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Visuospatial perspective-taking in conversation and the role of bilingual experience

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ABSTRACT

Little is known about how listeners use spatial perspective information to guide comprehension. Perspective-taking abilities have been linked to executive function in both children and adults. Bilingual children excel at perspective-taking tasks compared to their monolingual counterparts (e.g., Greenberg, Bellana, & Bialystok, 2013), possibly due to the executive function benefits conferred by the experience of switching between languages. Here we examine the mechanisms of visuo-spatial perspective-taking in adults, and the effects of bilingualism on this process. We report novel results regarding the ability of listeners to appreciate the spatial perspective of another person in conversation: While spatial perspective-taking does pose challenges, listeners rapidly accommodated the speaker's perspective, in time to guide the on-line processing of the speaker's utterances. Moreover, once adopted, spatial perspectives were enduring, resulting in costs when switching to a different perspective, even when that perspective is one's own. In addition to these findings, direct comparison of monolingual and bilingual participants offer no support for the hypothesis that bilingualism improves the ability to appreciate the perspective of another person during language comprehension. In fact, in some cases adult bilinguals have significantly *more* difficulty with perspective-laden language.

Introduction

Perspective-taking refers to the ability to represent the knowledge state of another person. 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; Clark & Marshall, 1981). 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). 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 in play. Indeed, individual differences in children's inhibitory control predict success in both theory-of-mind tasks (Carlson & Moses, 2001), and in perspective-taking in conversation (Nilsen & Graham, 2009).

Perspective-taking

In adulthood, perspective representations are thought to be integral to even the most basic aspects of language

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use (Clark & Marshall, 1978). For example, if I have a question about statistics, it is important that I ask someone whom I *believe knows about statistics*, and not someone who does not know about statistics. Doing so requires distinguishing between knowledge that is privately held by one member of the conversation (termed "privileged ground"), from knowledge that is jointly known, termed the "common ground". While adults overwhelmingly are sensitive to perspective (Hanna, Tanenhaus, & Trueswell, 2003), they still show interference from their egocentric perspective (Birch & Bloom, 2007; Keysar, Lin, & Barr, 2003). Further, the degree to which adults appreciate perspective is modulated by basic cognitive functions including working memory and inhibition (Brown-Schmidt, 2009; Grodner, Dalini, Pearlstein-Levy, & Ward, 2012; Lin, Keysar, & Epley, 2010; Wardlow, 2013). A potential mechanism for the role of inhibitory control is that, in order to access a representation of another's perspective, participants must inhibit the prepotent representation of their own perspective. Alternatively, maintaining the relative activation of items that are in common and privileged ground may place high demands on more general attentional monitoring processes.

Spatial perspective-taking, in particular, is challenging for adults (Schober, 2009), despite the fact that adults have a lifetime of experience with disparities in viewpoint. In any face-to-face conversation, the speakers never view the world from the same spatial perspective (Schober, 1993). This difficulty may be due to the fact that spatial perspective-taking requires the mental transformation of one's own viewpoint to match another. Perspective-taking in conversation has typically been examined in tasks that manipulate what is in common or privileged visual ground using occlusion (e.g., Brown-Schmidt, Gunlogson, & Tanenhaus, 2008; Hanna et al., 2003). For example, a listener might be asked to "*Pick up the duck*" in a situation with two ducks, only one of which is visible from the speaker's perspective. In these studies, linguistic ambiguity (i.e., which duck is intended by the speaker) can be resolved using a simple line-of-sight perspective-taking strategy (Michelon & Zacks, 2006). By contrast, little is known about how listeners utilize *spatial* perspective information during comprehension. For example, in a face-to-face conversation, to understand an instruction such as "*I'd like the steak on the left*", the listener must consider which perspective the speaker is adopting—whether "left" is from the addressee's perspective or the speaker's. In such situations, the candidate referents are mutually visible and only the appropriate viewpoint transformation can disambiguate them. However, it is unknown how rapidly such processes guide language comprehension, and whether individual differences in executive function, for example, are a mediating factor.

Bilingual advantages

Notably, bilingual children perform better on a spatial perspective-taking task than do monolingual children (Greenberg et al., 2013). Similarly, bilingual children have been shown to have more developed theory of mind abilities (Goetz, 2003; Kovács, 2009). At least two mechanisms may contribute to this bilingual advantage in children's perspective-taking. Executive function has been proposed as one such mechanism. Indeed, bilingual children have been shown to benefit from accelerated mastery of basic cognitive skills such as inhibitory control (e.g., Bialystok, 1999; Bialystok & Martin, 2004; Carlson & Meltzoff, 2008). Another potential mechanism includes the cultural differences and experiences between monolingual and bilingual children. For instance, knowing that some people speak one language and others speak a different one, has also been proposed as an explanation for bilingual children's early mastery of perspective skills (Goetz, 2003).

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. Evidence in support of the bilingual advantage hypothesis has been found primarily in young children and in older adults. Bilingual children demonstrate cognitive advantages in a variety of domains (Bialystok, 2010; Bialystok & Majumder, 1998; Bialystok & Viswanathan, 2009), including problem solving (Bialystok & Codd, 1997; Kessler & Quinn, 1980), understanding of quantity (Bialystok, 1999), and knowledge of grammar (Bialystok, 1988). Among older adults, the evidence suggests that bilingualism diminishes cognitive decline associated with aging (Bialystok, Craik, & Freedman, 2007; Bialystok, Craik, Klein, & Viswanathan, 2004) and may even delay the onset of Alzheimer's (Chertkow et al., 2010; Schweizer, Ware, Fischer, Craik, & Bialystok, 2012).

Relevant findings in young adults include bilingual advantages in multiple components of executive function: inhibitory control (Bialystok, Craik, & Luk, 2008), monitoring (Bialystok et al., 2004; Costa, Hernández, & Sebastián-Gallés, 2008), and switching (Prior & MacWhinney, 2010; though the advantage may only manifest in a subset of tasks, cf. Paap & Greenberg, 2013, p. 252). However, several studies have failed to replicate a bilingual executive control advantage (Colzato et al., 2008; Kousaie & Phillips, 2012; Paap & Greenberg, 2013; Rosselli et al., 2002; see Hilchey & Klein, 2011) particularly in young adults.

In view of the literature suggesting that bilingualism may provide executive function advantages and perspective-taking is linked to certain aspects of executive function, a key question, then, is whether perspective-taking skills might also benefit from bilingualism in young adulthood. A study by Wu and Keysar (2007) showed that adult 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 Gardner, Gabriel, & Lee, 1999), bilingualism, rather than culture, may have mediated this effect. Consistent with this interpretation, Rubio-Fernández and Glucksberg (2012) report that bilingual adults are less susceptible to egocentric bias in a false-belief task. However, the eye-tracking measures they report (first fixation locations and latencies to look at the target object) are 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 some findings support a bilingual advantage in general cognitive abilities, other evidence suggests that these advantages come with costs. Adult bilinguals demonstrate delays and more errors, as compared to monolinguals, in verbal fluency tasks (Bialystok et al., 2008; Gollan, Montoya, & Werner, 2002; Rosselli et al., 2000), as well as in picture naming tasks (Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Kaplan, Goodglass, & Weintraub, 1983; Roberts, Garcia, Desrochers, & Hernandez, 2002). 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. One possible mechanism 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 (Emmorey, Luk, Pyers, & Bialystok, 2008; Gollan et al., 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 (Levy, Mcveigh, Marful, & Anderson, 2007; Meuter & Allport, 1999)—notably, this is the same inhibitory process implicated in the proposed general cognitive advantage for bilinguals.

The present research

The primary goals of the present research are to explore the mechanisms underlying the integration of visuo-spatial perspective information during language processing and to test whether bilingualism may modulate adult perspective-taking abilities. We examined perspective-taking in a language task for two reasons. First, perspective-based representations are widely encoded in the languages of the world (Bloom, 2001; Clark, 1996; Clark & Brennan, 1991; Papafragou, 2002), 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 et al., 2008; Gunlogson, 2001). Second, the unique linguistic challenges associated with bilingualism suggest that perspective-taking in conversation – a common activity in daily life – might shed some light on the complex interplay between domain-general executive functioning and the language processing system.

Spatial perspective-taking, examined in Experiments 1 and 2, is particularly of interest because little is known about how listeners adjust their comprehension when the speaker's spatial perspective differs from their own. Additionally, Greenberg et al. (2013) found an advantage for bilingual children on an analogous task. We complement this approach with a more standard line-of-sight perspective-taking task, modeled after Brown-Schmidt et al. (2008). A final goal of the present research is to use a number of individual differences measures (inhibition, executive attention, working memory, etc.) to 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., 2007; 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.

Method

Participants

Participants were 31 self-identified monolingual speakers of English (16 female) and 33 self-identified bilinguals (21 female) who spoke English and at least one other language fluently. These languages 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 26 ($M = 20.07$, $SD = 1.52$). They either received partial course credit for their participation or were paid \$8/h. One participant was excluded because he was 50 years old. Two participants were excluded because they were not clearly bilingual, monolingual, or a native speaker of English, based on their language questionnaire responses. Exclusion criteria included age, age of first exposure to a language, self-described proficiency in languages, percent weekly use, and quality and duration of exposure. In order to test whether inhibitory control might be a mediating factor for any perspective-taking benefits, we modeled our sample after Bialystok et al. (2008), where they found a bilingual advantage on the Stroop task, and did not explicitly match participants on specific criteria.

Table 1 summarizes the results of the language background questionnaire. Of the bilinguals, 13 self-reported English as their L1 (first language) (this includes participants who reported learning both languages at the same time), and 14 self-reported that English was their L2 (second language). Three of the questionnaire responses (proficiency in non-English second language, percent weekly use of non-English second language, and duration of non-

Table 1
Average, standard deviation, and 95% confidence intervals of difference between monolingual and bilingual participants (*N* is specified when different from the overall group *N* due to subgroup analysis or missing values).

	Bilinguals (*N* = 32)		Monolinguals (*N* = 32)		95% CI
	M	*SD* (*N*)	*M*	*SD* (*N*)	
Age	20.00	1.27	21.16	1.76	[−0.95 to 0.61]
Percent weekly use of English	82.55	16.05	99.43	1.50	[−22.70 to −11.08]
Age of first exposure to second language (collapsed across languages)	4.26	3.78 (27)	13.36	2.63 (28)	[−10.87 to −7.33]
L1-English: Age of first exposure to non-English second language (in years)	2.73	3.57 (13)	13.36	2.63 (28)	[−12.95 to −8.30]
L1-Other: Age of first exposure to English as a second language (in years)	5.68	3.50 (14)	NA	NA	NA
Percent weekly use of non-English language	21.08	17.15	1.43	3.52	[13.35–25.95]
Self-rated speaking ability in non-English language (0-beginner to 3-near native)	2.70	0.53 (30)	0.64	0.68 (28)	[1.73–2.38]
Years of exposure to non-English language	10.81	6.76 (16)	4.03	1.66 (31)	[3.14–10.42]
Parental education (0-some HS to 3-graduate school)	1.63	1.20	1.91	0.89	[−0.81 to 0.25]

English second language exposure) were used to compute a continuous measure of bilingualism using an unweighted average of the standardized scores. These three questions were used because they have been commonly used to assess bilingual experience (e.g., Jia, Aaronson, & Wu, 2002; Paradis, 2011; Unsworth et al., 2011). The other questions on the questionnaire contained many blank values or were highly correlated with these three, so they were excluded from the quotient calculation. This bilingualism quotient provided each participant with an individual measure of their experience with their non-English language. Because all participants were tested in the US, this measure provides a sense of how much use and exposure to a non-English language they had. Hereafter, and in Table 1, 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 self-identified as bilingual but their quotient score turned out to be below the median), leading to a sample of 32 bilinguals and 32 monolinguals. Parental education was used as a proxy measure for socio-economic status (SES).

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. These included perceptual speed (Salthouse & Babcock, 1991), alphabet span, reading span, listening span, minus 2 span (these 4 were combined into a composite Working Memory score), and two versions of the Stroop task. The monolinguals and bilinguals did not differ significantly on any one of these measures (Appendix A).

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 Fig. 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 condition, the experimenter's maps were identical to the participant's (Fig. 2a), except that the experimenter saw a path drawn on the map (Fig. 2b). In the Perspective-taking condition, the experimenter's maps showed the opposite visual perspective from the participant (Fig. 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.

Linguistic stimuli. In the no Perspective-taking 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 Perspective-taking 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 10 map trials and the training trial were video-recorded. Participants' errors were coded by comparing the paths that the participants drew to the experimenter' directions. 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 no Perspective-taking condition) a path drawn around the right side of the ball was counted as one error. Small variability in paths was not treated as an error. For example, if the participant drew the line slightly closer to one object than the experimenter, this was treated as correct.

We also measured the onset (in milliseconds) of the last word in each instruction spoken by the experimenter, as well as the onset times of the participant's pen movement relative to the last word in the instruction. The onset of 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 binary self-report bilingualism status.

