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Short Communication

Individual differences in switching and inhibition predict perspective-taking across the lifespan

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ABSTRACT

Studies exploring the influence of executive functions (EF) on perspective-taking have focused on inhibition and working memory in young adults or clinical populations. Less consideration has been given to more complex capacities that also involve switching attention between perspectives, or to changes in EF and concomitant effects on perspective-taking across the lifespan. To address this, we assessed whether individual differences in inhibition and attentional switching in healthy adults (ages 17–84) predict performance on a task in which speakers identified targets for a listener with size-contrasting competitors in common or privileged ground. Modification differences across conditions decreased with age. Further, perspective taking interacted with EF measures: youngest adults' sensitivity to perspective was best captured by their inhibitory performance; oldest adults' sensitivity was best captured by switching performance. Perspective-taking likely involves multiple aspects of EF, as revealed by considering a wider range of EF tasks and individual capacities across the lifespan.

1. Introduction

During interactive discourse, we often rely on estimates about what is shared with an interlocutor (common ground) and what is not (privileged ground). Such estimates typically require *perspective-taking* to consider another's knowledge and how it may differ from one's own. The process by which people consider others' perspectives is essential to communication, yet questions remain regarding its underlying cognitive mechanisms, and about possible variation in individual perspective-taking abilities.

A central question in language research is the degree to which linguistic behaviors reflect language-specific or domain-general mechanisms. For perspective-taking, executive functions (EF) are theorized to play a role in inhibiting privileged information when considering common ground. Some studies show that differences in inhibitory control and working memory predict communicative perspective-taking performance (Brown-Schmidt, 2009; Lin, Keysar, & Epley, 2010; Wardlow, 2013), whereas others have failed to replicate these patterns (Brown-Schmidt & Fraundorf, 2015; Ryskin, Benjamin, Tullis, & Brown-Schmidt, 2015; Ryskin, Brown-Schmidt, Canseco-Gonzalez, Yiu, & Nguyen, 2014).

This disparity may reflect the participant populations: the aforementioned studies focused exclusively on college-aged students. Compared to children and elderly adults, whose cognitive control exhibit substantial variability, young adults as a group likely operate at peak cognitive capacity, potentially concealing any influence of individual differences (Brown-Schmidt & Fraundorf, 2015; Cepeda, Kramer, & Gonzalez de Sather, 2001; Comalli, Wapner, & Werner, 1962; Zelazo, Craik, & Booth, 2004). This performance advantage in early adulthood extends to interactive dialogue: younger adults use more succinct, contextually-relevant, partner-specific language, whereas older adults are often less effective in making adjustments for particular partners (Bortfeld, Leon, Bloom, Schober, & Brennan, 2001; Healey & Grossman, 2016; Horton & Spieler, 2007; Lysander & Horton, 2012).

In this context, it is reasonable to ask whether age-related communicative patterns are mediated by underlying differences in EF. In children, inhibitory control is negatively correlated with communicative egocentrism (Nilsen & Graham, 2009). At the other end of the lifespan, Wardlow, Ivanova, and Gollan (2014) observed that perspective-taking correlates more strongly with EF in Alzheimer's patients than in healthy age-matched controls. However, those EF measures were simplified for the patients, leading to ceiling-level performance in controls and possibly obscuring a relationship between perspective-taking and cognitive mechanisms in older adults. The current study addresses this by testing healthy adults of all ages.

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As noted above, EF capacities targeted in prior perspective-taking work have been primarily limited to inhibition and working memory. Equally important, however, may be the ability to efficiently switch attention between perspectives, mediated by mechanisms of attentional *shifting* (Miyake et al., 2000) involving a combination of both inhibition and release from inhibition/refocusing of attention. People restrict attention to perspective-relevant information less efficiently when switching from a previous perspective, as shown in comparisons of trials that require a perspective shift from a previous context with trials that do not (Bradford, Jentzsch, & Gomez, 2015; Ryskin, Wang, & Brown-Schmidt, 2016; Ryskin et al., 2014). This suggests a role for domain-general switching capacities in perspective-taking, alongside inhibition.

