in order to see the target letter, participants must actively inhibit a saccade towards the flashing cue and instead make a saccade in the opposite direction. If unable to inhibit the saccade, the participant would not have time to see the letter before the mask. Accuracy and reaction times were recorded.

The fourth individual difference measure was the Picture-naming task, and unlike tasks 1-3, was used to measure fluency in English. Participants saw pictures of objects and were instructed to name them as fast as possible and press a key to move to the next picture. 233 pictures were selected from the International Picture Naming Project's object database, specifically the pictures normed by Szekely, D'Amico, Devescovi, Federmeier, Herron, Iyer, Jacobsen, and Bates (2003). Our selection criterion was based on the proportion of people who had named them correctly in Szekely et al. (2003). Only pictures that were named correctly by at

least 85% of participants were included. Participants' naming responses were audio recorded and the reaction times from their key presses were also recorded. The onsets of the audio-recorded words were identified in Matlab using code written by Bansal, Griffin, and Spieler, (2001).

The fifth test was based on Raven's Progressive Matrices (Raven & Court, 1958) and was intended to assess general intelligence and reasoning ability. The task was designed using the Sandia Matrix Generation Software (Matzen, Benz, Dixon, Poset, Kroger, & Speed, 2010). Participants saw a 3x3 matrix in which all but one cell contained a figure (Figure 4B). These figures were made up of basic shapes with various colors (in gray scale) and patterns (different sizes, orientations, numbers, etc.). The figures were arranged according to specific rules and parameters (e.g., each row has figures comprised of the same number of shapes, all figures on the diagonal are dark grey). The participants' goal was to discern what these rules were and apply them in order to complete the missing cell. Six options were presented under the matrix and the participant had to click on the one that would correctly fill in the empty cell. The score was based on accuracy.

Perspective-taking task

Following completion of the individual differences measures, participants completed an interactive perspective-taking task. Eye movements were monitored using an Eyelink-1000 desktop-mounted eye-tracker at 1000hz, and stimulus presentation was controlled using Matlab's Psychophysics Toolbox (PTB-3, Brainard, 1997; Pelli, 1997). Participants viewed a series of 5x5 grids on the computer screen (Figure 4a). Each grid cell contained a picture of an animal (i.e., pig, horse, fish, cow, rhinoceros, turtle, orangutan, bear, or chicken) with an object or accessory (e.g., hat, shoes, flower, purse, lips, or bowtie). These pictures were similar to stimuli previously used by Brown-Schmidt, Gunlogson, and Tanenhaus (2008). In addition, the scene contained a

picture of a star that the participant could drag about the screen using the mouse. The experimenter sat across from the participant and viewed an identical grid in a printed booklet, along with scripted instructions for how to move the star. The scripted instructions were not made visible to the participant. The participant's task was to follow the experimenter's instructions to drag the star to specific locations on the grid (e.g., *Go left to the pig with the hat*). The alignment of speaker and listener perspective was manipulated within-subjects, such that during half of the trials, the experimenter's perspective on the grid was identical to the participant's (no Perspective-Taking, or nPT, condition; Figure 4b). On the other half of the trials, the experimenter viewed his or her grid from the *opposite* perspective (the Perspective-taking (PT) condition, Figure 4c).

Each participant completed a total of 33 grids throughout the course of the experiment. Each grid was visible during five consecutive trials for a total of 165 trials per participant. Of the five trials, one tested non-verbal spatial perspective-taking, and four were used to test verbal perspective-taking. Each set of five trials was either in the nPT condition where the spatial references are aligned (e.g., "left" spoken by the experimenter refers to *left* on the participant's grid) or the PT condition (e.g., "left" spoken by the experimenter refers to *right* on the participant's grid).

Non-verbal trials. The first trial for each new grid was a non-verbal task used to assess spatial perspective-taking. When each new grid appeared, the star was always at the bottom of the participant's screen, whereas the star was on an animal on the experimenter's booklet. At the beginning of each new grid, the experimenter showed his or her booklet to the participant, so that the participant could see the spatial layout of his or her grid, and the location of the star. The participant's task was to drag the star on their screen to the corresponding location shown in the

experimenter's booklet. Only accuracy was recorded on these trials due to a high rate of track loss when the participants were looking back and forth between their screen and the experimenter's grid. There were a total of 33 non-verbal trials, one for each grid. Perspective condition (nPT vs. PT) was manipulated within subjects.

Verbal trials. The remaining four trials associated with each grid consisted of a linguistic perspective-taking task (132 trials total per participant, including fillers). On each verbal trial, the experimenter instructed the participant about where to move the star next. Note that the participant was made aware of the experimenter's perspective on each grid during the preceding non-verbal trial. Verbal instructions were scripted and always of the form: "*Go [direction term] to the [animal] with the [accessory].*" For example, following a non-verbal instruction to place the star on the starting place (i.e., the alligator with the shoes; see Figures 6-7), the first verbal instruction might be, "*Go left to the pig with the hat*" in the nPT condition, and "*Go right to the pig with the hat*" in the PT condition. In the PT condition, on the experimenter's grid, the pig with the hat is to the *right* in relation to the alligator with the shoes (where the star should be at the start of the trial), whereas on the participant's grid, that pig is *left* in relation to the alligator⁶.

Our first measure of linguistic perspective-taking focused on the 99 critical verbal trials, each of which had a critical instruction that included a temporarily ambiguous reference to an animal on the grid that could have been disambiguated early if the participant took perspective into account. This was accomplished by creating situations where the scene contained a competitor animal of the same type as the target animal but with a different accessory, and in the opposite spatial direction as the target. For example, if the target animal was the pig with the hat (see Figure 5), the competitor was the pig with the purse, such that the underlined portion of the

⁶ Each participant heard the terms "left," "right," "forward," and "backward" an approximately equal amount of times (~33 times).

expression *Go right to the pig with the hat* was ambiguous between the two pigs, unless the addressee took into account the experimenter's spatial perspective (see Figure 7). Note that this temporary ambiguity is disambiguated at the final word (e.g., "hat").

The second measure of linguistic perspective taking concerned the perspective status of the competitor object (e.g., the pig with the purse in the above example), specifically whether that animal was visible to the experimenter, and thus in common ground between the participant and experimenter (Clark & Marshall, 1978), or visible only to the participant and not the experimenter, and thus in the participant's privileged ground. Grids were designed such that a subset of the critical trials, 16/99, contained privileged-ground competitors (i.e., seen only by the participant, PC-condition). The remaining critical trials, 83/99, contained common-ground competitors (i.e., visible to both experimenter and participant, CC-condition). Participants were made aware of the privileged animals during the initial non-verbal trial for each grid. 16 grids, out of 33, contained a privileged cell. We hypothesized that if the participant remembers the location of that hidden cell and uses this perspective information to guide interpretation of the critical instruction (e.g., Hanna et al., 2003; Brown-Schmidt et al., 2008), participants should show *fewer* fixations to the competitor on privileged-competitor trials since the experimenter could not be referring to the contents of a cell that is hidden to him/her.