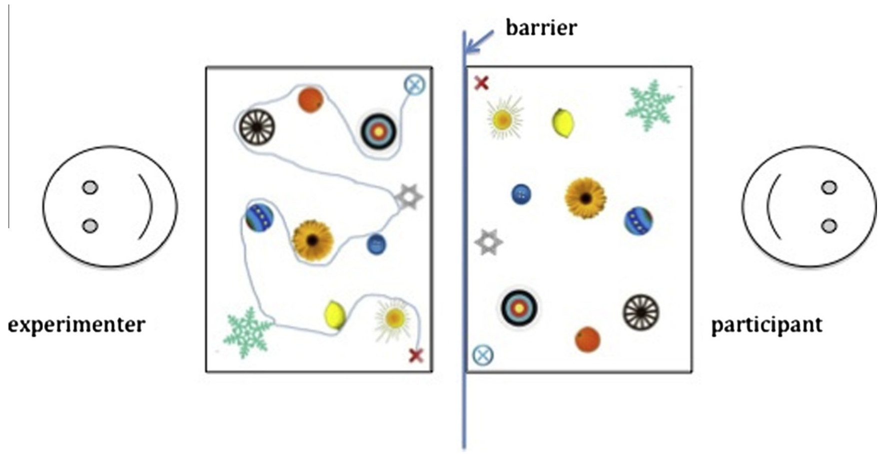

Fig. 1. Schematic of the experimental setup (no Perspective-taking condition).

Fig. 2. (a–c) Example maps for participant (a) and experimenter in the no Perspective-taking condition (b) and the Perspective-taking condition (c). Note the starting point for each map is the red X. In the no Perspective-taking condition, the objects on the experimenter's right are the same as the objects on the participant's right, whereas in the Perspective-taking condition, the objects on the experimenter's right are the same as the objects on the participant's *left*. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

participant's pen movement relative to the final word (e.g., "left") was coded from the video recording and used to measure latency (how long it took for the participant to start the movement).

Predictions

Spatial perspective-taking

Based on previous findings that one's egocentric perspective is never fully ignored, even when successfully appreciating another person's perspective (Hanna et al., 2003; Keysar, Barr & Horton, 1998; Rieser, 1989), we hypothesized that performance should be impaired (more errors and longer response latencies) in the perspective-taking condition compared to the no-perspective-taking condition. If so, this would demonstrate a sufficiently challenging perspective-taking task that could be used to measure group differences in the ability of accommodating another person's perspective.

Bilingualism

According to the bilingual advantage hypothesis (Bialystok et al., 2009), bilingual participants should perform better on executive function tasks. If advanced spatial perspective-taking skills in bilinguals extend to adulthood, we would expect to see a clear bilingual advantage in the perspective-taking task. However, according to both the frequency-lag hypothesis (Gollan et al., 2011) and the lexical-inhibition hypothesis (Levy et al., 2007; Meuter & Allport, 1999), bilinguals' performance is likely to be strained due to the linguistic nature of the task. Finally, if bilingual children's improved perspective-taking abilities (Greenberg et al., 2013; Kovács, 2009) are mediated by accelerated inhibitory 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

Perspective task: 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 (Fig. 3).

Error rates 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 (no Perspective-taking vs. Perspective-taking) was coded with mean-centered deviation contrast codes, and the bilingualism quotient was mean-centered. The model was fit with a maximal random effects structure justified by the data. Models with perceptual speed, working memory, and inhibition as mean-centered factors were attempted but those factors did not contribute signifi-

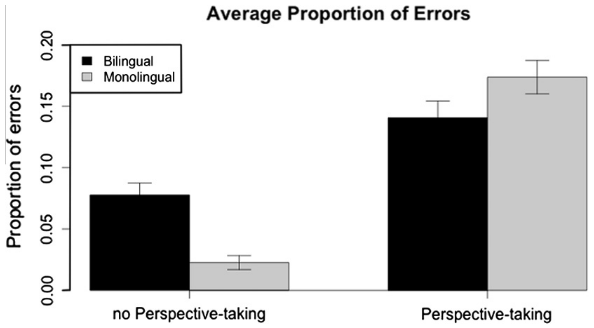

Fig. 3. The proportion of errors (based on a total of 174 possible errors per participant) by language group and condition with by-subject standard error of the mean bars.

cantly to the model (see Appendix B). The model revealed a significant effect of condition due to more errors, for all participants, in the Perspective-taking condition (Table 2).[2] 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 no Perspective-taking condition ($p < .005$) and numerically fewer errors in the Perspective-taking condition ($p = .95$).

Perspective task: Latency

The latency analysis examined the time it took for each participant to begin a pen movement and included both correct and incorrect trials. Data points that were over three standard deviations above or below the mean were excluded. Responses to the last instruction on each trial were 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 average latency per instruction for monolinguals and bilinguals by condition is summarized in Table 3.

The latency data were analyzed in a mixed effects model with bilingualism and perspective, and their interaction, as fixed effects, and a maximal random effects structure (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.

A model with perceptual speed, working memory, and inhibition as mean-centered factors (Appendix C) revealed that the first measure of inhibitory control (Stroop 1) significantly predicted latency ($p < .005$) such that participants who showed less interference on the Stroop were faster to respond. However, perspective did not interact significantly with inhibition, $p = .18$, or bilingualism, $p = .50$.

[2] An identical analysis using language group as a categorical predictor produced the same pattern of results, though the perspective * bilingualism interaction was not significant, likely due to lower power.

Discussion

Spatial perspective-taking

Consistent with previous findings of adult difficulties with spatial perspective-taking (Rieser, 1989; Shelton & McNamara, 2004; Zacks & Michelon, 2005), participants made more egocentric errors and were slower to respond when interpreting spatial instructions from a perspective that required a 180° transformation. These findings are consistent with Schober (1993), who found that interpreting spatial terms poses significant difficulty for some participants, and suggest we created a sufficiently challenging task.

Bilingualism

Based on previous findings that bilingual children exhibit better spatial perspective-taking skills (Greenberg et al., 2013), and that young bilingual adults outperform monolinguals on the Stroop task and working memory tasks (Bialystok et al., 2008), we hypothesized that our bilingual adults would outperform monolingual adults. These hypotheses were not clearly supported by the data. We found no evidence for a bilingual advantage in executive function or memory, although bilinguals were faster to initiate a response than monolinguals, consistent with findings of faster processing among bilinguals (Costa, Hernández, Costa-Faidella, & Sebastián-Gallés, 2009). Moreover, contrary to previous work with bilingual children, our young adult bilingual sample made significantly more errors in the spatial perspective task overall.

Notably, we did observe an interaction between perspective condition and bilingualism, though not in the predicted direction: Whereas the error rate in the Perspective-taking condition did not differ significantly between monolinguals and bilinguals, in the no Perspective-taking condition, bilinguals made significantly more errors. One potential interpretation of this interaction is that perspective-taking is less challenging for bilinguals, because the overall difference in error-rate between the no Perspective-taking and Perspective-taking conditions was smaller for bilinguals. Such an interpretation would be consistent with the bilingual advantage hypothesis. However, given that the effect is largely driven by group differences in the no Perspective-taking condition, it seems more prudent to not over-interpret a removable interaction (Loftus, 1978). A more sensitive task might be better positioned to reveal differences between monolinguals and bilinguals during perspective-taking – a possibility we explore in Experiment 2.

The lack of a bilingual advantage in the Stroop task is not unprecedented (Kousaie & Phillips, 2012; Rosselli et al., 2002). Findings of a bilingual advantage in working memory have also been mixed (see Feng, 2008). One explanation is that the magnitude of the effect size is small and we did not have enough power to test for it. However, the sample size in the present study was comparable to, or larger than, that used by Bialystok and colleagues (24 participants per group in Bialystok et al., 2008). Based on the estimated effect size in Bialystok et al. (2008) of $d = .7$, 80% power would be achieved with 33 participants per group (we tested 32 per group). Further, we tested a simi-

Table 2
Effects of condition and language on interpretation errors in spatial perspective task. Statistically significant effects are in bold.

Fixed effects	Estimate	Std. error	*z*-Value	*p*-Value
(Intercept)	−2.9162	0.1757	−16.602	<.0001
Perspective	**1.6732**	**0.3177**	**5.267**	**<.0001**
Bilingualism	**0.4723**	**0.1937**	**2.439**	**<.05**
Perspective × bilingualism	**−0.9063**	**0.3879**	**−2.337**	**<.05**
Random effects	Name	Variance	Std. dev.	
Subject	(Intercept)	1.3582582	1.16544	
Item	(Intercept)	0.0583447	0.24155	
	Perspective	0.0113086	0.10634	
	Bilingualism	0.0043744	0.06614	
	Perspective × Bilingualism	0.0286279	0.1692	

Number of observations: 11029, Subjects: 64, Items: 10.

Table 3
Mean and standard deviation of latency in milliseconds to respond to instructions by condition and language group (based on median split of the bilingualism quotient).

	No perspective-taking *M*(*SD*)	Perspective-taking *M*(*SD*)
Monolingual	323.85 (891.60)	841.86 (1291.67)
Bilingual	375.16 (1477.71)	602.56 (1441.66)

lar participant population to that in Bialystok et al. (2008) – young adult bilinguals from varied linguistic backgrounds. In Experiment 2, we explore other aspects of executive function that have more reliably been linked to bilingualism, using the Attentional Networks Test (Fan, McCandliss, Sommer, Raz, & Posner, 2002).

Summary

In summary, the present research finds no evidence for the hypothesis that young adult bilinguals outperform monolinguals in a test of spatial perspective-taking. One interpretation of these findings is that the observed benefit in bilingual *children's* spatial perspective-taking (Greenberg et al., 2013) does not extend to adulthood. However, another possibility is that our measures (errors and latency) were not sensitive enough to detect the effect. Thus, in Experiment 2 we use a more sensitive measure (eye-tracking) to examine whether bilinguals might outperform monolinguals in a time-sensitive spatial perspective-taking task.

Experiment 2

The primary goal of Experiment 2 was to examine the effects of bilingualism on spatial perspective-taking using a more sensitive dependent measure. 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 doing so, we created three manipulations which allowed us to further probe the process of spatial perspective-taking in the on-line processing of conversational language, a domain which has received comparatively little attention in the literature. These 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. Lastly, we used a large number of non-linguistic individual differences measures to evaluate claims that a bilingual executive function benefit might mediate any perspective-taking advantages.

Table 4
Effects of perspective and bilingualism on latency of response on spatial perspective-taking task. Statistically significant effects are in bold.

Fixed effects	Estimate	Std. error	*t*-Value	*p*-Value
(Intercept)	525.5	53.07	9.902	
Perspective	**403.59**	**95.38**	**4.231**	**<.01**
Bilingualism	−34.98	59.09	−0.592	.99
Perspective × Bilingualism	−219.04	119.09	−1.839	.42
Random effects	Name	Variance	St. dev.	
Subject	(Intercept)	1.09E+05	330.5918	
Item	(Intercept)	5.46E+03	73.9148	
	Perspective	9.53E+01	9.7607	
	Bilingualism	1.78E+01	4.2173	
	Perspective × Bilingualism	2.78E+03	52.7594	
Residual	1.56E+06	1249.7605		

Number of observations: 7883, Subjects: 54, Items: 10.

Table 5
Average and standard deviation of participant language characteristics, plus 95% confidence intervals of the difference between the means (*N* is specified when different from the overall group *N* due to subgroup analysis or missing values).

	Bilinguals (*N* = 20)		Monolinguals (*N* = 21)		95% Confidence interval of the diff.
	M	*SD* (*N*)	*M*	*SD* (*N*)	
Age	19.8	1.4	18.7	0.80	[0.40–1.86]
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 (19)	10.89	4.54 (19)	[−12.44 to −7.87]
L1-English: Age of first exposure to non-English second language (in years)	0.74	1.56 (19)	10.89	4.54 (19)	[−12.44 to −7.87]
L1-Other: Age of first exposure to English as a second language (in years)	NA	NA	NA	NA	NA
Percent weekly use of second language	20.85	15.95	0.52	1.21	[12.85–27.81]
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 (18)	[1.90–2.61]
Parental education (0-some HS to 3-graduate school)	1.21	0.96 (19)	0.74	0.82	[−1.10 to 0.05]

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 $8/h. for up to 2 h of participation. Data from an additional 16 participants were not analyzed due to experimenter error ($n = 9$) or equipment problems ($n = 7$).

Table 5 summarizes participant characteristics obtained from a language background questionnaire. A bilingualism quotient was calculated in the same way as in Experiment 1; again, higher scores indicate a greater degree of bilingualism. As in Experiment 1, a median split of bilingualism scores was used for data visualization purposes. The median split was consistent with the participants' self-defined 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 h. Participants then switched rooms and started the interactive dialog task with an experimenter, which lasted about 40 min.

Individual differences. Executive function was evaluated using a series of non-linguistic tasks, including the Attentional Networks Test[3,4] (Fan et al., 2002), a spatial working memory task (implemented on PEBL; Mueller, 2009), and an anti-saccade task (Kane, Bleckley, Conway, & Engle, 2001). The ANT program was not able to calculate scores for 6 participants due to technical difficulties. English fluency was assessed using a picture-naming test (233 pictures from the International Picture Naming Project's object database, normed by Székely et al., 2003). General intelligence was measured using a task modeled after Raven's Progressive Matrices (designed using the Sandia Matrix Generation Software; Matzen et al., 2010). Monolinguals and bilinguals did not differ on any measures of executive function or intelligence, and bilinguals were slower than monolinguals to name pictures (Appendix D).

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). Participants viewed a series of 5×5 grids on the computer screen (Fig. 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 et al. (2008). In addition, the scene contained a picture of a star that the participant could drag around 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. In half of the trials, the experimenter's perspective on the grid was identical to the participant's (no Perspective-Taking condition, Fig. 4b). On the other half of the trials, the experimenter viewed his or her grid from the *opposite* perspective (Perspective-taking, Fig. 4c).

[3] http://www.sacklerinstitute.org/users/jin.fan/.