Here, we explore the simultaneous contributions of inhibition and switching to performance in a conversational perspective-taking task. Interestingly, these EF capacities are associated with two semi-independent (yet possibly concurrently engaged) modes of cognitive control. The first is a 'proactive' (Braver, 2012) or 'goal-shielding' (Goschke & Dreisbach, 2008) mode, which prioritizes the maintenance of internal goals, preventing interference from irrelevant information at the price of ignoring potentially significant contextual cues. The second is a 'reactive' or 'background monitoring' mode, which enhances the sensitivity to contextual cues at the expense of goal-maintenance. In conversation, speakers must balance the salience of their own perspectives against the need to attend to the interlocutor's. These pressures may require both the inhibition of salient-but-irrelevant information along with the readiness to refocus attention on appropriate contextual information. An individual's 'proactive' goal maintenance could be taken as the ability to consistently inhibit privileged context. In contrast, a 'reactive' mode allows for enhanced sensitivity to contextual cues, requiring modulation of inhibition when a speaker switches perspectives.

To measure these capacities, we used the Test of Everyday Attention (TEA) (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1994), a well-established clinical test with one subtest examining inhibition alone and another examining switching (jointly tapping into inhibition and release from inhibition) in a closely-related task. Recent work on bilingualism and language learning has used the TEA (Bak, Long, Vega-Mendoza, & Sorace, 2016; Bak, Vega-Mendoza, & Sorace, 2014; Vega-Mendoza, West, Sorace, & Bak, 2015). However, it has not been used in linguistic perspective-taking research. Thus, we hope to diversify approaches to analyzing EF capacities in communicative contexts.

Our perspective-taking study adapts a referential communication task from prior research (e.g., Wardlow, 2013; Wardlow et al., 2014) whereby a speaker identifies target objects presented in 4-object displays for a listener. On experimental trials, a size-contrasting competitor is also present. For common ground (CG) trials, both the target and competitor are mutually visible, while for privileged ground (PG) trials, the target is visible but the competitor is occluded from the listener's view. Successful perspective-taking is indexed by the relative frequency with which speakers include appropriate modification on CG trials but refrain from doing so on PG trials.

2. Method

2.1. Participants

Participants (N = 121) were recruited from Scottish educational institutions, including the University of Edinburgh Psychology Volunteer Panel, the University of Edinburgh Centre for Open Learning, and Sabhal Mòr Ostaig. Written informed consent was obtained. Prior to analysis, we removed data from 21 participants: 18 non-native speakers of English, 1 aphasiac, 1 with abnormally low TEA scores, and 1 due to technical malfunction. We report data from 100 native English-speaking participants aged 17–84.[1]

[1] Parental consent was obtained for the 17-year-old.

2.2. Materials/procedures

2.2.1. Test of everyday attention

The TEA measures aspects of attention based on Posner and Petersen's (1990) multi-system attentional model. By separating attention into theoretically distinct factors—*sustained attention*, *selective attention*, and *attentional switching*—the TEA offers a fine-grained method of assessing an individual's cognitive resources (McAnespie, 2001). Designed to monitor the effects of neurorehabilitation in clinical populations, it is sensitive enough to detect subtle attentional impairments and has been standardized through a normative sample of healthy adults aged 18–80 (Robertson, Ward, Ridgeway, & Nimmo-Smith, 1996).

Test instructions require participants to envision that they have entered an elevator on the ground floor. Because the floor indicator doesn't work, participants must count auditory tones to track the elevator's location. After each trial, a recorded voice asks which floor they ended up on. There are three subtests:

Elevator Task (sustained attention): Participants count tones of the same pitch presented at irregular intervals (7 trials). The task is not computationally difficult but participants must maintain attention. Healthy individuals are expected to perform near ceiling.

Elevator Task with Distraction (selective attention/inhibition): Participants count low tones and ignore interspersed high tones. Performing well requires that participants selectively attend to low tones only (10 trials).

Elevator Task with Reversal (attentional switching): Participants are presented with high, medium, and low tones, and must count only medium tones. High tones indicate the elevator is moving up (thus, subsequent medium tones increase the floor count) while low tones indicate the elevator is moving down (thus, subsequent medium tones decrease the floor count). Performing well requires keeping track of the count while shifting between counting up and down (10 trials).