Finally, the third measure of linguistic perspective-taking tested whether participants' ability to take their partner's spatial perspective was mediated by the perspective used on the *previous* grid of objects. Perspective transitions from grid to grid were balanced such that participants saw all four possible transitions between conditions (i.e., nPT to PT, PT to nPT, nPT to nPT, PT to PT) an approximately equal number of times. Based on previous findings of greater interference in Stroop and flanker-like tasks when the inconsistent response was activated

recently (Warren, 1974; Gratton, Coles, & Donchin, 1992; Durston, Davidson, Thomas, Worden, Tottenham, Martinez, et al., 2003), we hypothesized that listeners would show faster interpretation of the critical instruction, regardless of the perspective condition (nPT or PT), if the previous grid used the same perspective scheme.

The remaining 33 trials were fillers and did not contain a competitor. Thus, the cell opposite the target animal contained a different type of animal, or the starting place (where the star was located) was at the edge of the screen, so that the perspective-inappropriate interpretation of the target instruction would have moved the star off-screen (this was not possible).

The experimenter's spoken instructions were recorded live, separately for each participant and trial. The onsets of the direction term, animal, and accessory word were coded using Praat software (Boersma & Weenink, 2012), allowing eye-movement analyses to be time-locked to the experimenter's utterances. Aside from the fact that the animals were positioned so as to create the potential for linguistic ambiguity, the positions of the animals in the grid were randomly assigned.

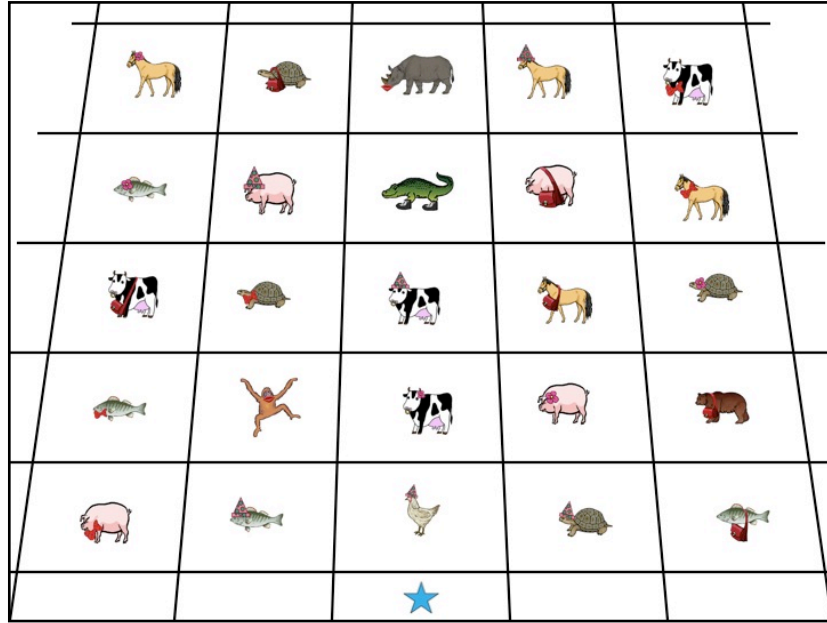


Figure 5. Example grid seen by participant.

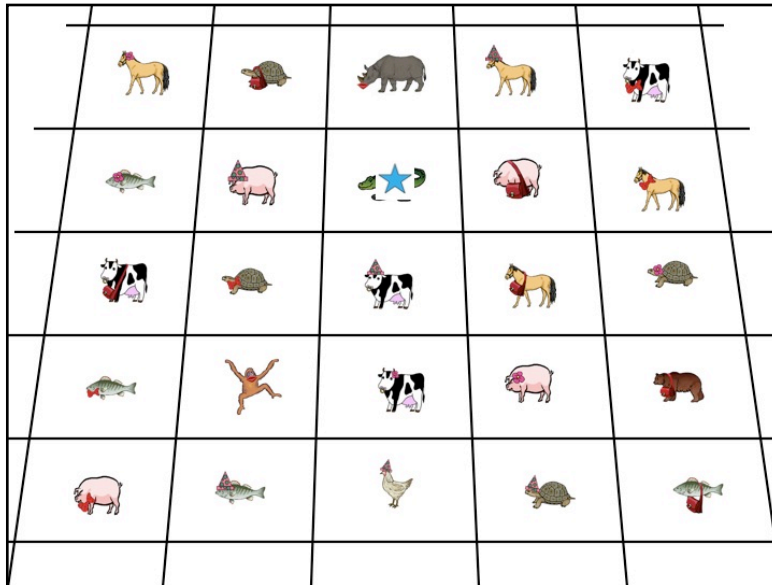


Figure 6. Example grid seen by experimenter in nPT condition.

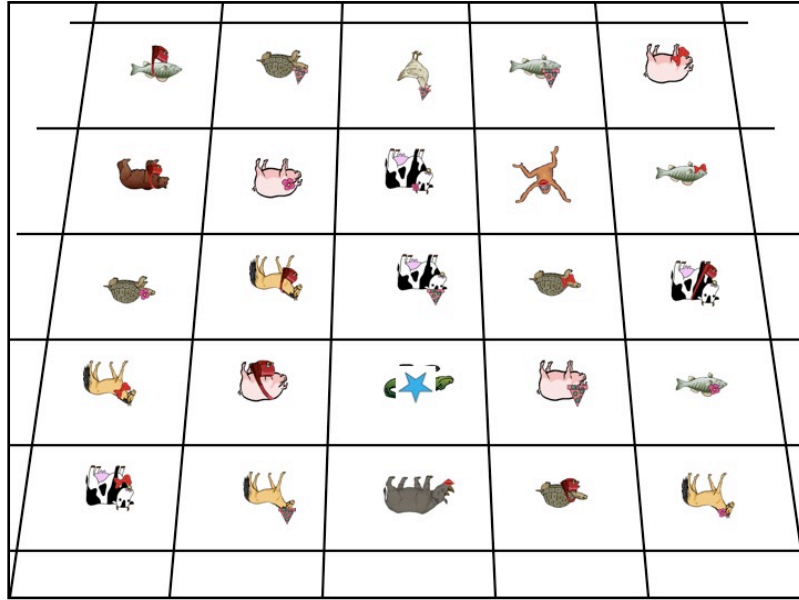


Figure 7. Example grid seen by experimenter in PT condition.

Predictions

The dependent measures in this experiment included (a) individual differences measures of non-linguistic executive function, and a linguistic naming task; (b) a non-linguistic spatial perspective-taking task; (c) three measures of linguistic perspective-taking, including a spatial perspective-taking measure (this was the main measure), as well as two supplementary measures which tested use of visual cues to perspective, and perspective-switching.

According to the bilingual advantage hypothesis, bilingual participants should perform significantly better on the measures of executive function due to superior executive control. Further, if young adult bilinguals are more adept at interpreting a perspective that is different from their own, bilinguals should be more accurate in the non-linguistic spatial perspective-taking task. Comparison of monolingual and bilingual participants in the measures of linguistic perspective-taking will indicate whether the hypothesized bilingual cognitive control advantages override any possible linguistic disadvantages, the latter of which are measured by the linguistic

naming task. The perspective-switching manipulation should also speak to any potential differences in conflict-monitoring abilities between monolinguals and bilinguals (Garbin et al., 2010).

Alternatively, if young adult bilinguals do not have an executive control advantage, this would predict no effects of bilingualism on individual difference measures and potentially a bilingual deficit on the perspective-taking task due to bilinguals' less fluent mastery of English.