[4] Incongruent trials constituted 33% of the trials, with neutral and congruent trials each making up another 33%. This is the same test-structure that was used in Costa et al. (2008) and similar to the high-monitoring condition (version 1) used by Costa et al. (2009), both of which demonstrated a bilingual advantage.

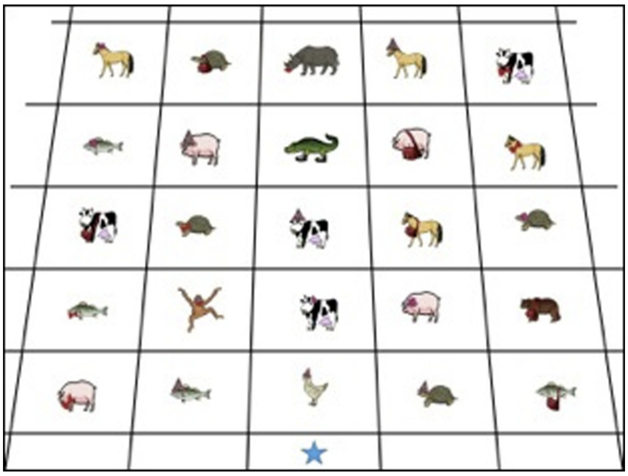

Fig. 4a. Example grid seen by participant.

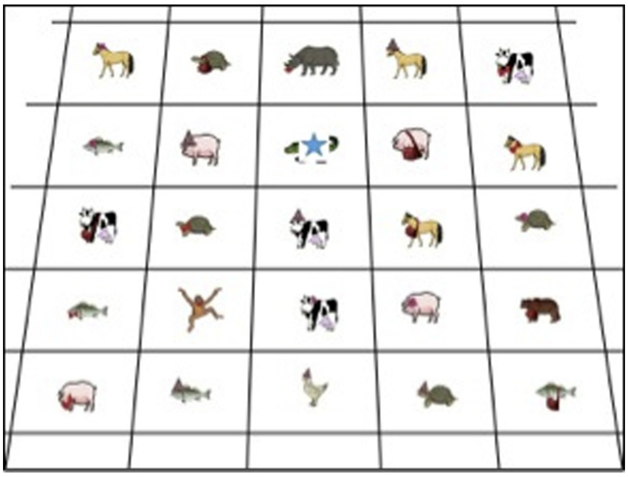

Fig. 4b. Example grid seen by experimenter in no Perspective-taking condition.

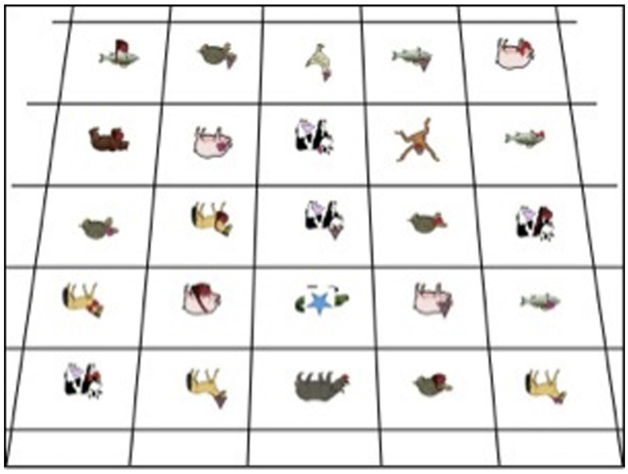

Fig. 4c. Example grid seen by experimenter in Perspective-taking condition.

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 tested verbal perspective-taking. Each set of five trials was either in the no Perspective-taking condition where the spatial references were aligned (e.g., "left" spoken by the experimenter refers to *left* on the participant's grid) or the Perspective-taking 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, as well as which animals, if any, were not visible to the experimenter (i.e., there was a blacked out cell instead of an animal). The experimenter's grid was visible to the participant during the entire duration of the non-verbal trial. 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 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.

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 Figs. 4b and 4c), the first verbal instruction might be, "*Go <u>left</u> to the pig with the hat*" in the no Perspective-taking condition, and "*Go <u>right</u> to the pig with the hat*" in the Perspective-taking condition. In the Perspective-taking 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 alligator.[5] Eye movements to the candidate referents were monitored throughout these trials as a measure of on-line understanding.

Our <u>first</u> measure of linguistic perspective-taking focused on the 99 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 disam-

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

biguated 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 Fig. 4a), the competitor was the pig with the purse, such that the underlined portion of the 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 Fig. 4c). 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, 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 one privileged-ground competitor (i.e., seen only by the participant). The remaining critical trials, 83/99, contained common-ground competitors (i.e., visible to both experimenter and participant). Participants were made aware of the privileged animals during the initial non-verbal trial for each grid. Sixteen grids, out of 33, contained a privileged cell.

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., no Perspective-taking to Perspective-taking, Perspective-taking to no Perspective-taking, no Perspective-taking to no Perspective-taking, Perspective-taking to Perspective-taking) an approximately equal number of times.

The remaining 33 trials were fillers and did not contain a competitor. Thus, the cell opposite the target 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. The onsets of each 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.

Predictions

Perspective-taking

This experiment was designed to examine three novel questions regarding perspective-taking in conversation. First, we asked whether listeners could appreciate the opposite spatial perspective of their partner, and use this information in time to guide on-line interpretation of a referring expression. If so, listeners should interpret the temporarily ambiguous critical instruction, "*Go right to the pig with the*...", as referring to the target referent, even in the perspective-taking condition, and would be indicated by a positive target-advantage score (more looks to the target than the competitor). Note that egocentric processing in the perspective-taking condition would be indicated by a *negative* target-advantage score. Previous research has not examined the time-course of spatial perspective-taking in conversation and it is unknown whether participants would be able to appreciate their partner's perspective from the earliest moments of processing. Second, we asked whether listeners could use information about a remembered perspective to guide processing, by manipulating whether the competitor referent was physically seen by the listener only. Recall that in order to use this information, listeners would have to remember from the initial set-up trial which object was in their privileged ground. If listeners can remember and use this information, we would expect larger target-advantage scores when the competitor is privileged since the experimenter could not be referring to the contents of a cell that is hidden to him/her. Note that while extensive evidence shows that listeners use information about physical co-presence (Brown-Schmidt et al., 2008; Hanna et al., 2003; Heller, Grodner, & Tanenhaus, 2008), in these experiments privileged ground is marked in the immediate scene. It is currently unknown whether *memory* for physical co-presence plays as strong of a role. Third, we asked, for the first time, whether listeners experience costs when switching between perspectives. Based on previous findings of negative priming when switching between spatial reference frames (Carlson-Radvansky & Jiang, 1998) and greater interference in Stroop and flanker-like tasks when the inconsistent response was activated recently (Durston et al., 2003; Gratton, Coles, & Donchin, 1992; Warren, 1974), we predicted faster interpretation of the critical instruction when the previous grid used the same perspective scheme. If so, this would suggest that perspective-representations endure over time.

Bilingualism

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 appreciating a different perspective, 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

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 (Perspective-taking) or the participant's (no Perspective-taking). A response was coded as correct when the participant placed the star on the intended target and incorrect when the star was placed anywhere else on the screen. On average, participants were less accurate in the Perspective-taking condition ($M = 0.94$, $SD = 0.24$) than in the no Perspective-taking 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 subjects.[6] The maximal random effects structure was used. Accuracy rates were not significantly different between monolinguals and bilinguals ($z = 0.52$, $p = .60$). An effect of perspective condition ($z = -3.4$, $p < .01$) was due to more errors in the Perspective-taking condition (Appendix E).

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 (Figs. 5 and 6). 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 (no Perspective-taking vs. Perspective-taking, Fig. 7), competitor condition (common/shared vs. privileged, Fig. 8), and perspective-switching condition (switch vs. no switch, Fig. 9).

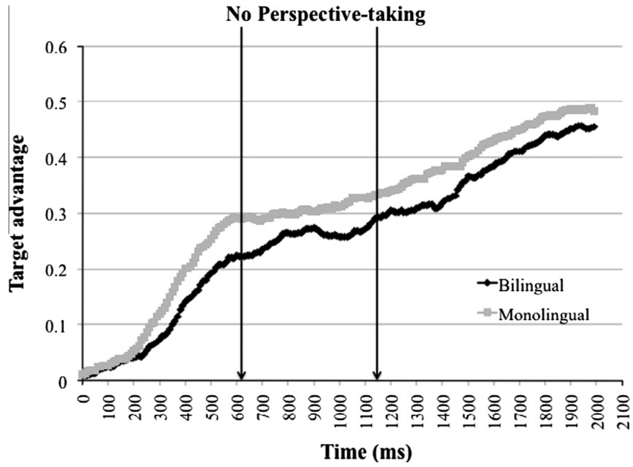

Fig. 5. Target advantage scores by language group in the no Perspective-taking condition. Zero ms corresponds to the onset of the word "left" in *Go left to the pig with the hat*. The vertical lines indicate, from left to right, the average onset of "pig" and "hat."

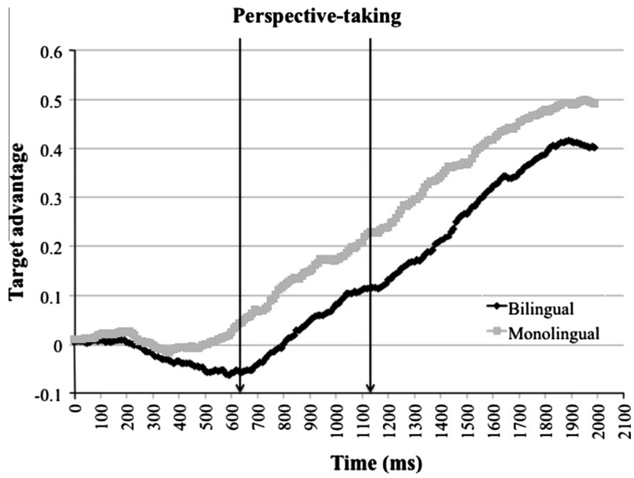

Fig. 6. Target advantage scores by language group in the Perspective-taking condition. Zero ms corresponds to the onset of the word "right" in *Go right to the pig with the hat*. The vertical lines indicate, from left to right, the average onsets of "pig" and "hat".

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

Spatial perspective-taking and sensitivity to privileged competitors. The target advantage scores were analyzed in a mixed effects regression model as before (Table 6). Perspective condition (no Perspective-taking vs. Perspective-taking) and time window (first vs. second) were entered as mean-centered deviation contrast codes. Competitor condition (privileged vs. common ground competitor) was dummy coded such that the common ground competitor condition was the reference level. The maximal random effects structure was attempted first but did not converge. Instead, a backwards-fitting procedure in which random slopes were removed one at a time beginning with higher-order slopes first, was used to determine the maximal random effects structure model that would converge.

A significant effect of perspective was due to a larger target preference in the no Perspective-taking vs. the Perspective-taking condition. A significant interaction of perspective by time window was due to attenuation of the perspective effect over the course of a trial. Finally, participants with a higher rating on the bilingualism quotient had significantly *lower* target advantage scores in both time windows. This effect did not interact with perspective condition, showing that bilinguals were slower to interpret the spatial instruction, regardless of whether the instructions were tailored to the participant's own perspective, or not.

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

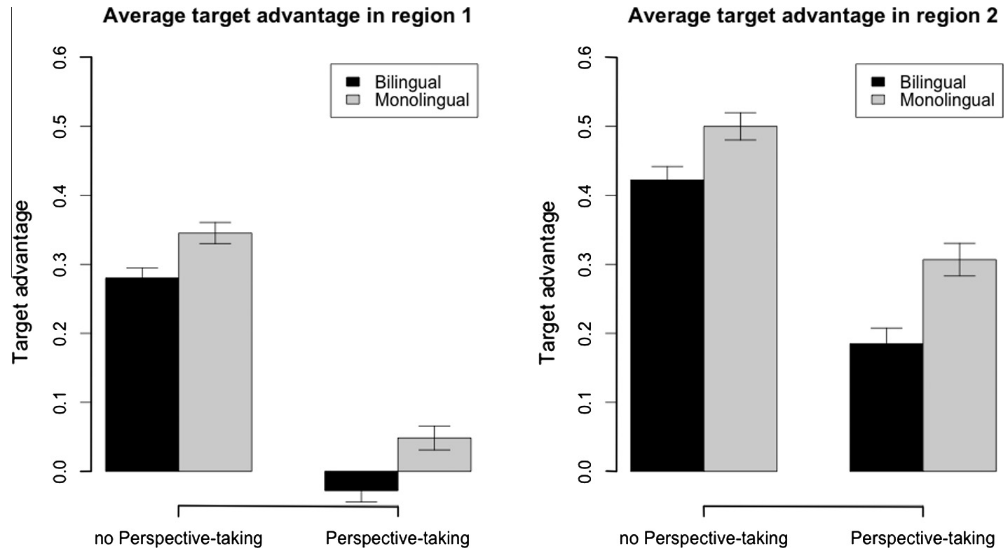

Fig. 7. Target advantage scores by language group and spatial perspective for each time region.