Performance on each subtest is measured as the percentage of trials with correct responses (0–100).

2.2.2. Referential communication task

The referential communication task required participants to describe target objects in 4-object displays presented on an iPad that lay flat between the participant and the experimenter (see Fig. 1). In two practice trials, participants had to demonstrate the ability to use the iPad to control the task; all successfully did so. To start each trial, the experimenter closed her eyes while the participant tapped anywhere on the screen to reveal one object in a box that flashed red, indicating it was to be occluded. The participant placed a folded index card on the surface of the iPad to occlude this object from the experimenter's view. Then, the participant tapped the screen again to reveal 3 more objects in boxes. The target location flashed green for 1.5 s. The participant named the target for the experimenter, who opened her eyes and pointed to the object.

Critical trials involved size contrasts between the target and a competitor. On 16 CG trials, the competitor was mutually visible, requiring modification to disambiguate the target. On 16 PG trials, the competitor was occluded, thus no modification was necessary. For 24 filler trials, the target was always unique, although two other mutually visible locations often contained size-contrasting objects. Finally, for 7 privileged target fillers, the target was occluded; the experimenter would infer that it was occluded because the description failed to match any visible objects. This procedure, adopted from Wardlow Lane and Ferreira (2008), was intended to increase the salience of privileged objects on critical trials.