Results

Individual Differences

Participants' scores on the ANT task, the Spatial WM task, the antisaccade task, the picture-naming task, and the matrices task were compared to investigate potential differences between monolinguals and bilinguals. In contrast to previous findings of a bilingual advantage in measures of executive function (Bialystok et al., 2008), there were no significant differences found between groups on the ANT task measures, the spatial working memory measure, the matrices task, the antisaccade task, or the picture-naming task as measured by onsets of recordings⁷. We did, however, observe a significant difference ($p=0.04$) between monolinguals and bilinguals on the picture-naming task, as measured by keypress reaction times. On average, monolinguals ($M= 1.54$ seconds) were faster than bilinguals ($M=1.77$ seconds), which is consistent with previous findings of a bilingual deficit in speeded language tasks (Gollan et al., 2005)⁸. The results of group comparisons are summarized in Table 6⁹. In addition, bilinguals

⁷ When the picture-naming items were split by frequency, bilinguals ($M= 1973.8$) were found to be marginally slower ($t=1.90$, $p=0.07$) to name lower frequency items than the monolinguals ($M=1797.36$). There were no group differences for higher frequency items ($t=1.35$, $p= 0.19$).

⁸ A regression analysis of picture-naming performance revealed that word frequency predicted word onsets ($t= -3.9$, $p<0.001$) and button presses ($t= -4.2$, $p<0.001$) such that participants were faster to name higher frequency words. Language group also predicted word onsets ($t= -1.9$, $p= 0.06$) and button presses ($t= -2.4$, $p= 0.02$) such that bilinguals were slower. The interaction of frequency and language group was

were not faster ($p=0.68$) overall on the ANT trials, collapsing across trial types (neutral, congruent, incongruent), as might be expected based on findings of a conflict monitoring advantage in bilinguals (Costa et al., 2009).

	Group means and standard deviations		95% CI diff
ANT orienting	Monolingual: $M=43.06$ ($SD= 29.40$)	Bilingual: $M=45.06$ ($SD= 23.26$)	[-20.20, 16.19]
ANT alerting	Monolingual: $M=37.79$ ($SD= 49.19$)	Bilingual: $M=30.94$ ($SD= 58.43$)	[-43.06, 29.37]
ANT conflict resolution	Monolingual: $M=136.06$ ($SD=44.27$)	Bilingual: $M=180$ ($SD= 136.90$)	[-28.86, 116.75]
Anti-saccade	Monolingual: $M=86.6$ ($SD= 12.55$)	Bilingual: $M=84.05$ ($SD=11.89$)	[-10.38, 5.28]
Spatial WM	Monolingual: $M=14.48$ ($SD= 3.17$)	Bilingual: $M=14.75$ ($SD=1.97$)	[-1.39, 1.94]
Matrices	Monolingual: $M=$ 26.26 ($SD= 10.18$)	Bilingual: $M=22.55$ ($SD=9.30$)	[-10.06, 2.63]
Picture Naming – Word Onsets (in milliseconds)	Monolingual: $M=1715.91$ ($SD=$ 268.25)	Bilingual: $M=1866.55$ ($SD=272.86$)	[-27.61, 328.89]
Picture Naming – Button presses (in seconds)	Monolingual: $M=1.54$ ($SD= 0.37$)	Bilingual: $M=1.77$ ($SD= 0.29$)	[0.013, 0.46]*

Table 6. Group comparisons of individual difference measures

Non-linguistic Perspective-taking task

In the non-verbal task, participants saw the experimenter's grid with a star and had to place their star in the analogous location on their computer screen. The experimenter's grid was shown either from the experimenter's perspective (PT) or the participant's (nPT). A response was coded as correct when the participant placed the star on the intended target and incorrect

marginal for both measures ($t= 1.7$, $p= 0.098$); the bilingual disadvantage was more pronounced for low frequency items.

⁹ A measure of reliability calculated by correlating the even and odd trials indicated relatively high reliability for the anti-saccade task ($R=0.76$) the Raven's Matrices-like task ($R= 0.78$), and the Picture Naming task ($R= 0.97$ for button presses). Similar calculations for the other measures were not possible due to task complexity.

when the star was placed anywhere else on the screen. On average, participants were less accurate in the PT condition ($M= 0.94$, $SD= 0.24$) than in the nPT condition ($M=0.96$, $SD= 0.20$), and bilinguals ($M= 0.97$, $SD= 0.18$) were more accurate than monolinguals ($M=0.93$, $SD= 0.25$).

The accuracy data were analyzed in a mixed-effects logistic regression, with perspective condition by bilingualism as a fixed effect, and random intercepts for subjects¹⁰. The maximal random effects structure was used. The model revealed that accuracy rates were not significantly different between monolinguals and bilinguals. This null result may partially be due to a ceiling effect; the accuracy rates were around 95%. However, there was an effect of perspective condition such that participants made significantly more errors in the PT condition (Table 7). The significant effect of perspective demonstrates that we successfully implemented a challenging perspective-taking task.

<i>Fixed Effects</i>	Estimated parameter	Standard Error	z - value	p value
(Intercept)	5.99965	0.6735	8.908	<2.00E-16
Perspective	-1.587	0.47063	-3.372	0.000746
Bilingualism	0.39326	0.75538	0.521	0.602637
Perspective x Bilingualism	-0.04214	0.48999	-0.086	0.931462
<i>Random Effects</i>		Variance	Std. Dev.	
Subject	(Intercept)	10.335	3.21481	
	Perspective	0.48399	0.6957	
Item	(Intercept)	0.38607	0.62134	
	Bilingualism	0.20189	0.44933	
Number of observations: 1353, groups: Subject, 41				

Table 7. Effects of condition and language group on accuracy during non-verbal perspective task.

¹⁰ For all of the analyses reported for Experiment 2, the pattern of results was replicated using the language group categorical predictor (monolingual vs. bilingual) instead of the bilingualism quotient. The bilingualism quotient was preferred as the predictor because it affords greater statistical power.

Linguistic Perspective-taking tasks

The primary dependent measure for analyses of linguistic perspective-taking (spatial perspective-taking, visual perspective cues, and perspective-switching) was the eye-movements that participants made as they interpreted the potentially ambiguous instruction (e.g., *Go left to the pig with the hat.*) Eye movements associated with the interpretation of spatial perspective were analyzed in terms of target advantage (Arnold, Eisenband, Brown-Schmidt, & Trueswell, 2000), calculated as the proportion of fixations to the target minus the proportion of fixations to the competitor (Figures 8-9). Due to the non-normality of the proportion scale, proportions were first transformed based on the empirical logit (Barr, 2008). The target was defined as the area on the grid to which the subject should move the star if he or she has correctly interpreted the current instruction. The competitor was defined as the cell that was in the opposite direction. For example, if the target was the cell to the *left*, the competitor was the cell to the *right*. In the critical conditions, the competitor cell always contained a competitor animal which was identical to the target animal, but with a different accessory.

In order to examine both early and late processing effects, average target advantage scores were calculated in two consecutive time windows following the onset of the critical ambiguous instruction. The first time window (average duration 614 milliseconds) began at the onset of the direction term (e.g., *left*) and ended at the onset of the animal term (e.g., *pig*). The second time window (average duration 569 milliseconds) began at the onset of the animal term and ended at the onset of the accessory term (e.g., *hat*). Both windows captured interpretation of the ambiguous portion of the critical instruction, with the first window focusing on interpretation of the spatial term per se, and the second focusing on the ambiguous noun. The regions were both offset by 200 milliseconds due to the time needed to program and launch an eye movement

(Hallett, 1986). Average target advantage scores in the two regions are plotted by bilingualism and perspective condition (nPT vs. PT, Figure 10), competitor condition (shared vs. privileged, Figure 11), and perspective-switching condition (switch vs. no switch, Figure 12).