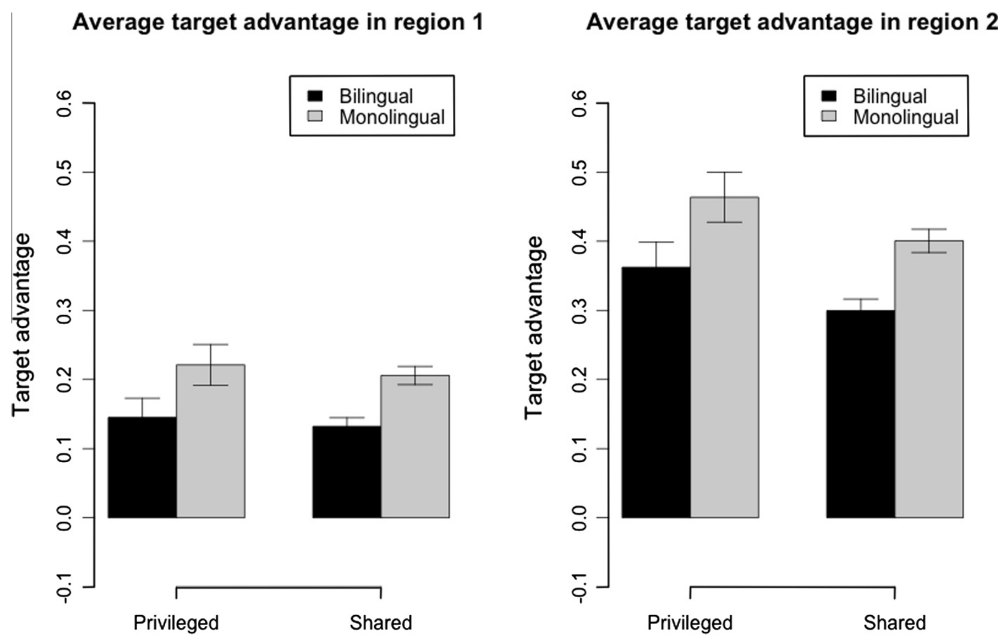

Fig. 8. Target advantage scores by language group and competitor condition for each time region.

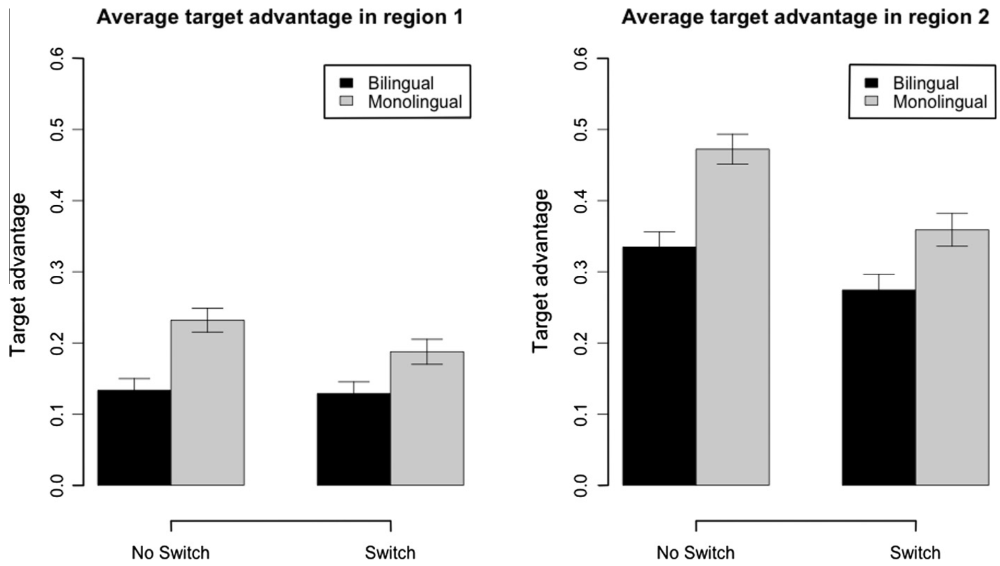

Fig. 9. Target advantage scores by language group and grid switching condition by time region.

Table 6
Effects of bilingualism, and perspective and competitor conditions on target advantage. Statistically significant effects are in bold.

Fixed effects	Estimated parameters	Std. error	*t*-Value	*p*-Value
(Intercept)	0.664312	0.077353	8.588	
Perspective	**−0.582293**	**0.095598**	**−6.091**	**<.0001**
Time	**0.479701**	**0.056772**	**8.45**	**<.0001**
Competitor	0.082045	0.100597	0.816	.42
Bilingualism	**−0.174434**	**0.079813**	**−2.186**	**<.05**
Perspective × Time	**0.226365**	**0.074949**	**3.02**	**<.01**
Perspective × Competitor	−0.369122	0.200872	−1.838	.06
Time × Competitor	0.130725	0.093626	1.396	.16
Perspective × Bilingualism	−0.07223	0.08022	−0.9	.33
Time × Bilingualism	−0.084633	0.061297	−1.381	.17
Competitor × Bilingualism	0.002199	0.068594	0.032	1.00
Perspective × Time × Competitor	−0.274774	0.188189	−1.46	.14
Perspective × Time × Bilingualism	−0.060832	0.075295	−0.808	.38
Perspective × Competitor × Bilingualism	−0.018566	0.13529	−0.137	1.00
Time × Competitor × Bilingualism	0.020016	0.093928	0.213	.83
Perspective × Time × Competitor × Bilingualism	0.004531	0.188753	0.024	.97
Random effects		Variance	Std. dev.	
Item	(Intercept)	0.1103892	0.332249	
	Time	0.0241807	0.155501	
	Bilingualism	0.0310863	0.176313	
Subject	(Intercept)	0.1798156	0.424047	
	Perspective	0.1122401	0.335023	
	Time	0.0746681	0.273255	
	Competitor	0.0055609	0.074572	
Residual	1.7721343	1.331215		
Number of observations: 7592, Subjects: 41, Items: 100.				

the 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, 2009, 2012).

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). Average target advantage scores in the two time windows are plotted by bilingualism and perspective-switching condition (switch vs. no switch) in Fig. 9.

A mixed effects model included perspective condition, time window, and grid switch condition as mean-centered deviation contrasts (Table 7). As before, a backwards-stepping procedure, removing higher-order slopes first, was used to determine the maximal random effects structure that would converge.

In addition to the fixed effects reported in the main analysis, this analysis revealed a marginal effect of grid switch condition, due to lower target advantage scores following a reversal of perspective, regardless of which perspective (no Perspective-taking or Perspective-taking) 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 ($t = -1.20$, $p = .24$). However, in the second time window, it is significant ($t = -2.34$, $p < .05$).

Analysis with individual differences. The individual differences measures were analyzed separately because 9 subjects (3 bilingual) 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 differences measures with the corresponding maximal random effects structure failed to converge. A simpler random-intercept only model is presented in Appendix F. General intelligence predicted performance; participants who made fewer errors on the matrix task had a larger target preference. The effects of perspective condition and time were also significant. A similar model included the perspective switch factor and was fit using the same backwards-stepping procedure as before. Only perspective, time, and the interaction of the switch with time were significant (Appendix G). These analyses show that, in addition to there being no significant differences between monolinguals and bilinguals in the measures of executive function, there was no evidence that these constructs contributed to perspective-taking.

A remaining question is whether the overall bilingual *disadvantage* in the spatial task is 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. The bilingualism quotient was first regressed onto picture naming time (for which bilinguals are significantly slower), 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 still predicted reduced performance, $t(38) = -2.20$, $p < .05$. This result suggests that the bilingualism penalty in the spatial

Table 7
Effects of perspective, bilingualism, and grid switch on target advantage. Statistically significant effects are in bold.

Fixed effects	Estimate	Std. error	*t*-Value	*p*-Value
(Intercept)	0.679761	0.074223	9.158	
Perspective	**−0.666872**	**0.090851**	**−7.34**	**<.0001**
Time	**0.507235**	**0.05472**	**9.27**	**<.0001**
Bilingualism	**−0.183117**	**0.077218**	**−2.371**	**<.05**
Switch	−0.158649	0.083057	−1.91	.06
Perspective × Time	**0.170372**	**0.079855**	**2.134**	**<.05**
Perspective × Bilingualism	−0.056413	0.078199	−0.721	.47
Time × Bilingualism	−0.088063	0.059259	−1.486	.14
Perspective × Switch	0.153637	0.154828	0.992	.29
Time × Switch	**−0.164418**	**0.07508**	**−2.19**	**<.05**
Bilingualism × Switch	0.065989	0.066146	0.998	.30
Perspective × Time × Bilingualism	−0.046985	0.082684	−0.568	.58
Perspective × Time × Switch	0.096198	0.145778	0.66	.51
Perspective × Bilingualism × Switch	0.078355	0.113327	0.691	.49
Time × Bilingualism × Switch	−0.009222	0.076741	−0.12	.93
Perspective × Time × Bilingualism × Switch	0.140312	0.14795	0.948	.34
Random effects		Variance	Std. dev.	
Item	(Intercept)	0.106958	0.32704	
	Time	0.024219	0.15562	
	Bilingualism	0.030186	0.17374	
Subject	(Intercept)	0.170204	0.41256	
	Perspective	0.115712	0.34016	
	Time	0.073204	0.27056	
	Switch	0.060376	0.24572	
	Perspective × time	0.062907	0.25081	
	Perspective × switch	0.093112	0.30514	
	Time × switch	0.032912	0.18142	
	Perspective × time × switch	0.078154	0.27956	
Residual	1.743158	1.32029		
Number of observations: 7312, Subjects: 41, Items: 96.				

perspective-taking task is not exclusively due to differences in verbal fluency (as measured by the picture naming task).

Discussion

Spatial Perspective-taking

The present experiment created situations in which participants were tasked with appreciating the spatial perspective of another person in order to interpret that person's utterances. The results demonstrate that this process is challenging, particularly when perspectives are misaligned, and when switching between spatial perspectives. Despite the challenges, participants rapidly appreciated their partner's perspective, even in the perspective-taking condition. By contrast, we found no evidence that remembered visual perspective guided processing, possibly due to the memory demands required to do so. The perspective-switch penalty may be related to a switch cost previously observed in studies of Stroop-like interference tasks (e.g., Gratton et al., 1992; Warren, 1974). 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 no Perspective-taking → Perspective-taking vs. Perspective-taking → no Perspective-taking), suggesting that participants did not approach each grid by defaulting to the egocentric perspective (cf. Epley, Keysar, Van Boven, & Gilovich, 2004). Instead, the results suggest that once a perspective is adopted (allocentric or egocentric), the perspective representation is enduring—even in cases where it means preferring the partner's perspective over one's own perspective.

Bilingualism

Bilinguals and monolinguals incurred the same switch costs, contrary to previous results with simpler task-switching paradigms (Garbin et al., 2010; Prior & MacWhinney, 2010). In addition, 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 (Costa et al., 2008), though the comparatively smaller sample sizes in the present work may have not provided sufficient statistical power to detect these effects.

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, during interpretation of linguistic ambiguities, bilinguals interpreted spatial instructions significantly more slowly than monolinguals. Clearly, verbal fluency may be relevant to understanding these group differences. However, reaction times in the picture-naming test (on which bilinguals were slower) did not significantly predict the magnitude of the bilingualism deficit in the perspective-taking task, and the bilingualism deficit was still apparent 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.

Experiment 3

The results of Experiments 1–2 did not provide support for the hypothesis that bilinguals are better at spatial perspective-taking. However, a remaining possibility is that bilingualism does improve perspective-taking in conversation, but not for the special case of spatial perspective. Indeed, it may be the case that the repeated viewpoint transformations required of the spatial perspective-taking task are so challenging as to obscure any benefits obtained from bilingualism. In order to address this possibility, Experiment 3 uses a different paradigm to compare the perspective-taking skills of monolingual and bilingual participants, in order to provide another opportunity to observe the bilingualism-perspective-taking link, if one exists. In particular, we use a design modeled after Brown-Schmidt et al. (2008) in which perspective-representations are established on the basis of physical (i.e., we can both see *x*) and linguistic co-presence (i.e., we have jointly discussed *x*). In addition, questionnaires evaluate the degree to which the participants exhibited individualistic versus collectivist values, and are motivated by recent claims that cross-cultural differences in collectivism, rather than bilingualism, affect perspective-taking (Wu & Keysar, 2007).

Methods

Participants

Participants were 22 English-speaking monolinguals and 19 bilinguals who spoke English and at least one other language fluently. As in Experiments 1–2, the second languages (11 total) were heterogeneous. All participants were undergraduates at Reed College in Portland, Oregon between the ages of 18 and 25. Participants were compensated with two Psychology department lottery tickets for a chance to win up to $150. In addition to the 41 undergraduate participants, we collected data from 7 older participants (age range 30–60 years). However, the data from these older participants were not included in the final analysis because we did not have enough older adults to compare their performance with the young adults. Finally, the data from 7 additional participants were not analyzed due to failure to complete the task ($n = 2$) or equipment problems ($n = 5$).

Participants completed the same language background questionnaire as in Experiments 1–2 (Table 8). Monolinguals and bilinguals did not differ in age or SES, as measured by the average of the parental education levels. Though bilinguals differed in which language they learned first (English or another language), they all became bilingual before puberty. Some monolinguals had limited experience with a second language; this occurred primarily after puberty. Both monolinguals and bilinguals spent the majority of their daily life speaking English. However, bilinguals spent more time speaking their non-English language compared to monolinguals. All participants rated their English speaking ability as Native/Near-Native. Bilinguals also rated their second language ability as Native/Near-Native, while monolinguals rated it as Intermediate, on average.

A bilingualism quotient was calculated in the same way as in Experiments 1 and 2; again, higher scores indicate a greater degree of bilingualism. As before, we calculated a median split based on the bilingualism quotient. One self-reported bilingual participant was re-categorized as monolingual based on the median split.