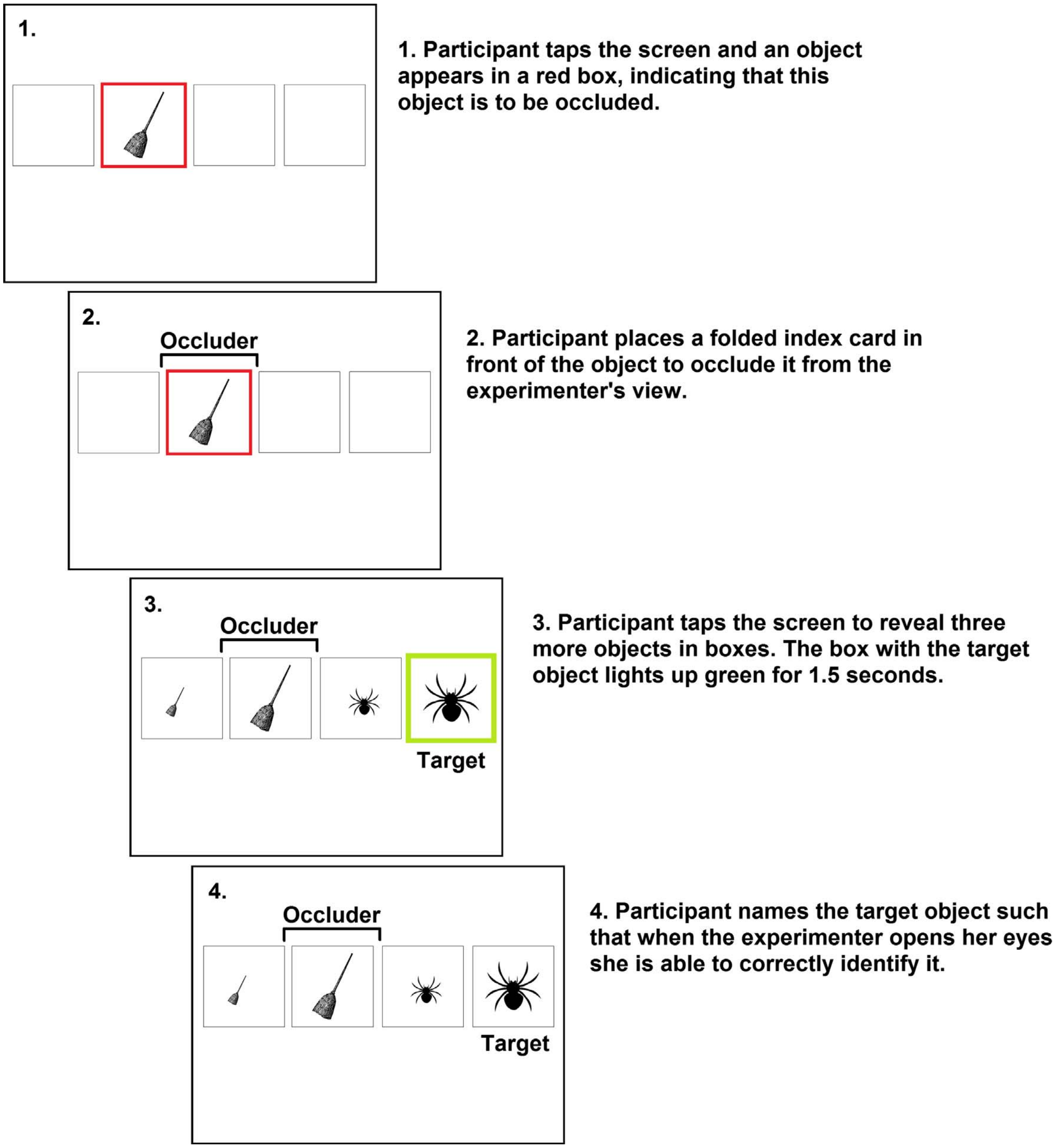

Fig. 1. Typical common ground trial, referential communication task.

Powerpoint on the iPad was used to present the displays and cues. Experimental and filler items were randomly slotted into the presentation order, with the restriction that no more than two trials of a given type could appear in succession. Each participant completed 65 trials (two practice). Participants were told that their task on each trial was to first hide the "red" object with the occluder then name the "green" object so the experimenter could point to it.

Participants' utterances were recorded and transcribed for analysis. We coded whether each target description on experimental trials reflected the presence of the size-contrasting competitor through modification of the head noun. We implemented this coding in two ways. A liberal coding ("Any Modification") counted the presence of *any* modifying information. For example, in the CG trial in Fig. 1, this includes prenominal modification (e.g., "big spider"), post-nominal modification (e.g., "spider that's big"), or repairs (e.g., "spider, the big spider"). A conservative coding ("Prenominal Modification") only counted prenominal modification as evidence that speakers distinguished the target from the competitor early in production (Brown-Schmidt & Tanenhaus, 2006).

3. Results

As expected, performance was at ceiling (M = 99%) on the TEA Elevator Task, so this will not be considered further.[2] An effect of participant age was found for the TEA switching subtest (linear regression: $\beta = -8.415$, $p < 0.05$) but not for the inhibition subtest ($\beta = -1.424$, $p = 0.44$). Following Brown-Schmidt and Fraundorf (2015), we also examined reliability in the communication task by computing split-half correlations between odd and even privileged ground trials. A strong correlation ($r = 0.95$)[3] provides confidence that this task tapped into a stable aspect of perspective-taking.

Using logistic mixed effects regression we modelled the binary

[2] Descriptive statistics for the TEA and perspective-taking tasks (for all participants, as well as for youngest and oldest subgroups separately) are reported in Supplementary material.

[3] High split-half reliability ($r \geq 0.9$), was found for both any- and prenominal modification measures in PG trials alone and for modification differences on CG versus PG trials, as well as when examining older and younger adults separately.