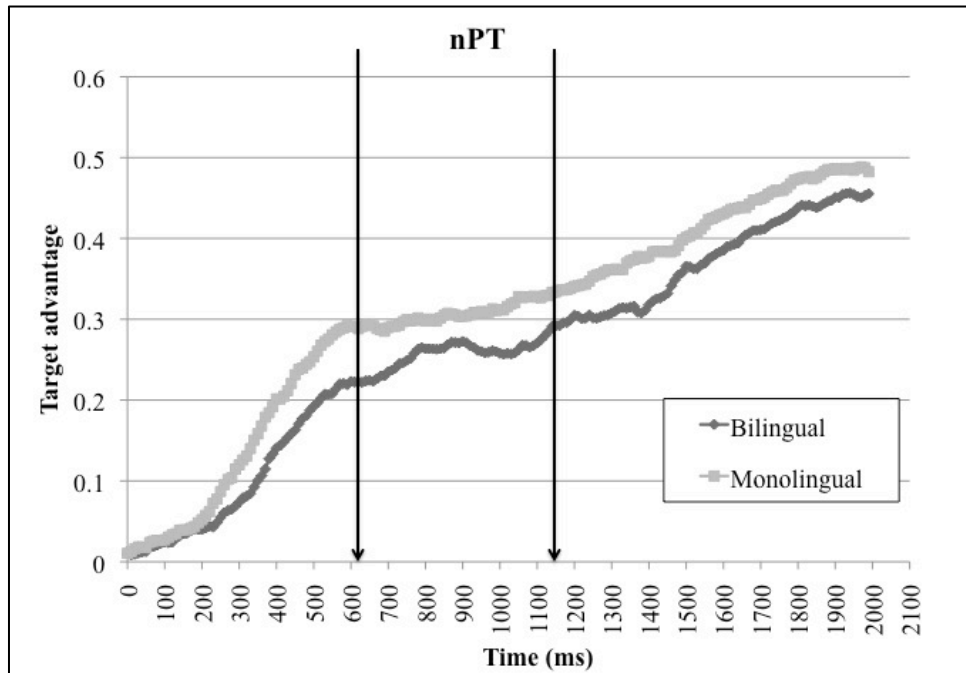


Figure 8. Target advantage scores by language group in the nPT condition. Zero ms corresponds to the onset of the word “left” in *Go left to the pig with the hat*. The vertical lines indicate, from left to right, the average onset of “pig” and “hat.”

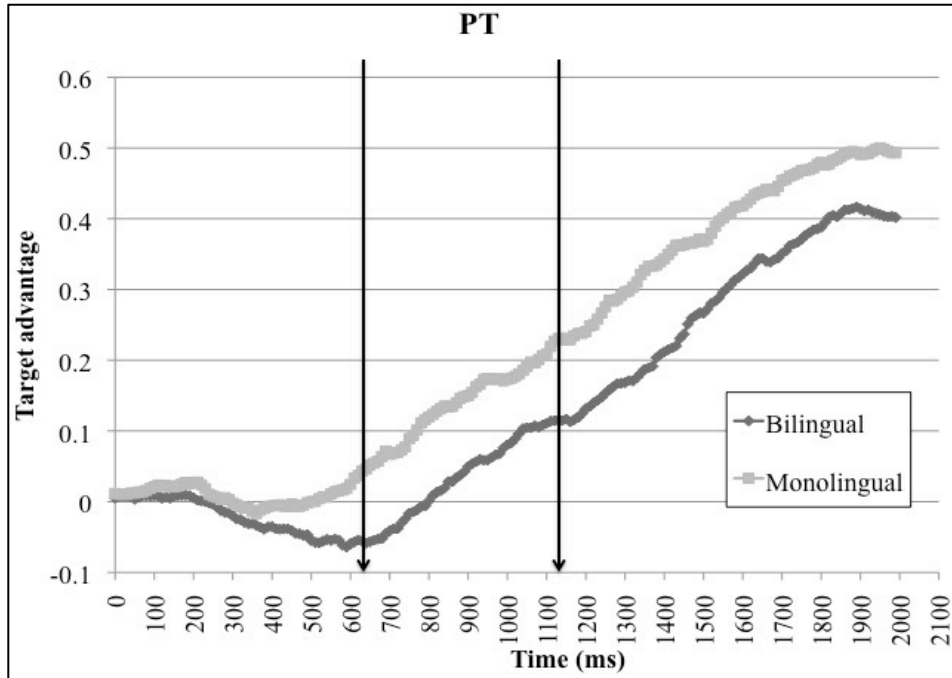


Figure 9. Target advantage scores by language group in the PT condition. Zero ms corresponds (Fig. 9 continued) to the onset of the word “right” in *Go right to the pig with the hat*. The vertical lines indicate, from left to right, the average onsets of “pig” and “hat”.

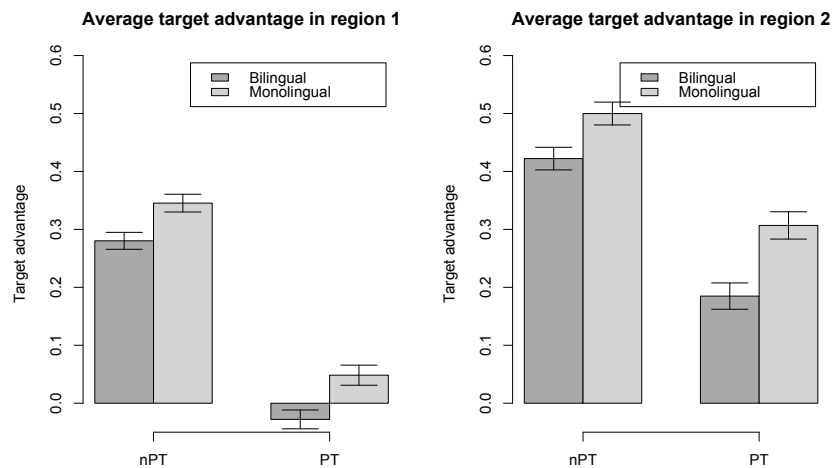


Figure 10. Target advantage scores by language group and perspective for each time region.

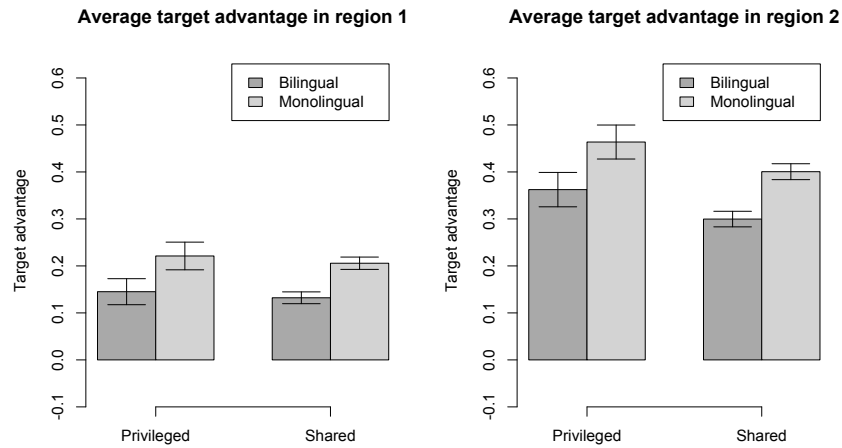


Figure 11. Target advantage scores by language group and competitor condition for each region.