Materials and procedure

Perspective-taking task. The perspective-taking task was identical to one used by Brown-Schmidt et al. (2008; Experiment 2). In a series of trials, the participant and experimenter each sat at a computer in adjacent rooms and communicated via a walkie-talkie-like intercom system. On each trial, the participant and experimenter viewed a 3 × 3 grid of animals (Fig. 10). Animals were horses, cows, and pigs, and each wore an accessory (shoes, glasses, or a hat). Accessories were designed to promote post-nominal modification (e.g., *the cow wearing the hat*). The participant's eye-movements were monitored using a desktop ISCAN eye-tracker at 60hz. The eye movement data were saved as a video file with the image of the scene and the eye-fixation position superimposed. Voices of both experimenter and participant were recorded during the task, and were saved, along with the eye-fixation position, to digital tape using a Sony DSR-30.

On each trial, the participant collaborated with the experimenter to determine whether the arrangement of the animals was in accordance with the rules, which were explained as follows: "Two animals of the same type cannot be next to each other; and two animals wearing the same accessory cannot be next to each other". Participants were informed that information-sharing was necessary to accomplish this task because neither the participant nor the experimenter could see all the squares. In particular, in each trial, 3 of the squares were in common ground, visible to both the experimenter and the participant (shown on a white background), 3 were in the participant's privileged ground, visible only to the participant (shown on a gray background), and 3 were in the experimenter's privileged ground, visible only to the experimenter (shown as black squares).

Each participant completed 36 trials. Twenty-four were critical trials on which the experimenter produced a scripted question which formed the conditions of interest. Critical questions were of the form, *What's above/below the (animal) that's wearing (accessory)?*, and were carefully designed to be temporarily ambiguous between two different animals on the screen. The critical manipulation was whether perspective information could be used to resolve the ambiguity earlier in time.

Experimenter script:

(1) **Late POD**: *There's a pig that's wearing shoes in the middle. <u>What's below the horse that's wearing the hat?</u>*
(2) **Early-linguistic**: *What's in your bottom left corner? (participant: A cow with shoes.) <u>What's below the horse that's wearing the hat?</u>*
(3) **Early-visual** [Note, in this condition the cow with shoes would have a white background, and would be seen by both participant and experimenter]: *What's in the top middle? (participant: A cow with glasses.) <u>What's below the horse that's wearing the hat?</u>*

Of the 24 critical trials, half had a late point-of-disambiguation (POD), such that the animal referenced in the question was not identified until the accessory term (e.g., *hat*). For example, given Fig. 10a, if the experimenter asked "*What's below the horse that's wearing the hat?*" (example 1), there are two horses in the scene, each of which has an animal below it that the experimenter cannot see, and the post-nominal accessory term is required to resolve the ambiguity. The other half of critical trials could be disambiguated earlier than the accessory, <u>if</u> the participant were to take into consideration which of the animals the experimenter already knew about. Of the 12 early-disambiguation trials, 6 were designed such that the competitor animal (e.g., the cow wearing shoes that is below the horse wearing glasses) was in linguistic common ground. This was accomplished by having the experimenter ask about that animal before the critical question (example 2). The other 6 early-disambiguation trials were designed such that the competitor animal was in visual common ground (e.g., the cow wearing shoes that is below the horse wearing glasses was in a white background, and visible to both participant and experimenter).

The remaining conversation was unscripted. The experimenter and participant worked together to find errors

Table 8
Average and standard deviation of participant language characteristics, plus 95% confidence intervals of the difference between bilingual and monolinguals means (*N* is specified when different from the overall group *N* due to subgroup analysis or missing values).

	Bilinguals (*N* = 19)		Monolinguals (*N* = 22)		95% Conf. interval of the diff.
	M	*SD* (*N*)	*M*	*SD* (*N*)	
Age	20.11	1.41	20.86	1.93	[−1.82 to 0.30]
Percent weekly use of English	83.53	10.46	97.39	3.77	[−0.19 to −0.09]
Age of first exposure to second language (collapsed across language)	4.68	4.71	11.00	3.81 (16)	[−9.25 to −3.38]
L1-English: Age of first exposure to non-English second language (in years)	0.57	1.51 (7)	11.00	3.81 (16)	[−13.03 to −8.23]
L1-Other: Age of first exposure to English as a second language (in years)	7.08	4.25 (12)	NA	NA	NA
Percent weekly use of non-English second language	13.8	9.77	2.15	3.48 (20)	[6.72–16.55]
Self-rated speaking ability in English (0-beginner to 3 near-native)	2.67	0.49 (18)	3	0	[−0.57 to −0.09]
Self-rated speaking ability in non-English second language (0-beginner to 3-near-native)	2.95	0.23	1.05	0.90	[1.49–2.31]
Parental education (0-some HS to 3-graduate school)	2.16	0.97	2.55	0.72	[−0.94 to 0.16]

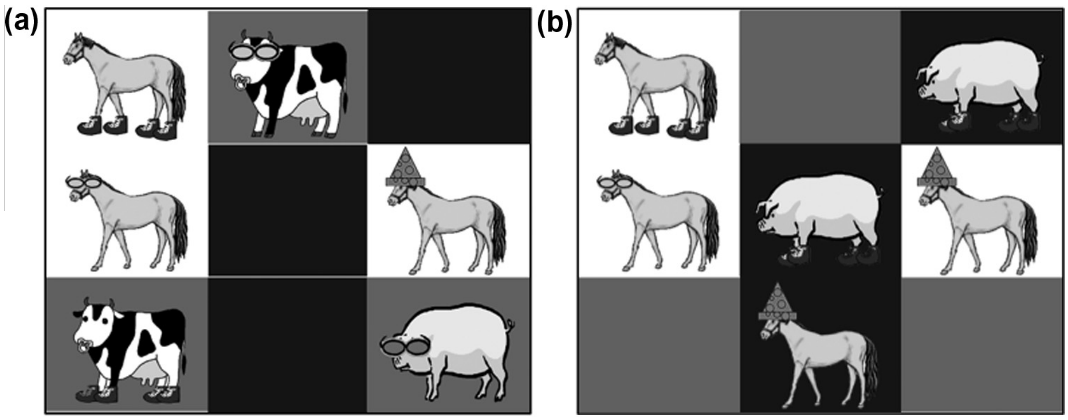

Fig. 10. (a and b) Example display for Experiment 3 from the Participant's (a) and Experimenter's (b) perspective.

(i.e., adjacent animals that matched in species or accessory). After an error was identified, they moved to the next trial. Critical trials never contained errors. Filler trials were similar to critical trials, except 8/12 had an error, and the experimenter did not produce a scripted utterance. The 24 critical trials were rotated through the conditions across 4 lists. Critical and filler trials were presented together in one of two random orders, resulting in 8 total lists. Each participant completed a single list.

Individual differences measures. Following the communication task, participants completed a version of the Stroop task to obtain a measure of inhibitory control. They then completed a Values questionnaire. Participants rated twenty concepts such as "Social Justice (care for weak)" on a scale from 1 to 7 (1 = not important, 7 = very important); see Appendix H for complete list. Idiocentrism scores were calculated for each participant based on previous ratings in Triandis, McCusker, and Hui (1990). In the last phase, the Twenty Statements Test, each participant answered the question, "*Who am I?*" twenty times (Kuhn & McPartland, 1954) and responses were categorized using the system described in Kanagawa, Cross, and Markus (2001). The percentage of relational responses out of twenty was used as a measure of whether self-concept was idiocentric or allocentric.

Monolinguals and bilinguals did not differ significantly on Stroop performance or the value ratings (Appendix I). However, bilinguals did have a higher rate of relational responses in the twenty statements test, Welch's $t(34) = 2.29$, $p < .05$.

Predictions

Perspective-taking

If linguistic common ground and immediately available cues to visual common ground guide perspective-taking, we would expect larger target advantage scores in the early-disambiguation conditions. If so, this would replicate Brown-Schmidt et al. (2008) with a new participant group.

Bilingualism and individual differences

If bilinguals exhibit better inhibitory control, we would expect bilinguals to show a reduced cost in the Stroop task, replicating previous findings (Bialystok et al., 2008), but inconsistent with our own results (Experiment 1). If the bilingual advantage in young children's perspective-taking extends to adulthood, we would predict a larger magnitude perspective-effect in the bilingual participants (Goetz, 2003; Greenberg et al., 2013; Kovács, 2009). Finally, if individual differences in allocentrism and collectivity modulate perspective-taking (Wu & Keysar, 2007), we would expect the magnitude of the perspective-taking effect to be predicted by the values questionnaire and twenty-statements test.

Results

Coders who were blind to condition identified the onset of the critical question in the video-tape, and hand-coded eye fixations during interpretation of the critical question. Fixations to the target were defined as fixations to either the animal explicitly mentioned in the question (in the example above, the horse wearing the hat) or the animal being asked about (the pig wearing glasses). Fixations to the competitor were defined as fixations to the animal that was temporarily ambiguous with the animal that was explicitly mentioned in the question (the horse wearing glasses), or the animal above/below it (the cow wearing shoes). Fixations to all other animals were categorized as "other" fixations. Fig. 11a and b plot the time-course of fixations.

Eye movement data were analyzed in four time-regions, aligned on a trial-by-trial basis with the onsets of the words in the critical question, e.g., *What's below the horse that's wearing the hat?*. The regions were offset by 200 milliseconds due to the time needed to program and launch an eye movement (Hallett, 1986). The Baseline region was used to examine viewing preferences before the critical question and was from −200 ms to 200 ms following the onset of "*What*" (400 ms total). The first critical region examined interpretation of the initial part of the question, and was from 200 ms following the onset of "*What*" until 200 ms following the onset of the animal name, e.g., "*horse*" (on average, 832 ms). The second critical region examined interpretation of the critical noun and was from 200 ms following the animal name until 200 ms following the accessory term, e.g., "*hat*" (on average, 1015 ms).

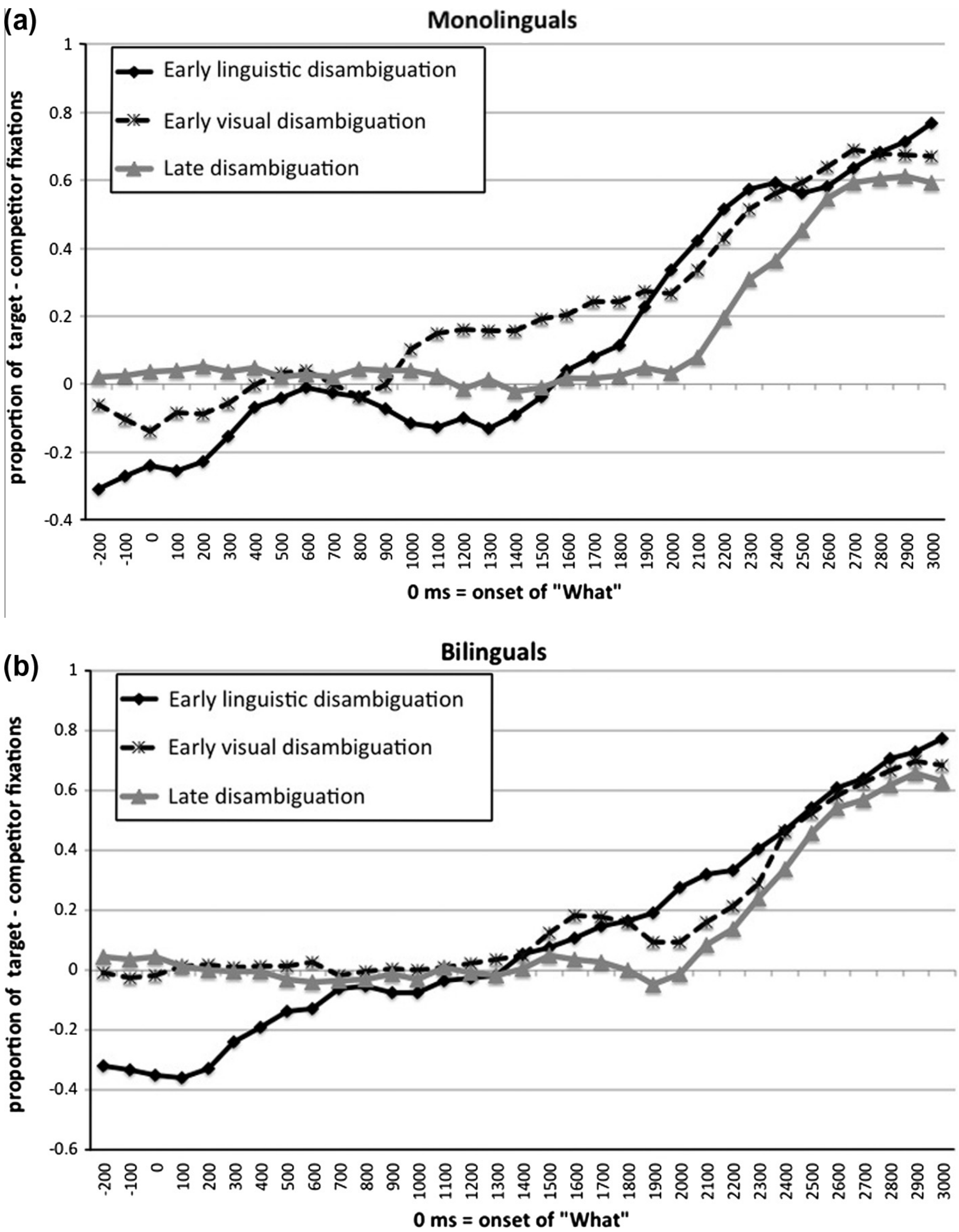

Fig. 11. (a and b) Experiment 3. Proportion of target minus competitor fixations following the onset of the WH-term for Monolinguals and Bilinguals. Vertical bars mark average onset of animal name (e.g., *horse*), and the disambiguating accessory term (e.g., *hat*).