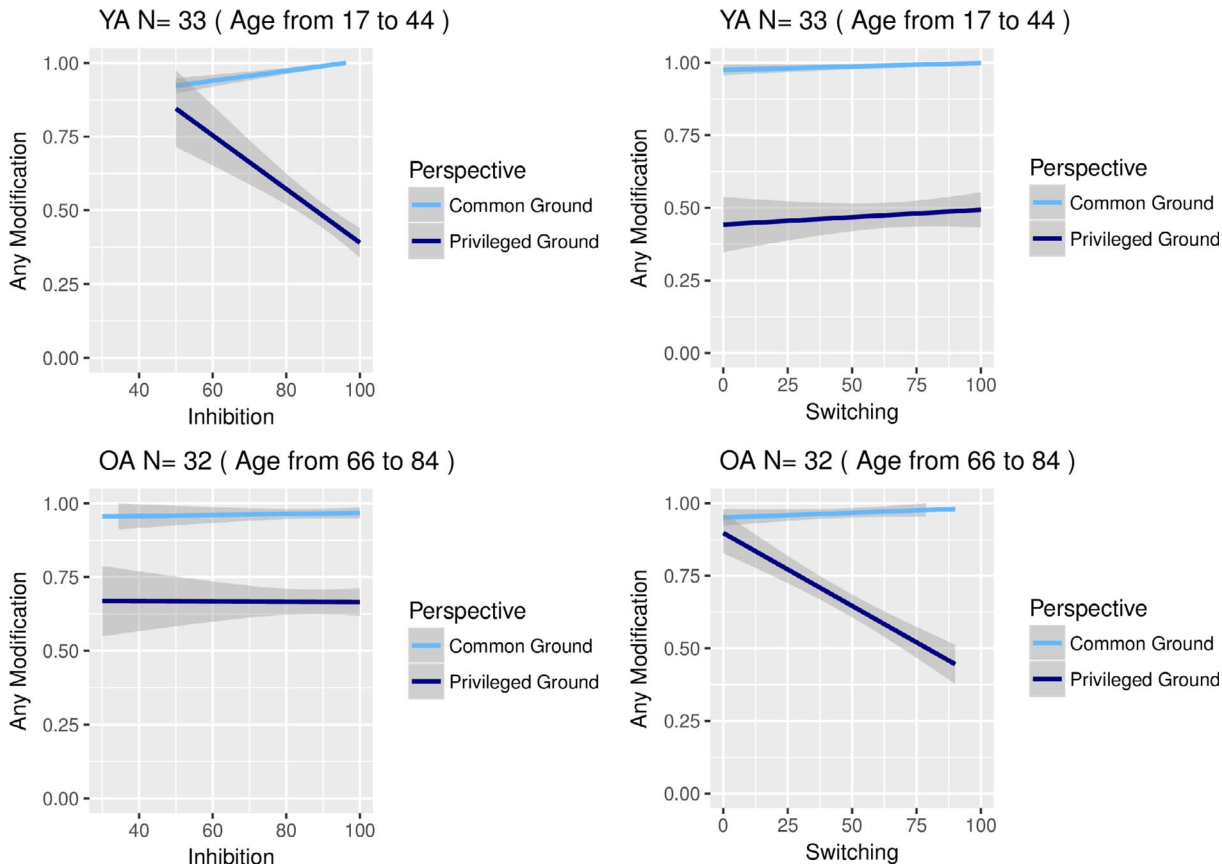

Fig. 2. Perspective-taking performance of tertile split Youngest Adults (YA) and Oldest Adults (OA) using *Any* Modification, by inhibition and switching EF performance. Notes: 95% confidence level intervals displayed in the plots.

outcome of presence/absence of modification with Perspective, Age, and scores for the inhibition and switching tasks as fixed effects, and both subjects and items as random effects. Deviation coding was used for Perspective (CG trial = −0.5, PG trial = 0.5), while participant age and inhibition and switching scores were entered as scaled continuous predictors. Our models also included participants' education level as an additional covariate. When possible, the model was fit with the maximal random effect structure for both subjects and items (Barr, Levy, Scheepers, & Tily, 2013).

3.1. Results of "Any Modification" coding

For the liberal "any" modification measure (any modification = 1; bare NP = 0), participants showed strong evidence of perspective-taking (significant effect of Perspective: $\beta = -4.715$, $SE = 0.721$, $p < 0.001$), with higher rates of modification on CG trials ($M = 0.98$, $SD = 0.14$) than PG trials ($M = 0.52$, $SD = 0.50$). However, differences in modification rates decreased with increasing participant age (Age × Perspective: $\beta = 1.944$, $SE = 0.605$, $p < 0.005$). Differences in modification rates across trial types increased with inhibition scores (Perspective × Inhibition: $\beta = -1.548$, $SE = 0.584$, $p < 0.01$). But this interaction with EF capacity varied by age, with significant three-way interactions for both EF measures (Age × Perspective × Inhibition: $\beta = 1.624$, $SE = 0.565$, $p < 0.005$; Age × Perspective × Switching: $\beta = -1.357$, $SE = 0.628$, $p < 0.05$).