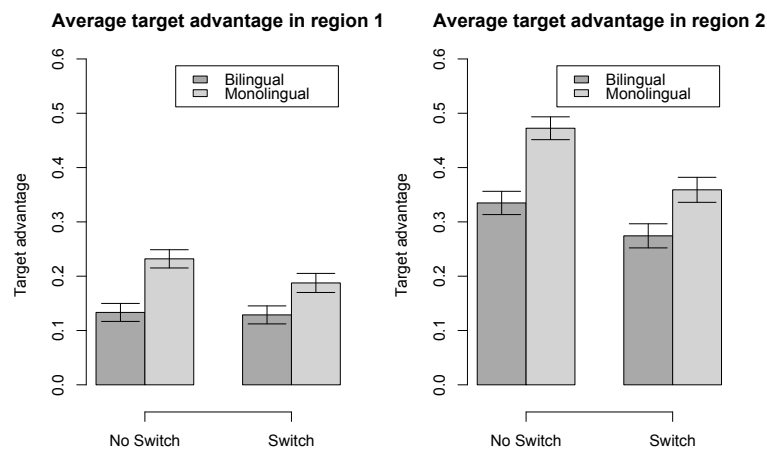


Figure 12. Target advantage scores by language group and grid switching condition.

Eye-tracking results. The target advantage scores for both time-regions were analyzed in a mixed effects regression model as before. Perspective condition (nPT vs. PT), competitor condition (PC vs. C), and time window (first vs. second) were entered as orthogonal contrast codes. The target advantage score was modeled as a function of the interaction between bilingualism, perspective condition, competitor condition and time with random intercepts for

subject and item. The maximal random effects structure was first attempted but did not converge. Instead, a backwards-fitting procedure was used to determine the maximal random effects structure model that would converge. This process indicated that by-subject random slopes for perspective, competitor, and time, and by-item random slopes for bilingualism, and time were included and improved model fit (based on the deviance test statistic and evaluation of the AIC; Aikake, 1974). The estimated parameters are summarized in Table 8.

The model results indicated that the effect of perspective condition was significant such that participants made fewer fixations to the target, and more fixations to the competitor, when they were in the PT condition than in the nPT condition. This indicates that, as predicted, interpretation was more challenging when perspectives were not aligned. The effect of time was significant, such that over the course of each trial, participants made more fixations to the target and fewer fixations to the competitor, regardless of perspective condition. Further, there was a significant interaction of perspective by time window, due to attenuation of the perspective condition effect over the course of a trial. In other words, participants were more likely to consider the competitor animal during the first time window when they were interpreting the potentially ambiguous direction term (*Go left to the..*) than in the second time window when they were interpreting the potentially ambiguous animal name (e.g., .. *pig that's..*). Finally, there was a significant effect of bilingualism such that participants with a higher rating on the bilingualism quotient had *lower* target advantage scores in both time windows.

<i>Fixed effects</i>	Estimated parameters	Std. Error	t-value	p-value
(Intercept)	0.659821	0.077207	8.546	0.000
Perspective	-0.584148	0.095058	-6.145	0.000
Time	0.477531	0.056787	8.409	0.000
Competitor	0.082105	0.09978	0.823	0.416
Bilingualism	-0.174432	0.079812	-2.186	0.035
Perspective x Time	0.224781	0.074944	2.999	0.005

Table 8. Effects of bilingualism, and perspective and competitor conditions on target advantage.

Perspective x Competitor	-0.369607	0.199216	-1.855	0.071
Time x Competitor	0.131226	0.093632	1.402	0.169
Perspective x Bilingualism	-0.072228	0.080216	-0.9	0.374
Time x Bilingualism	-0.084644	0.0613	-1.381	0.175
Competitor x Bilingualism	0.002198	0.068586	0.032	0.975
Perspective x Time x Competitor	-0.274629	0.188196	-1.459	0.153
Perspective x Time x Bilingualism	-0.060834	0.075295	-0.808	0.424
Perspective x Competitor x Bilingualism	-0.018575	0.135272	-0.137	0.892
Time x Competitor x Bilingualism	0.020023	0.093929	0.213	0.832
Perspective x Time x Competitor x Bilingualism	0.004537	0.188754	0.024	0.981
<i>Random effects</i>		Variance	Std.Dev.	
Item	(Intercept)	0.1081914	0.328925	
	Time	0.0241799	0.155499	
	Bilingualism	0.0310698	0.176266	
Subject	(Intercept)	0.1798168	0.424048	
	Perspective	0.1122426	0.335026	
	Time	0.074679	0.273275	
	Competitor	0.0055629	0.074585	
Residual	1.7721488	1.331221		
Number of observations: 7592, Items: 100, Subject: 41				

Table 8. (continued)

The effect of competitor status (privileged vs. common) was not significant, inconsistent with previous evidence that participants rule out visually privileged objects when interpreting imperatives (Hanna et al., 2003; Nadig & Sedivy, 2002). The lack of an effect may be due to the memory burden associated with remembering the location of the visually privileged object. Indeed, while it has never been explicitly tested in the experimental literature, this type of delayed physical co-presence is hypothesized to provide weaker evidence for common ground than immediate physical co-presence (i.e., when the fact that some information is or is not visually shared is immediately available in the current scene, Clark & Marshall, 1978). Our finding is consistent with other evidence that in cases where common ground is only weakly established, perspective effects are reduced, or completely absent (Brown-Schmidt, 2012; 2009).

Perspective-switching. The analysis of participants' ability to switch from one perspective to another was conducted separately from the main analysis because it required excluding the data from the first grid (for which participants were not switching from a different perspective). The target advantage scores for both time regions were analyzed in a mixed effects model with perspective condition, time window, and grid switch condition as orthogonal contrasts. The target advantage score was modeled as a function of the interaction between perspective condition, bilingualism, grid switch condition and time. Random intercepts for subject and item were entered, as well as by-subject random slopes for perspective, grid switch, and time (and their interaction), and by-item random slopes for time and bilingualism. These significantly improved model fit based on the deviance test statistic and evaluation of the AIC (Aikaike, 1974). The estimated parameters are summarized in Table 9.

In addition to the fixed effects reported in the main analysis, this analysis revealed a marginal ($p=0.06$) effect of grid switch condition, due to lower target advantage scores following a reversal of perspective, regardless of which perspective (nPT or PT) was on the current trial. A significant time by grid switch interaction indicated that this effect emerged over the course of a single trial: in the first time window, the effect of grid switch is not significant ($t=-1.178$, $p=0.246$). However, in the second time window, it is ($t=-2.335$, $p=0.025$).