Finally, the late region captured interpretation of the disambiguating accessory term, and ran from 200 ms to 1000 ms following the accessory term (800 ms total).

The analysis was conducted in the same way as Experiment 2, fitting a mixed-effects model to the ratio of the log of target vs. competitor fixations (Table 9). Fixed effects included condition, time-region, and each participant's bilingualism quotient. Condition was coded using two mean-centered deviation codes. The first coded whether the question *could* have been disambiguated early if common ground were taken into account (Early vs. Late POD = point of disambiguation); the second contrast coded whether that disambiguating information was visual or linguistic. The bilingualism quotients were mean-centered. Time-region was coded as a continuous variable centered at baseline.

The effect of Early vs. Late POD ($t = -4.948$) was driven by an initial *competitor* preference in the Early linguistic condition at baseline (Fig. 12a and b). Similarly, the effect of Visual vs. Linguistic POD ($t = -4.571$) is due to a baseline competitor preference in the Early linguistic condition. This pattern is expected because participants had just answered a question about the competitor in the Early Linguistic condition. The Early–Late effect interacted with time ($t = 7.397$), due to a reversal in the pattern at the final two time windows, where the target preference was larger for the Early disambiguation conditions compared to the Late disambiguation conditions. An interaction of the Visual-Linguistic effect with time ($t = 3.885$) was due to a flip in the means for the Visual and Linguistic conditions such that by the final time-region, the target preference was larger for the Early linguistic condition. These effects

Table 9
Experiment 3: Effects of time-region, bilingualism, and condition on target preference. Statistically significant effects are in bold.

Fixed effects	Estimate	*SE*	*t*-Value	*p*-Value
(Intercept)	−0.579	0.080	−7.213	
Bilingualism quotient	0.015	0.084	0.175	.89
Early vs. Late POD	**−0.698**	**0.141**	**−4.948**	**<.0001**
Visual vs. Linguistic	**0.977**	**0.214**	**−4.571**	**<.0001**
Time region	**0.681**	**0.035**	**19.47**	**<.0001**
Bilingualism × Early vs. Late	−0.168	0.162	−1.032	.29
Bilingualism × Visual vs. Linguistic	0.423	0.246	−1.718	.08
Bilingualism × Time	0.000	0.040	−0.007	.91
Early vs. Late × Time	**0.479**	**0.065**	**7.397**	**<.0001**
Visual vs. Linguistic × Time	**−0.357**	**0.092**	**3.885**	**<.001**
Bilingualism × Early vs. Late × Time	0.042	0.075	0.559	.56
Bilingualism × Visual vs. Linguistic × Time	−0.193	0.106	1.822	.07
Random effects		Variance	*SD*	
Subject	(Intercept)	0.067	0.259	
	Early vs. Late POD	0.205	0.453	
	Visual vs. Linguistic	0.634	0.796	
	Time region	0.006	0.080	
Item	(Intercept)	0.010	0.099	
	Time region	0.000	0.012	
Residual		4.783	2.187	
Number of observations: 3648, Subjects: 41, Items: 9.				

indicate that despite an early competitor preference in the Early linguistic condition, listeners were able to use information about the common ground status of a potential competitor to resolve the referential ambiguity.

Separate planned comparisons at each time region examined the emergence of the condition effects over time (Appendix J). Following the early competitor preference in the Early linguistic condition at baseline, there was no effect of common ground (Early–Late) at the WH-region, $t = -1.29$, $p = .18$, though a competitor preference was still apparent in the Linguistic condition (Visual-Linguistic, $t = -1.93$, $p = .03$). During interpretation of the animal region (e.g., *horse that's wearing*), target advantage scores were – for the first time – significantly higher for the conditions in which common ground supported early resolution of the ambiguity ($t = 2.47$, $p < .05$). Also at this time-region, the competitor preference was still apparent in the Linguistic condition ($t = -2.076$, $p < .05$). The larger target advantage for the Early disambiguation conditions persisted in the final analysis region which captured the interpretation of the disambiguating accessory term (e.g., *hat*; $t = 4.42$, $p < .001$).

At no point was there evidence for a bilingual advantage in perspective-taking. If anything, the means indicated that participants with larger bilingualism quotients showed a lower ability to use early disambiguating information provided by common ground. Lastly, a model that included the interaction of Condition, Time-region and the individual differences measures (Appendix K) indicated that none of these measures (Stroop interference, values ratings and Age) significantly predicted the magnitude of the perspective-taking effect.

Discussion

The results of Experiment 3 showed that participants used common ground to resolve a potentially ambiguous question, replicating previous findings (Brown-Schmidt et al., 2008). However, there was no evidence that bilingual participants were better at this ability; if anything bilinguals showed a numerically worse ability to use these sources of information. Allocentric thinking also did not lead to better performance on the perspective-taking task.

General discussion

Here we presented the results of three experiments examining the dynamics of visuospatial perspective-taking in conversation. In what follows, we discuss the insights that our work brings to the domain of perspective-taking, then discuss the implications of our findings for theories about the relationship between bilingualism and cognition.

Perspective-taking

The present experiments offer several novel insights into the mechanisms of perspective-taking. Experiment 1 revealed impairments in participants' ability to adjust to another person's spatial perspective when it was opposite of their own. This result is surprising considering that conversational partners often produce egocentric spatial expressions (Schober, 1993), thus adapting to egocentric spatial expressions is likely a common challenge. More generally, it underscores the cognitive difficulty of adapting to a conceptual scheme which is different from one's own experience of the world.

In Experiment 2, we probed—for the first time—the time-course of spatial perspective-taking in conversation. As soon as participants began to interpret a spatial term, they had more difficulty if their partner was speaking from the opposite spatial perspective. Of note is that despite struggling with the opposite spatial perspective, as soon as monolinguals heard the critical spatial term, they increasingly preferred the perspective-appropriate

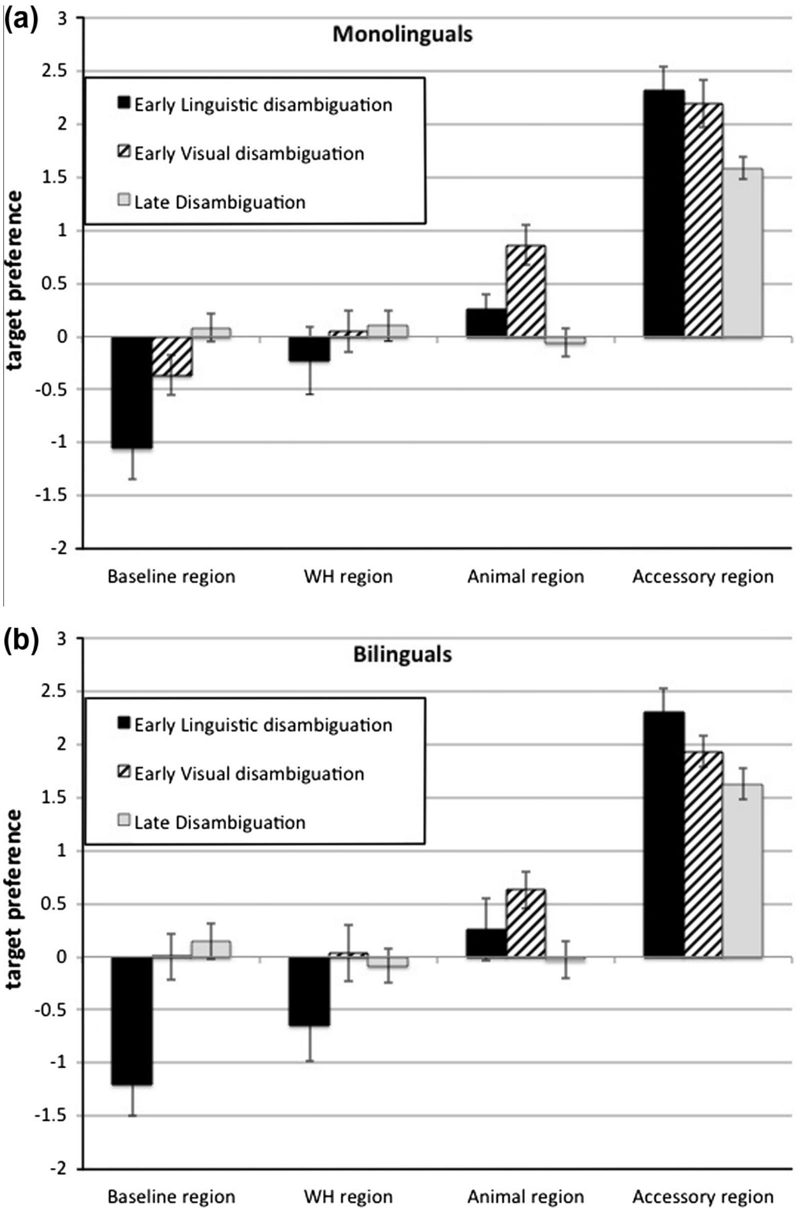

Fig. 12. (a and b) Mean target preference score (log ratio of target vs. competitor fixations), in four critical time-regions. Error bars indicate by-subjects *SEM*.

referent. This integration of perspective and language is inconsistent with the idea that perspective is not integrated with interpretation processes (e.g., Barr, 2008). Further, unlike bilingual participants, monolinguals never showed a bias to the egocentric competitor, inconsistent with egocentric-default theories of language processing (e.g., Keysar et al., 2003). While participants were adept at adjusting to the spatial perspective, we found no ability for participants to remember, from the initial trial to test, which of the animals on the board was visually hidden to their partner. This result points to limits on our ability to remember visually-presented perspective-differences in the absence of other supporting cues.

Experiment 3 directly replicated previous evidence of real-time integration of visuospatial line-of-sight perspective as well as linguistic perspective during the interpretation of questions (Brown-Schmidt et al., 2008). In addition, this experiment revealed that, while on one measure bilinguals reported a more relational self-concept, bilinguals were not better at perspective-taking. This result is in contrast to claims in the literature that cultural collectivism can lead to better perspective-taking (cf., Wu & Keysar, 2007).

Perspective switching

Experiment 2 found that switching between perspectives confers deficits. This switch-penalty was predicted on the basis of findings of a switch penalty in Stroop and flanker tasks (Durston et al., 2003; Gratton et al., 1992; Warren, 1974), as well as negative priming when alternating between frames of reference (Carlson-Radvansky & Jiang, 1998). The fact that the deficit occurred regardless of the current spatial perspective is important because it shows that listeners do not approach each event or utterance from an egocentric default (cf., Epley et al., 2004).

Instead, our findings suggest that listeners maintain representations of the most recent perspective, and adjust as needed.

Why do we fail to observe a relationship between executive function and perspective-taking?

A noteworthy point concerns the hypothesis that individual differences in working memory or inhibitory control modulate perspective-taking ability (Brown-Schmidt, 2009; Grodner et al., 2012; Lin et al., 2010; Wardlow, 2013). Across Experiments 1–3, only a single measure of executive function significantly predicted performance in the perspective-taking tasks: In Experiment 1, individuals who performed better on the Stroop task were faster to initiate a response, though this did not interact with the need to take perspective. The lack of a robust relationship between the measures of executive function and perspective-taking may speak to a lack of power to test for what are likely small effect sizes. If so, small effect sizes may explain other failures to replicate this link (Brown-Schmidt, 2012). A further consideration is that Experiments 1 and 2 rely on a different type of perspective-taking than the visual, occlusion-based perspective-taking that has previously been shown to rely on executive function (Brown-Schmidt, 2009). The former spatial perspective-taking requires a spatial viewpoint transformation, while the latter can be done by imagining the line of sight of the partner (Michelon & Zacks, 2006). Though it seems natural to extrapolate that spatial viewpoint transformation should also rely on executive function, this had not previously been empirically tested. To better evaluate the nature of the hypothesized link between executive function and perspective-taking—and whether it differs for different types of perspective-taking—may require higher powered designs with many participants or testing of participants pre-identified to be in the very high or very low executive function range (e.g., see Lin et al., 2010).

Bilingualism

In addition to furthering our understanding of how spatial perspectives can be used on-line during comprehension, our experiments do not offer strong support for the hypothesis that bilingualism enhances perspective-taking abilities in adults. 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 Experiment 1, we found an interaction between bilingualism and the perspective-taking effect, but not in the predicted direction. Bilinguals performed significantly worse than monolinguals in the easier condition that did not require perspective-taking, but equivalently to monolinguals in the harder, perspective-taking condition. Experiment 2 used more sensitive measures to provide a better test of the hypothesis that bilinguals have a perspective-taking advantage, but in fact we found a significant bilingual *disadvantage* in interpreting spatial perspective language (Experiment 2). We also find no evidence that bilinguals out-performed monolinguals in a visuo-linguistic perspective-taking task (Experiment 3). In addition, we failed to find a benefit for bilinguals in multiple domains of executive function. While our participant population and sample sizes were modeled after an experiment that *did* find a bilingual advantage in inhibition control (Bialystok et al., 2008), the magnitude of the bilingual benefit may be too small to consistently observe at sample sizes of about 40–60 participants. At the same time, these null effects are consistent with reports of a lack of a bilingual advantage in various measures of interference and response inhibition (Colzato et al., 2008; Kousaie & Phillips, 2012; Paap & Greenberg, 2013; Rosselli et al., 2002), as well as recent meta-analytic findings of an inconsistent bilingualism advantage on measures of conflict resolution (Hilchey & Klein, 2011). Age may also be in play, as peak performance in young adulthood may have masked underlying group differences in our measures (see Bialystok, Craik, & Luk, 2012). Our findings suggest that, even if a difference in basic cognitive functioning exists between bilinguals and monolinguals, it may not confer consistent benefits in higher-level cognition.