To explore these interactions, we carried out a tertile age split to identify the youngest 1/3rd (Age < 45) and oldest 1/3rd participants (Age > 65).[4] For each group, we fit a model that included Perspective and the two EF measures as fixed effects. Fig. 2 presents plots for each subgroup showing the relationship between CG and PG modification rates and each of the inhibition and switching measures.[5] As these plots show, young adults' sensitivity to perspective varied with their inhibition performance (Perspective × Inhibition: $\beta = -5.371$, $SE = 2.620$, $p < 0.05$) but not switching (Perspective × Switching: $\beta = 2.147$, $SE = 1.391$, $p = 0.12$). In this group, better inhibition was associated with less modification on PG trials ($\beta = -1.121$, $SE = 0.537$, $p < 0.05$) and more modification on CG trials ($\beta = 2.381$, $SE = 1.144$, $p < 0.05$). Conversely, the oldest adults' sensitivity to perspective varied by their switching performance (Perspective × Switching: $\beta = -3.503$, $SE = 1.483$, $p < 0.05$) but not inhibition (Perspective × Inhibition: $\beta = 1.095$, $SE = 1.519$, $p = 0.47$). In this group, better switching performance was associated with less modification on PG trials ($\beta = -3.485$, $SE = 1.246$, $p < 0.01$) but did not predict modification on CG trials ($\beta = 0.193$, $SE = 0.546$, $p = 0.72$).

3.2. Results of "Prenominal Modification" coding

We carried out the same analyses on our conservative measure (prenominal modification = 1; anything else = 0). Again, participants showed evidence of perspective-taking (significant effect of Perspective: $\beta = -1.301$, $SE = 0.547$, $p < 0.05$), with more modification on CG trials ($M = 0.77$, $SD = 0.42$) than on PG trials ($M = 0.49$, $SD = 0.50$). On this measure, modification rates on CG trials were no longer at ceiling. Even so, differences in modification rates across trial types decreased with increasing participant age (Age × Perspective: $\beta = 1.389$, $SE = 0.398$, $p < 0.001$), although pre-modification differences across trial types varied with switching performance

[4] The same patterns hold with a median age split.

[5] For plots of the full dataset, see Supplementary material.