<i>Fixed Effects</i>	Estimate	Std. Error	t-value	p-value
(Intercept)	0.675047	0.074101	9.11	0.000
Perspective	-0.668324	0.090389	-7.394	0.000
Time	0.504972	0.054732	9.226	0.000
Bilingualism	-0.183115	0.077215	-2.371	0.023
Switch	-0.156955	0.082547	-1.901	0.065
Perspective x Time	0.169154	0.079862	2.118	0.041
Perspective x Bilingualism	-0.056412	0.078195	-0.721	0.475
Time x Bilingualism	-0.088073	0.059257	-1.486	0.145

Table 9. Effects of perspective, bilingualism, and grid switch on target advantage

Perspective x Switch	0.155649	0.153724	1.013	0.317
Time x Switch	-0.164654	0.075087	-2.193	0.034
Bilingualism x Switch	0.065991	0.066144	0.998	0.324
Perspective x Time x Bilingualism	-0.04699	0.082682	-0.568	0.573
Perspective x Time x Switch	0.099783	0.145783	0.684	0.498
Perspective x Bilingualism x Switch	0.078357	0.113326	0.691	0.494
Time x Bilingualism x Switch	-0.009222	0.076741	-0.12	0.905
Perspective x Time x Bilingualism x Switch	0.140313	0.147947	0.948	0.349
<i>Random Effects</i>		Variance	Std. Dev.	
Item	(Intercept)	0.104902	0.32389	
	Time	0.024224	0.15564	
	Bilingualism	0.030177	0.17371	
Subject	(Intercept)	0.170195	0.41255	
	Perspective	0.115705	0.34015	
	Time	0.073196	0.27055	
	Switch	0.060379	0.24572	
	Perspective x time	0.062896	0.25079	
	Perspective x switch	0.09315	0.30521	
	Time x switch	0.032913	0.18142	
	Perspective x time x switch	0.078124	0.27951	
Residual	1.743166	1.32029		
Number of observations: 7312, Items: 96, Subjects: 41				

Table 9. (continued)

Analysis with Individual Differences. The individual difference measures were analyzed separately because 9 subjects did not have a score for one or more of the 7 measures due to technical errors. A full model with perspective, time, bilingualism, and all the individual difference measures (including picture naming) entered as predictors with the corresponding maximal random effects structure was attempted but did not converge. A simpler random-intercept only model is presented in Appendix C. Only the effects of perspective condition and time were found to be significant at the adjusted alpha level of 0.006 (due to multiple comparisons). A similar model with the perspective switch factor as an interaction term with

bilingualism, time, perspective, and the individual difference measures was also analyzed. The maximal random effects structure as justified by the data was used. The parameter estimates can be seen in Appendix D. Again, only perspective and time were significant. These analyses show that in addition to there being no significant differences between monolinguals and bilinguals in the measures of executive function, that there was no evidence that these constructs contributed to perspective-taking.

A remaining question is whether the overall bilingual *disadvantage* in perspective-taking is specifically due to differences in linguistic ability in English. While the lack of a significant effect of picture naming on the perspective-taking measure is inconsistent with this hypothesis, we provided a stronger test by creating a residualized measure of bilingualism that excluded picture naming time. Picture naming time (for which bilinguals are significantly slower) was first regressed onto the bilingualism quotient, and the resulting residualized bilingualism scores were then entered as a predictor variable in an analysis of the target advantage scores. This analysis revealed that bilingualism was still a marginal predictor of perspective-taking ($t(38)=-1.926$, $p=0.062$), suggesting that the effects of bilingualism are not exclusively due to differences in verbal fluency (as measured by picture naming times).

Discussion

The present experiment created situations in which participants were tasked with appreciating the spatial perspective of another person in order to interpret their utterances. The results of this experiment demonstrate that this process is challenging, particularly when perspectives are misaligned, and when switching between spatial perspectives. The perspective-switch penalty may be related to a switch cost previously observed in studies of Stroop-like interference tasks (e.g., Warren, 1974, Gratton et al., 1992), due to lingering activation of the

inconsistent response on a previous trial. Of note is that the cost of switching perspectives did not interact with the perspective on the current trial (i.e., there was not a significant difference in the cost of switching from nPT -> PT vs. PT -> nPT), suggesting that participants did not approach each grid by defaulting to the egocentric perspective. However, both bilinguals and monolinguals incurred the same switch costs, contrary to previous results with simpler task-switching paradigms (Garbin et al., 2010, Prior & MacWhinney, 2010), suggesting that there may not be substantial differences in control monitoring between these groups.

With respect to group differences, multiple non-linguistic measures of executive function showed no bilingual advantage, inconsistent with previous findings of executive function advantages in young bilingual over young monolingual adults (Bialystok et al., 2008; Costa et al., 2008; Bialystok et al., 2004). The sample size in the present study was comparable or larger than that used by Bialystok and colleagues (24 participants per group in Bialystok et al., 2008; 10 and 32 participants per group in Bialystok et al., 2004, Experiments 1 and 2, respectively). Further, the participant population used in the present work (young adult bilinguals from varied linguistic backgrounds) was similar to that in Bialystok et al., 2008, suggesting that population differences are unlikely to be key to the difference in the results.

As to the question of whether young adult bilinguals show better perspective-taking, we find no bilingual advantage in a non-linguistic perspective-taking task. Further, analyses of the use of spatial perspective information to resolve linguistic ambiguity show that individuals with higher bilingualism scores make more fixations to the competitor and fewer fixations to the target across perspective conditions. This suggests that bilinguals are not able to interpret spatial instructions as quickly and efficiently, during on-line language processing, as monolinguals. In fact, the only other measure on which monolinguals and bilinguals significantly differed was in

their reaction time to press a button in the picture-naming task. However, verbal fluency was likely not the only element at play in the bilingual disadvantage in the perspective-taking task, as there was no significant interaction between the bilingualism effect and the picture naming RT (Appendix C), and the effect of bilingualism was still marginally significant when picture naming RT was residualized out of the bilingualism quotient. These results suggest that if a bilingual advantage in executive function and perspective-taking does exist, it was not robust in this sample.

General Discussion

The bilingual advantage hypothesis predicts that, due to enhanced executive control, bilinguals should demonstrate superior performance on various cognitive tasks such as the interpretation and on-line use of an interlocutor's perspective. In the experiments described in this paper, we failed to find a benefit for bilinguals in the domain of inhibitory control. This result is consistent with reports of a lack of a bilingual advantage in the Stroop task (Rosselli et al., 2002, Kousaie & Phillips, 2012), and in tests of active inhibition (Colzato et al., 2008). Our findings are also consistent with recent meta-analytic findings of an inconsistent (at best) bilingualism advantage on measures of conflict resolution (Klein & Hilchey, 2011). In addition to finding no evidence for a bilingual advantage in multiple measures of executive function across two separate groups of participants, our findings reveal a significant bilingual *disadvantage* in interpreting spatial perspective language. This suggests that, even if a difference in basic cognitive functioning exists among bilinguals and monolinguals, this does not always translate into a positive impact on higher-level cognition.

The difference in performance between bilinguals and monolinguals may be partially the result of different linguistic experiences and systems. Bilinguals are known to have subtle impairments in the rapid retrieval, processing and production of language. Various theories exist about the cause of these difficulties. In the present research, competing activation of linguistic terms from both languages in the bilinguals' cognitive repertoire may result in slower interpretation of the spatial instructions. Slower interpretation may also be the result of less experience with each word, or the additional time required to retrieve words from a larger lexicon. Consistent with this view, one measure of lexical access in our second experiment revealed a small bilingual disadvantage. Importantly, however, the bilingual deficit in on-line

interpretation of spatial language was still apparent when this measure was controlled for, and the magnitude of the deficit did not significantly vary as a function of lexical access. This suggests that the bilingual deficit in the interpretation of spatial perspective terms was not directly linked to lexical access.