The fact that we did observe a significant bilingualism penalty on a measure of verbal fluency in Experiment 2 suggests that differences in language experience may be relevant to understanding the observed perspective-taking deficit in bilinguals. Bilinguals are known to have subtle impairments in the rapid retrieval, processing and production of language (see Sandoval et al., 2010). In the present research, competing activation of linguistic terms from the languages in the bilinguals' cognitive repertoire may result in slower language interpretation. 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.

To be sure, we found no evidence that verbal fluency predicted perspective-taking in Experiment 2, and the observed bilingual disadvantage was still apparent even when the verbal fluency measure was regressed out of the data. An open question, then, is whether other aspects of the different linguistic experiences and systems of the bilinguals and monolinguals may explain the performance differences.

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 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 or elite college, and a measure of SES in Experiments 1–3 revealed no differences between groups, suggesting SES is unlikely to blame for the bilingual disadvantage.

Conclusion

In conclusion, we report novel findings regarding the use of spatial perspective in language processing. Experiments 1 and 2 show that adopting the spatial perspective of a dialogue partner poses challenges, but listeners quickly adapt, allowing for the on-line interpretation of ambiguous spatial terms. A lack of continuity over time in adopted spatial perspective poses challenges (Experiment 2), suggesting that once adopted, representations of spatial perspective may be enduring. While listeners readily use recently mentioned linguistic cues and immediately available visual cues to physical perspective (Experiment 3), when visual cues to perspective must be remembered over time, perspective-taking can fail (Experiment 2). These findings point to a complex interplay of memory and attentional processes in the development, maintenance, and use of perspective-information in language processing and emphasizes the need to better understand the role of memory processes in perspective-taking (see Horton & Gerrig, 2005). Finally, bilingual participants exhibited deficits in processing perspective-laden language, suggesting that previous findings of a bilingual perspective-taking advantage in children may not extend to young adulthood. 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 by the fact that speaking multiple languages offers many practical advantages in life.

Acknowledgments

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Appendix A

	Monolingual (n = 32)		Bilingual (n = 32)		95% CI	Correlation with bilingualism
	M	*SD*	*M*	*SD*		
Perceptual speed	77.44	11.72	79.08	10.90	[−4.06 to 7.34]	r = .09, p = .50
Working memory	8.31	0.98	8.03	0.99	[−0.77 to 0.21]	r = −.11, p = .38
Inhibition (Stroop 1 – Interference score in seconds)	0.23	0.13	0.17	0.20	[−0.15 to 0.02]	r = −.11, p = .41
Inhibition (Stroop 2 – Number of correct trials)	48.61	8.39	46.59	6.72	[−5.86 to 1.82]	r = −.21, p = .09

Experiment 1. Descriptive statistics, 95% confidence intervals for difference of the means, and correlations between bilingualism quotient and individuals' scores.

Appendix B

Fixed effects	Estimate	Std. error	*z*-Value	*p*-Value
(Intercept)	−2.952	0.19683	−14.998	<.0001
Perspective condition	**1.56139**	**0.36113**	**4.324**	**<.0001**
Bilingualism	0.4635	0.21443	2.162	<.05
Perceptual speed	−0.03161	0.01711	−1.848	.06
Working memory	−0.10183	0.24016	−0.424	.67
Stroop 1	−1.35108	1.06704	−1.266	.21
Stroop 2	−0.03864	0.02682	−1.44	.15
Perspective × Bilingualism	−0.98158	0.42905	−2.288	<.05
Perspective × perceptual speed	0.01603	0.03415	0.469	.64
Perspective × WM	−0.08546	0.47808	−0.179	.86
Perspective × Stroop 1	1.19888	2.12982	0.563	.57
Perspective × Stroop 2	0.04605	0.05369	0.858	.39
Random effects		Variance	Std. dev.	
Subject	(Intercept)	1.2336757	1.11071	
Trial	(Intercept)	0.0627006	0.250401	
	Perspective	0.0110743	0.105235	
	Bilingualism	0.0021405	0.046266	
	Perspective × Bilingualism	0.0206671	0.14376	
Number of observations: 10333, Subjects, 64; Trials, 10.				

Experiment 1. Effects of perspective, language group, and individual difference measures on the errors. Alpha level (corrected for multiple comparisons of 5 interactions) = 0.05/5 = 0.01.
Statistically significant effects are in bold.

Appendix C

Fixed effects	Estimate	Std. error	*t*-Value	*p*-Value
(Intercept)	535.323	59.756	8.958	
Perspective	**519.1**	**108.243**	**4.796**	**<.0005**
Bilingualism	−44.367	62.232	−0.713	.99
Perceptual speed	6.412	5.026	1.276	.19
Working memory	−10.709	71.251	−0.15	.95
Stroop1	**928.926**	**334.139**	**2.78**	**<.005**
Stroop2	−1.609	7.854	−0.205	.95
Perspective × Bilingualism	−201.31	124.943	−1.611	.50
Perspective × Perceptual speed	−3.019	10.065	−0.3	1.0
Perspective × Working memory	−11.384	141.706	−0.08	1.0
Perspective × Stroop 1	−879.77	668.18	−1.317	.18
Perspective × Stroop 2	−28.56	15.752	−1.813	<.05
Random effects	Name	Variance	Std. dev.	
Subject	(Intercept)	9.78E+04	312.7337	
Item	(Intercept)	6.51E+03	80.6905	
	Perspective	8.33E+01	9.1289	
	Bilingualism	9.99E+01	9.9937	
	Perspective × Bilingualism	2.25E+03	47.4682	
Residual	1.47E+06	1214.2764		
Number of observations: 7562, Subjects, 52; Items, 10.				

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

Appendix D

	Group means and standard deviations		95% CI diff.	Correlation with bilingualism quotient
	Monolingual (n = 21) M (SD)	Bilingual (n = 20) M (SD)		
ANT orienting	43.06 (29.40)	45.06 (23.26)	[−20.20, 16.19]	r = .02, p = .89
ANT alerting	37.79 (49.19)	30.94 (58.43)	[−43.06, 29.37]	r = −.03, p = .86
ANT conflict resolution	136.06 (44.27)	180 (136.90)	[−28.86, 116.75]	r = .11, p = .55
Anti-saccade	86.6 (12.55)	84.05 (11.89)	[−10.38, 5.28]	r = .02, p = .90
Spatial WM (number correct)	14.48 (3.17)	14.75 (1.97)	[−1.39, 1.94]	r = .09, p = .59
Matrices (number of errors)	26.26(10.18)	22.55 (9.30)	[−10.06, 2.63]	r = −.21, p = .20
Picture Naming[a] – Word Onsets (ms)	1715.91 (268.25)	1866.55 (272.86)	[−27.61, 328.89]	r = .27, p = .10
Picture Naming[a] – Button presses (sec.)	**1.54 (0.37)**	**1.77 (0.29)**	**[0.013, 0.46]**[a]	**r = .37, p < .05**

Experiment 2. Group comparisons and correlations of individual difference measures. 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.
Statistically significant effects are in bold.

[a] When the picture-naming items were split by frequency, bilinguals (M = 1973.8) were found to be marginally slower (t = 1.90, p = .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 = .19). A regression analysis of picture-naming revealed word frequency predicted word onsets (t = −3.9, p < .0001) and key presses (t = −4.2, p < .0001) such that participants were faster to name higher frequency words. Language group predicted onsets (t = −1.9, p = .06) and presses (t = −2.4, p < .05) such that bilinguals were slower. The interaction of frequency and language group was marginal for both measures (t = 1.7, p < .1 for both); the bilingual disadvantage was more pronounced for low frequency items.

Appendix E

Fixed effects	Estimated parameter	Standard error	*z*-Value	*p*-Value
(Intercept)	5.99965	0.6735	8.908	<.0001
Perspective	**−1.587**	**0.47063**	**−3.372**	**<.0001**
Bilingualism	0.39326	0.75538	0.521	.60
Perspective × Bilingualism	−0.04214	0.48999	−0.086	.93
Random effects		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.				

Experiment 2. Effects of condition and group on accuracy during non-verbal perspective task.

Appendix F

Fixed effects	Estimate	Std. error	*t*-Value	*p*-Value
(Intercept)	6.62E−01	8.36E−02	7.926	
Perspective	**−6.30E−01**	**1.08E−01**	**−5.832**	**<.0001**
Time	**4.87E−01**	**6.36E−02**	**7.66**	**<.0001**
Bilingualism	**−1.59E−01**	**8.62E−02**	**−1.846**	**<.0001**
Competitor	5.99E−02	1.09E−01	0.551	.47
Orienting	−3.73E−03	3.07E−03	−1.214	.21
Alerting	−1.41E−03	1.76E−03	−0.802	.45
Conflict resolution	1.96E−04	6.84E−04	0.286	1.0
Antisaccade	5.71E−04	6.22E−03	0.092	1.0
Spatial WM	8.49E−04	2.60E−02	0.033	1.0
Picture naming[a]	−8.42E−02	8.38E−02	−1.004	.34
Matrix	2.13E−01	8.40E−02	2.531	<.01
Perspective × Time	−5.98E−03	9.48E−02	−0.063	<.05
Perspective × Bilingualism	−7.59E−02	6.99E−02	−1.086	1.0
Time × Bilingualism	−3.71E−01	2.16E−01	−1.719	.27
Perspective × Competitor	1.14E−01	1.03E−01	1.105	.08
Time × Competitor	8.43E−03	7.33E−02	0.115	.27
Bilingualism × Competitor	−3.92E−03	2.64E−03	−1.487	.91
Time × Orienting	4.40E−03	3.27E−03	1.345	.08
Perspective × Orienting	−1.36E−03	1.52E−03	−0.895	.15
Time × Alerting	4.49E−04	1.88E−03	0.239	.37
Perspective × Alerting	−8.92E−05	5.87E−04	−0.152	1.0
Time × Conflict resolution	5.16E−04	7.29E−04	0.708	1.0
Perspective × Conflict resolution	−2.53E−03	5.31E−03	−0.475	.62
Time × Antisaccade	7.17E−03	6.61E−03	1.085	.79
Perspective × Antisaccade	2.96E−04	2.22E−02	0.013	.28
Time × Spatial WM	−2.73E−02	2.77E−02	−0.988	1.0
Perspective × Spatial WM	−9.20E−02	7.24E−02	−1.27	.36
Time × Picture naming	−1.03E−01	8.98E−02	−1.152	.19
Perspective × Picture naming	−1.60E−02	7.71E−03	−2.07	.26
Time × Matrix	−1.49E−01	2.07E−01	−0.721	<.05
Perspective × Matrix	−6.30E−02	1.42E−01	−0.443	.62
Perspective × Time × Bilingualism	2.00E−02	1.02E−01	0.196	.57
Perspective × Time × Competitor	6.94E−03	3.23E−03	2.146	.47
Perspective × Bilingualism × Competitor	−1.26E−03	1.90E−03	−0.661	.66
Time × Bilingualism × Competitor	5.46E−04	7.18E−04	0.76	.84

(*continued on next page*)

Appendix F (*continued*)

Fixed effects	Estimate	Std. error	*t*-Value	*p*-Value
Perspective × Time × Orienting	−1.78E−03	6.47E−03	−0.275	<.05
Perspective × Time × Alerting	−2.05E−02	2.70E−02	−0.76	.51
Perspective × Time × Conflict resolution	−4.70E−02	9.02E−02	−0.521	.45
Perspective × Time × Antisaccade	−1.48E−02	9.39E−03	−1.574	.78
Perspective × Time × Spatial WM	−5.55E−02	2.04E−01	−0.272	.45
Perspective × Time × Picture naming	6.62E−01	8.36E−02	7.926	.60
Perspective × Time × Matrix	4.87E−01	6.36E−02	7.66	.12
Perspective × Time × Bilingualism × Competitor	−1.59E−01	8.62E−02	−1.846	.78
Random effects		Variance	Std. dev.	
Item	(Intercept)	0.123524	0.35146	
	Time	0.020525	0.14326	
	Bilingualism	0.032368	0.17991	
	Time × Bilingualism	0.154436	0.39298	
Subject	(Intercept)	0.127225	0.35669	
	Perspective	0.068554	0.26183	
	Time	0.010207	0.10103	
	Competitor	0.123524	0.35146	
Residual	1.80723	1.34438		
Number of observations: 6032, Subjects: 32, Items: 100.				

Experiment 2. Effects of language group, perspective, time, competitor, and individual difference measures on target advantage scores. Alpha level (corrected for multiple comparisons of 10 interactions) = 0.05/9 = 0.006.

[a] Picture naming is an average of the two picture naming scores (onsets and key presses) because these are highly correlated (r = .75).