An important consideration in between-group comparisons is the possibility that monolingual and bilingual participants differed in other ways beyond their language experience. For example, differences in socio-economic status (SES) are sometimes raised as a potential confounding variable in studies of bilingualism (see Mindt et al., 2008), and in one of the few studies to carefully control SES, there was no effect of bilingualism on executive function in a sample of young children (Morton & Harper, 2007; 2009). However, all of our participants were students at a major university, and a measure of SES in both experiments revealed no differences between groups, suggesting SES is unlikely to blame in the lack of a bilingual advantage. Another possibility is that evidence of a bilingual advantage only manifests in groups of bilinguals with an active, immediate experience with bilingualism, including frequent code-switching between languages. However, all of our bilingual participants had spoken two languages throughout life, and used the second language significantly more often than monolinguals, suggesting there was regular daily exposure to two languages. Further, a very similar population (college students) has been tested in previous work claiming a bilingual advantage in young adults (Bialystok et al., 2008), suggesting that this cannot be the only reason for inconsistency in the findings. Finally, age may also be at play; perhaps due to their young age all participants, monolingual and bilingual were at peak performance, masking underlying group differences (note however, that such an explanation is inconsistent with previous reports of a bilingual advantage in young adults; Costa et al., 2008; Bialystok et al., 2004; Bialystok et al.,

2008, though small sample sizes and changes in the findings across the experiment suggest the effects might be small and/or fleeting; see Hilchey & Klein, 2011). However, the argument that a youth advantage masked a bilingual advantage, is inconsistent with the finding that bilinguals performed consistently worse on the perspective tasks.

In conclusion, the present findings demonstrate that the extent to which bilingual cognitive advantages exist, these advantages may be small in effect size and not present in all groups of bilinguals. Further, the degree to which these cognitive advantages extend to cognitively complex everyday tasks, such as conversation, is limited, and in some cases bilingualism may confer deficits. Deficits in higher-level cognition associated with bilingualism may be largely restricted to tasks for which language is involved, possibly due to a cost to the language system of speaking two languages. An important note, however, is that in the grand scheme these small costs in the speed or efficiency of processing may entirely be made up for the fact that speaking multiple languages offers many practical advantages in life.

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Appendix A

<i>Fixed Effects</i>	Estimate	Std. Error	z value	p value
(Intercept)	-2.96062	0.19413	-15.25	<2.00E-16
Perspective condition	1.59882	0.35884	4.455	8.37E-06
Bilingualism	0.56525	0.2184	2.588	0.010
Perceptual speed	-0.02895	0.01656	-1.749	0.080
Working memory	-0.08787	0.23154	-0.379	0.704
Stroop 1	-1.18518	1.05047	-1.128	0.259
Stroop 2	-0.03786	0.02561	-1.479	0.139
Perspective x Bilingualism	-1.06399	0.43764	-2.431	0.015
Perspective x perceptual speed	0.01111	0.03315	0.335	0.737
Perspective x WM	-0.10274	0.4645	-0.221	0.825
Perspective x Stroop 1	1.02756	2.10328	0.489	0.625
Perspective x Stroop 2	0.055	0.05121	1.074	0.283
<i>Random Effects</i>		Variance	Std. Dev.	
Subject	(Intercept)	1.1881219	1.09001	
Trial	(Intercept)	0.0615504	0.248094	
	Condition	0.025569	0.159903	
	Bilingualism	0.0048043	0.069313	
	Condition x Bilingualism	0.19839678	0.44542	
Number of observations: 10507, Subjects, 65; Trials, 10				

A. Effects of perspective, language group, and individual difference measures on the errors (Experiment 1). Alpha level (corrected for multiple comparisons of 5 interactions)= $0.05/5=0.01$.

Appendix B

Fixed Effects	Estimate	Std. Error	t-value	p-value
(Intercept)	523.81182	59.77372	8.763	0.000
Perspective	492.1735	107.71497	4.569	0.000
Bilingualism	-72.11021	63.86385	-1.129	0.264
Perceptual speed	6.13192	4.89076	1.254	0.216
Working memory	-26.37656	68.95409	-0.383	0.703
Stroop1	889.00433	328.87456	2.703	0.009
Stroop2	-0.03737	7.53287	-0.005	0.996
Perspective x Bilingualism	-233.28788	127.10034	-1.835	0.072
Perspective x Perceptual speed	-4.57787	9.79756	-0.467	0.643
Perspective x Working memory	-22.23258	137.18097	-0.162	
Perspective x Stroop 1	-994.44129	657.81769	-1.512	0.137
Perspective x Stroop 2	-26.38852	15.10235	-1.747	0.087
Random Effects	Name	Variance	Std. Dev.	
Subject	(Intercept)	93421.8	305.65	
Trial	(Intercept)	6854.67	82.793	
	Perspective	211.53	14.544	
	Bilingualism	265.66	16.299	
Residual	1474712.49	1214.377		
Number of observations: 7562, Subjects, 52; Trials, 10				

B. Effects of perspective, language group, and individual difference measures on the latencies (Experiment 1). Alpha level (corrected for multiple comparisons of 5 interactions)= 0.05/5=0.01.

Appendix C

<i>Fixed Effects</i>	Estimate	Std. Error	t-value	p-value
(Intercept)	6.50E-01	8.29E-02	7.838	0.000
Perspective	-6.19E-01	1.06E-01	-5.861	0.000
Time	4.80E-01	6.40E-02	7.497	0.000
Bilingualism	-1.33E-01	8.76E-02	-1.512	0.141
Competitor	6.01E-02	1.08E-01	0.558	0.581
Orienting	-2.54E-03	3.16E-03	-0.806	0.427
Alerting	-1.87E-04	1.95E-03	-0.096	0.924
Conflict resolution	2.77E-05	6.86E-04	0.04	0.970
Antisaccade	-2.10E-04	6.14E-03	-0.034	0.973
Spatial WM	2.08E-03	2.56E-02	0.081	0.936
Picture naming onsets	1.24E+00	1.46E+00	0.849	0.403
Picture naming RTs	-1.95E+00	1.20E+00	-1.617	0.116
Matrix	-2.40E-02	9.02E-03	-2.663	0.012
Perspective x Time	2.07E-01	8.41E-02	2.459	0.020
Perspective x Language group	-4.10E-02	9.40E-02	-0.436	0.666
Time x Language group	-5.92E-02	7.22E-02	-0.82	0.419
Perspective x Competitor	-3.72E-01	2.14E-01	-1.743	0.092
Time x Competitor	1.15E-01	1.03E-01	1.115	0.274
Bilingualism x Competitor	8.34E-03	7.33E-02	0.114	0.910
Time x Orienting	-3.15E-03	2.77E-03	-1.14	0.263
Perspective x Orienting	2.78E-03	3.29E-03	0.844	0.405
Time x Alerting	-5.80E-04	1.71E-03	-0.339	0.737
Perspective x Alerting	-1.16E-03	2.03E-03	-0.57	0.573
Time x Conflict resolution	-1.93E-04	6.00E-04	-0.322	0.750
Perspective x Conflict resolution	7.47E-04	7.15E-04	1.045	0.304
Time x Antisaccade	-3.02E-03	5.35E-03	-0.564	0.577
Perspective x Antisaccade	8.22E-03	6.39E-03	1.287	0.208
Time x Spatial WM	9.83E-04	2.23E-02	0.044	0.965
Perspective x Spatial WM	-2.92E-02	2.66E-02	-1.096	0.282
Time x Picture naming onsets	5.34E-01	1.29E+00	0.415	0.681
Perspective x Picture naming onsets	-3.10E+00	1.53E+00	-2.027	0.052
Time x Picture naming RTs	-1.43E+00	1.05E+00	-1.366	0.182
Perspective x Picture naming RTs	1.48E+00	1.25E+00	1.179	0.248
Time x Matrix	-1.75E-02	7.87E-03	-2.222	0.033
Perspective x Matrix	9.28E-03	9.39E-03	0.988	0.331
Perspective x Time x Bilingualism	-2.38E-02	9.03E-02	-0.264	0.794
Perspective x Time x Competitor	-1.51E-01	2.07E-01	-0.732	0.470

C. Effects of language group, perspective, time, competitor, and individual difference measures on target advantage scores (Experiment 2). Alpha adjusted for multiple comparisons (adjusted for 9 additional model terms) is $\alpha=0.05/9=0.006$.

Perspective x Bilingualism x Competitor	-6.28E-02	1.42E-01	-0.442	0.662
Time x Bilingualism x Competitor	2.03E-02	1.02E-01	0.2	0.843
Perspective x Time x Orienting	7.64E-03	3.39E-03	2.251	0.032
Perspective x Time x Alerting	-6.17E-04	2.12E-03	-0.29	0.774
Perspective x Time x Conflict resolution	4.49E-04	7.32E-04	0.612	0.545
Perspective x Time x Antisaccade	-2.19E-03	6.50E-03	-0.338	0.738
Perspective x Time x Spatial WM	-1.97E-02	2.70E-02	-0.729	0.472
Perspective x Time x Picture naming onsets	6.77E-01	1.59E+00	0.426	0.673
Perspective x Time x Picture naming RTs	-1.04E+00	1.28E+00	-0.815	0.421
Perspective x Time x Matrix	-1.61E-02	9.59E-03	-1.676	0.104
Perspective x Time x Bilingualismx Competitor	-5.56E-02	2.04E-01	-0.272	0.787
<i>Random Effects</i>		Variance	Std.Dev.	
Item	(Intercept)	0.121019	0.34788	
	Time	0.020562	0.14339	
	Bilingualism	0.032353	0.17987	
	Time x Bilingualism	0.151658	0.38943	
Subject	(Intercept)	0.114493	0.33837	
	Perspective	0.069606	0.26383	
	Time	0.010114	0.10057	
	Competitor	0.121019	0.34788	
Residual	1.807362	1.34438		
Number of observations: 6032, Subjects: 32, Items: 100				

C. (continued)

Appendix D

	Estimate	Std. Error	t-value	p-value
(Intercept)	0.6618543	0.079237	8.353	0.000
Perspective	-0.7060112	0.0986249	-7.159	0.000
Time	0.4934855	0.0625951	7.884	0.000
Bilingualism	-0.1378431	0.0859772	-1.603	0.119
Grid switch	-0.1910768	0.0878237	-2.176	0.038
Orienting	-0.00148	0.0033481	-0.442	0.662
Alerting	-0.0004223	0.0020625	-0.205	0.839
Conflict resolution	-0.0003979	0.0007284	-0.546	0.589
Antisaccade	-0.0016914	0.0065207	-0.259	0.797
Spatial WM	0.012536	0.0271896	0.461	0.648
Picture naming - Onsets	1.4745254	1.5516327	0.95	0.350
Picture naming - Key presses	-1.967703	1.2751812	-1.543	0.133
Matrix	-0.0231672	0.0095721	-2.42	0.022
Perspective x Time	0.1815654	0.0779448	2.329	0.027
Perspective x Bilingualism	-0.0384748	0.0911546	-0.422	0.676
Time x Bilingualism	-0.0587258	0.0717484	-0.818	0.420
Perspective x Grid switch	0.1838296	0.1537531	1.196	0.241
Time x Grid switch	-0.2210233	0.0758071	-2.916	0.007
Bilingualism x Grid switch	0.0653725	0.06949	0.941	0.354
Time x Orienting	-0.001968	0.0028043	-0.702	0.488
Perspective x Orienting	0.002502	0.0033473	0.747	0.461
Time x Alerting	-0.0004938	0.001739	-0.284	0.778
Perspective x Alerting	-0.0019392	0.0020712	-0.936	0.357
Time x Conflict resolution	-0.00042	0.0006098	-0.689	0.496
Perspective x Conflict resolution	0.0006241	0.0007271	0.858	0.398
Time x Antisaccade	-0.004066	0.0054318	-0.749	0.460
Perspective x Antisaccade	0.0066696	0.0064912	1.027	0.313
Time x Spatial WM	0.0075896	0.0226341	0.335	0.740

D. Effects of perspective, language group, time, switch and individual differences on target advantage (Experiment 2). Alpha adjusted for multiple comparisons (adjusted for 9 additional model terms) is $\alpha=0.05/9=0.006$.

Perspective x Spatial WM	-0.01457	0.0270511	-0.539	0.594
Time x Picture naming – Onsets	0.513783	1.3038548	0.394	0.696
Perspective x Picture naming – Onsets	-3.4086064	1.5549714	-2.192	0.036
Time x Picture naming – Key presses	-1.5033784	1.0643329	-1.413	0.168
Perspective x Picture naming – Key presses	1.9733699	1.2713004	1.552	0.131
Time x Matrix	-0.0218096	0.0079872	-2.731	0.010
Perspective x Matrix	0.0130132	0.0095393	1.364	0.183
Perspective x Time x Bilingualism	-0.013984	0.0864695	-0.162	0.872
Perspective x Time x Grid switch	0.054865	0.151679	0.362	0.720
Perspective x Bilingualism x Grid switch	0.0652684	0.105125	0.621	0.539
Time x Bilingualism x Grid switch	0.0135012	0.0769374	0.175	0.862
Perspective x Time x Orienting	0.0073472	0.0034379	2.137	0.041
Perspective x Time x Alerting	-0.0010159	0.0021562	-0.471	0.641
Perspective x Time x Conflict resolution	0.0004434	0.000745	0.595	0.556
Perspective x Time x Antisaccade	-0.0039537	0.0065873	-0.6	0.553
Perspective x Time x Spatial WM	-0.009317	0.0274058	-0.34	0.736
Perspective x Time x Picture naming – Onsets	1.0087619	1.6094028	0.627	0.535
Perspective x Time x Picture naming – Key presses	-1.4286075	1.2954118	-1.103	0.279
Perspective x Time x Matrix	-0.0144271	0.0097151	-1.485	0.148
Perspective x Time x Bilingualism x Grid switch	0.2064643	0.1539438	1.341	0.200
Random Effects	Name	Variance	Std.Dev.	

D. (continued)

Item	(Intercept)	0.111619	0.334094	
	Time	0.017982	0.134096	
	Bilingualism	0.031743	0.178166	
	Time x Bilingualism	0.004535	0.067343	
Subject	(Intercept)	0.142199	0.377093	
	Perspective	0.110868	0.332968	
	Time	0.07171	0.267788	
	Grid switch	0.057216	0.239199	
Residual	1.793264	1.339128		

Number of observations: 5800, Items, 96; Subjects, 32

D. (continued)