Appendix G

Fixed Effects	Estimate	Std. error	*t*-Value	*p*-Value
(Intercept)	6.78E−01	8.01E−02	8.467	
Perspective	−7.24E−01	1.02E−01	−7.076	**<.0001**
Time	5.03E−01	6.17E−02	8.144	**<.0001**
Bilingualism	−1.68E−01	8.44E−02	−1.988	<.05
Grid switch	−1.93E−01	8.85E−02	−2.179	<.05
Orienting	−3.01E−03	3.25E−03	−0.924	.40
Alerting	−1.72E−03	1.86E−03	−0.928	.37
Conflict resolution	−1.94E−04	7.25E−04	−0.268	1.0
Antisaccade	−3.28E−04	6.59E−03	−0.05	1.0
Spatial WM	8.33E−03	2.76E−02	0.302	1.0
Picture naming[a]	−5.69E−02	8.86E−02	−0.642	.67
Matrix	−1.86E−02	9.55E−03	−1.949	.07
Perspective × Time	1.89E−01	7.76E−02	2.437	<0.05
Perspective × Bilingualism	5.61E−03	9.32E−02	0.06	1.0
Time × Bilingualism	−7.66E−02	6.86E−02	−1.116	.25
Perspective × Grid switch	1.82E−01	1.55E−01	1.176	.24
Time × Grid switch	**−2.22E−01**	**7.58E−02**	**−2.923**	**<0.005**
Bilingualism × Grid switch	6.59E−02	6.93E−02	0.951	.34
Time × Orienting	−2.94E−03	2.68E−03	−1.097	.27
Perspective × Orienting	4.77E−03	3.38E−03	1.414	.14
Time × Alerting	−1.28E−03	1.55E−03	−0.83	.41
Perspective × Alerting	−2.26E−05	1.94E−03	−0.012	1.0
Time × Conflict resolution	−2.98E−04	5.97E−04	−0.499	.82
Perspective × Conflict resolution	3.24E−04	7.52E−04	0.431	1.0
Time × Antisaccade	−3.22E−03	5.40E−03	−0.597	.69

Appendix G (*continued*)

Fixed Effects	Estimate	Std. error	*t*-Value	*p*-Value
Perspective × Antisaccade	4.73E−03	6.82E−03	0.693	.57
Time × Spatial WM	4.99E−03	2.26E−02	0.221	1.0
Perspective × Spatial WM	−8.39E−03	2.85E−02	−0.294	1.0
Time × Picture naming	−9.32E−02	7.35E−02	−1.268	.24
Perspective × Picture naming	−9.78E−02	9.25E−02	−1.058	.34
Time × Matrix	−1.90E−02	7.84E−03	−2.424	<.05
Perspective × Matrix	6.21E−03	9.89E−03	0.628	.79
Perspective × Time × Bilingualism	−3.15E−02	8.30E−02	−0.38	.70
Perspective × Time × Grid switch	4.95E−02	1.52E−01	0.326	.75
Perspective × Bilingualism × Grid switch	6.49E−02	1.05E−01	0.621	.54
Time × Bilingualism × Grid switch	1.36E−02	7.57E−02	0.18	.82
Perspective × Time × Orienting	6.38E−03	3.28E−03	1.945	.05
Perspective × Time × Alerting	−1.93E−03	1.93E−03	−1.002	.31
Perspective × Time × Conflict resolution	5.85E−04	7.31E−04	0.8	.42
Perspective × Time × Antisaccade	−3.36E−03	6.56E−03	−0.513	.60
Perspective × Time × Spatial WM	−1.07E−02	2.74E−02	−0.39	.69
Perspective × Time × Picture naming	−5.82E−02	9.13E−02	−0.637	.52
Perspective × Time × Matrix	2.11E−01	1.52E−01	1.389	.18
Perspective × Time × Bilingualism × Grid switch	6.78E−01	8.01E−02	8.467	.16
Random effects		Variance	Std. dev.	
Item	(Intercept)	0.113892	0.33748	
	Time	0.017301	0.13153	
	Bilingualism	0.031026	0.17614	
Subject	(Intercept)	0.14605	0.38216	
	Perspective	0.130482	0.36122	
	Time	0.068936	0.26256	
	Grid switch	0.057431	0.23965	
Residual	1.794639	1.33964		
Number of observations: 5800, Items, 96; Subjects, 32				

Experiment 2. Effects of perspective, language group, time, switch and individual differences on target advantage. Alpha level (corrected for multiple comparisons of 10 interactions) = 0.05/9 = 0.006.

[a] Picture naming is an average of the two picture naming scores (onsets and key presses) because these are highly correlated ($r = .75$).

Appendix H

Values Questionnaire (Experiment 3)

Each participant was asked to rate the following values in terms of the importance to themselves on a scale of 1–7:

1. EQUALITY (equal opportunity for all)
2. SENSE OF BELONGING (others care about)
3. FAMILY SECURITY (safety of loved ones)
4. TRUE FRIENDSHIP (close friends)
5. SOCIAL JUSTICE (care for weak)
6. INDEPENDENT (self-reliant)
7. LOYAL (faithful to friends)
8. DARING (seeking adventure)
9. HONORING PARENTS AND ELDERS
10. CHOOSING OWN GOALS
11. ACCEPTING MY POSITION IN LIFE
12. AN EXCITING LIFE (stimulating)
13. ENJOYING LIFE
14. FREEDOM (freedom of action and thought)
15. HUMBLE
16. PRESERVING PUBLIC IMAGE
17. PROTECTING THE ENVIRONMENT

18. SELF-DISCIPLINE (resist temptation)
19. UNITY WITH NATURE
20. WORLD OF BEAUTY (nature, arts)

Appendix I

	Monolingual ($n = 20$)	Bilingual ($n = 19$)	95% CI diff.	Correlation w/ bilingualism quotient
Stroop effect[a]	$M = 151.39$ ($SD = 246.27$)	$M = 119.80$ ($SD = 159.93$)	[−162.64 to 99.46]	$r = -.048$, $p = .77$
Idiocentrism	$M = .07$ ($SD = .92$)	$M = -.26$ ($SD = .90$)	[−.91 to .26]	$r = -.151$, $p = .35$
US vs. PRC	$M = 1.05$ ($SD = .64$)	$M = 1.35$ ($SD = .89$)	[−.20 to .80]	$r = .249$, $p = .12$
Twenty statements	**$M = 25\%$ ($SD = 16$)**	**$M = 38\%$ ($SD = 18$)**	**[1.4% to 24%]**	**$r = .376$, $p < .05$**

Experiment 3: Group comparisons of individual difference measures.
Statistically significant effects are in bold.
[a] The reliability of the Stroop task was high (even-odd $r = .94$).

Appendix J

Fixed effects	Estimate	*SE*	*t*-Value	*p*-Value
(Intercept)	−0.265	0.066	−4.003	
Bilingualism quotient	0.042	0.068	0.615	.54
Early vs. Late POD	**−0.771**	**0.133**	**−5.778**	**<.0001**
Visual vs. Linguistic	**−0.948**	**0.227**	**−4.176**	**<.0001**
Bilingualism × Early vs. Late	−0.138	0.154	−0.897	.36
Bilingualism × Visual vs. Linguistic	−0.469	0.262	−1.792	.07
Random effects		Variance	Std. dev.	
Subject	(Intercept)	0	0	
	Early vs. Late POD	0.151	0.388	
	Visual vs. Linguistic	0.940	0.969	
Item	(Intercept)	0.008	0.088	
Residual	3.187	1.785		
Number of observations: 912, Items, 9; Subjects, 41				

Experiment 3. Model results at the baseline time-region.

Fixed Effects	Estimate	*SE*	*t*-Value	*p*-Value
(Intercept)	−0.097	0.101	−0.962	
Bilingualism quotient	−0.051	0.117	−0.438	.67
Early vs. Late POD	−0.217	0.168	−1.29	.18
Visual vs. Linguistic	**−0.498**	**0.258**	**−1.93**	**<.05**
Bilingualism × Early vs. Late	−0.203	0.194	−1.046	.25
Bilingualism × Visual vs. Linguistic	−0.297	0.297	−0.999	.23
Random effects		Variance	Std. dev.	
Subject	(Intercept)	0.184	0.428	
	Early vs. Late POD	0.208	0.456	
	Visual vs. Linguistic	0.809	0.900	
Item	(Intercept)	0.000	0.000	
Residual	5.211	2.283		
Number of observations: 912, Items, 9; Subjects, 41				

Experiment 3. Model results at the WH time-region.

Fixed effects		Estimate	SE	t-Value	p-Value
(Intercept)		0.231	0.101	2.292	
Bilingualism quotient		0.039	0.116	0.334	.77
Early vs. Late POD		**0.554**	**0.224**	**2.473**	**<.05**
Visual vs. Linguistic		**−0.499**	**0.240**	**−2.076**	**<.05**
Bilingualism × Early vs. Late		−0.059	0.259	−0.227	.88
Bilingualism × Visual vs. Linguistic		0.189	0.277	0.684	.49
Random effects			Variance	Std. dev.	
Subject	(Intercept)		0.140	0.374	
	Early vs. Late POD		0.952	0.976	
	Visual vs. Linguistic		0.144	0.379	
Item	(Intercept)		0.000	0.000	
Residual	6.092		2.468		
Number of observations: 912, Items, 9; Subjects, 41					

Experiment 3. Model results at the Animal name time-region.

Fixed effects		Estimate	SE	t-Value	p-Value
(Intercept)		1.899	0.100	19.031	
Bilingualism quotient		0.007	0.104	0.065	1.0
Early vs. Late POD		**0.579**	**0.131**	**4.42**	**<.001**
Visual vs. Linguistic		0.238	0.186	1.278	.21
Bilingualism × Early vs. Late		−0.053	0.151	−0.351	.77
Bilingualism × Visual vs. Linguistic		0.020	0.214	0.091	.93
Random effects			Variance	Std. dev.	
Subject	(Intercept)		0.156	0.395	
Item	(Intercept)		0.016	0.128	
Residual	3.886		1.971		
Number of observations: 912, Items, 9; Subjects, 41					

Experiment 3. Model results at the Accessory name time-region.
Statistically significant effects are in bold.

Appendix K

Fixed effects	Estimate	SE	t-Value	p-Value
(Intercept)	−0.581	0.183	−3.181	
Bilingualism quotient	0.039	0.101	0.382	1.0
Early vs. Late POD	−0.573	0.330	−1.74	.09
Visual vs. Linguistic	−0.551	0.497	−1.109	.30
Time region	**0.740**	**0.081**	**9.172**	**<.0001**
Stroop Effect	0.000	0.000	−0.325	.047
Idiocentrism	0.063	0.097	0.648	.52
US-PRC	−0.031	0.117	−0.261	.67
TST-relational%	0.106	0.513	0.206	.74
Age	0.054	0.054	0.999	.70
Bilingualism × Early vs. Late	−0.146	0.186	−0.786	.42
Bilingualism × Visual vs. Linguistic	−0.402	0.280	−1.436	.13
Bilingualism × Time	−0.020	0.046	−0.44	1.0
Early vs. Late × Time	**0.645**	**0.149**	**4.33**	**<.0001**
Visual vs. Linguistic × Time	0.247	0.211	1.171	.24
Early vs. Late × Stroop	0.001	0.001	0.748	.60
Visual vs. Linguistic × Stroop	0.001	0.001	0.807	.57

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Appendix K (*continued*)

Fixed effects	Estimate	*SE*	*t*-Value	*p*-Value
Time × Stroop	0.000	0.000	−1.708	.07
Early vs. Late × Idiocentrism	−0.041	0.179	−0.231	.99
Visual vs. Linguistic × Idiocentrism	0.191	0.271	0.707	.51
Time × Idiocentrism	−0.009	0.044	−0.2	1.0
Early vs. Late × US-PRC	0.126	0.215	0.585	.50
Visual vs. Linguistic × US-PRC	0.278	0.325	0.857	.34
Time × US-PRC	0.053	0.053	1.013	.30
Early vs. Late × TST	−0.256	0.945	−0.271	.82
Visual vs. Linguistic × TST	−0.969	1.438	−0.674	.89
Time × TST	−0.196	0.230	−0.851	.41
Early vs. Late × Age	0.111	0.099	1.122	.40
Visual vs. Linguistic × Age	0.028	0.151	0.183	1.0
Time × Age	−0.051	0.024	−2.096	.03
Bilingualism × Early vs. Late × Time	0.070	0.084	0.838	.41
Bilingualism × Visual vs. Linguistic × Time	0.175	0.119	1.466	.15
Early vs. Late × Time × Stroop	−0.001	0.000	−1.578	.11
Visual vs. Linguistic × Time × Stroop	0.000	0.000	−0.167	.85
Early vs. Late × Time × Idiocentrism	−0.002	0.080	−0.024	.94
Visual vs. Linguistic × Time × Idiocentrism	−0.102	0.115	−0.89	.37
Early vs. Late × Time × US-PRC	−0.026	0.097	−0.269	.75
Visual vs. Linguistic × Time × US-PRC	−0.056	0.138	−0.406	.71
Early vs. Late × Time × TST	−0.547	0.426	−1.285	.20
Visual vs. Linguistic × Time × TST	0.187	0.609	0.307	.77
Early vs. Late × Time × Age	−0.035	0.045	−0.775	.48
Visual vs. Linguistic × Time × Age	−0.060	0.065	−0.924	.81
Random effects		Variance	Std. dev.	
Subject	(Intercept)	0.09777272	0.312686	
	Early vs. Late POD	0.23706758	0.486896	
	Visual vs. Linguistic	0.69043706	0.830925	
	Time	0.00738001	0.085907	
Item	(Intercept)	0.01139	0.106724	
	Time	0.00021526	0.014672	
Number of observations: 3456, Items, 9; Subjects, 41				

Experiment 3. Model results including individual differences measures. Alpha was adjusted to .01 due to the addition of five additional measures. Statistically significant effects are in bold.

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