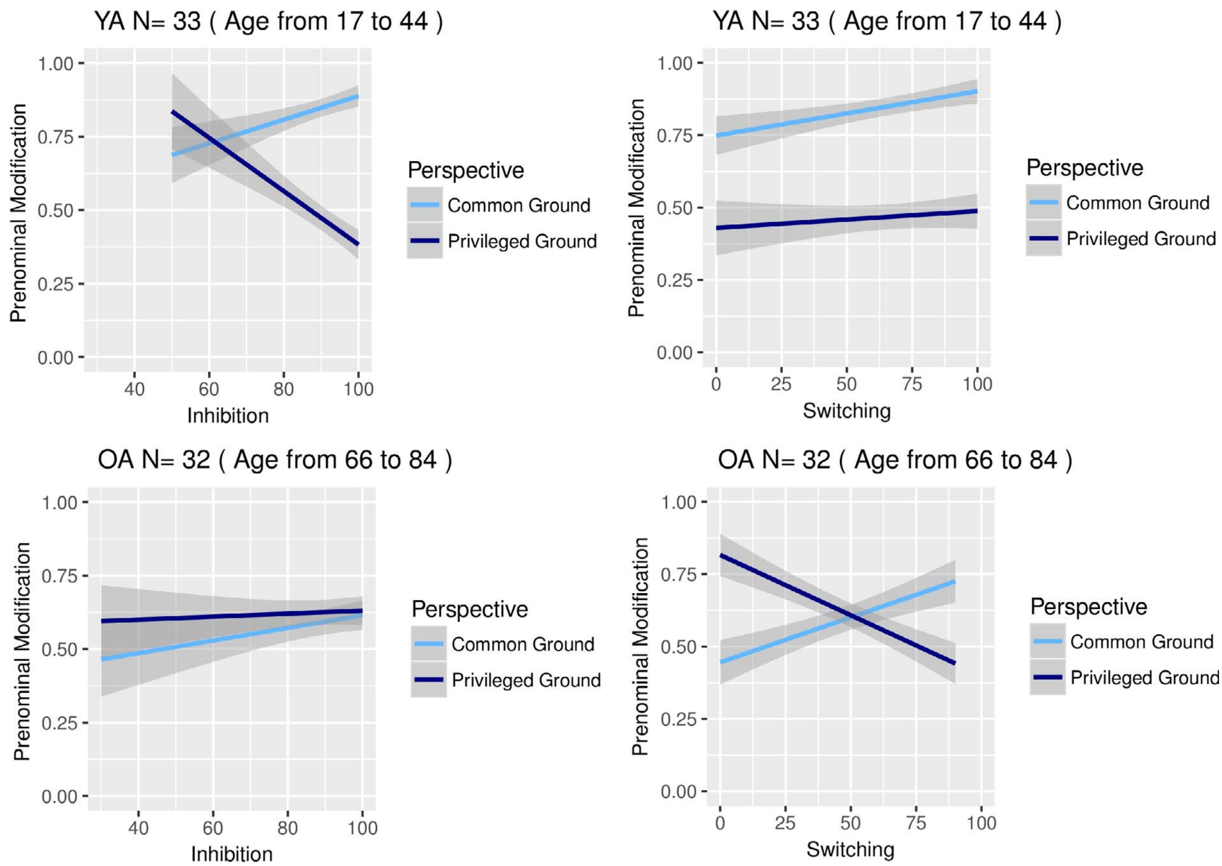

Fig. 3. Perspective-taking performance of tertile split Youngest Adults (YA) and Oldest Adults (OA) using Prenominal Modification only, by inhibition and switching EF performance. Notes: 95% confidence level intervals displayed in the plots.

(Perspective × Switching: $\beta = -0.872$, SE = 0.410, $p < 0.05$; cf. Perspective × Inhibition for 'any modification' above). Importantly, the relationship between perspective-taking and EF is modulated by Age, with significant three-way interactions for both EF measures (Age × Perspective × Inhibition: $\beta = 1.047$, SE = 0.420, $p < 0.05$; Age × Perspective × Switching: $\beta = -1.066$, SE = 0.459, $p < 0.05$).

Again, focusing on the data from the youngest (Age < 45) and oldest participants (Age > 65), we fit an additional model for each age group that included Perspective and the two EF measures as fixed effects (Fig. 3). Young adults' sensitivity to perspective was influenced by their inhibition performance (Perspective × Inhibition: $\beta = -1.531$, SE = 0.574, $p < 0.01$) but not switching (Perspective × Switching: $\beta = 0.219$, SE = 0.582, $p = 0.71$). Again for this group, better inhibition was associated with less modification on PG trials ($\beta = -1.092$, SE = 0.491, $p < 0.05$) and more modification on CG trials ($\beta = 0.642$, SE = 0.286, $p < 0.05$). Conversely, the oldest adults' sensitivity to perspective was influenced by their switching performance (Perspective × Switching: $\beta = -1.736$, SE = 0.755, $p < 0.05$) but not inhibition (Perspective × Inhibition: $\beta = 0.797$, SE = 0.760, $p = 0.29$). Here, better switching performance in older adults was associated with marginally less modification on PG trials ($\beta = -1.123$, SE = 0.674, $p = 0.10$) and more modification on CG trials ($\beta = 0.613$, SE = 0.268, $p < 0.05$).

4. Discussion

Based on the performance of a large sample of individuals varying widely in age, we provide support for the claim that individual differences—both in age and domain-general cognitive capacities—contribute to variability in communicative perspective-taking. While we cannot rule out other contributing factors, like how comfortable older participants were in responding via iPad, our results reveal striking age-related differences in the influence of both inhibition and switching: for young adults, perspective-taking abilities were best predicted by their inhibition capacity, whereas older adults' performance varied more strongly with their switching capacity. These patterns hold for both a liberal and conservative coding of modification, the latter especially revealing of older adults' switching abilities as it requires rapid attentional shifts to produce prenominal modification for CG size contrasts.

There are admittedly multiple ways in which inhibition and switching could be relevant in this perspective-taking context, and our own data can't fully adjudicate amongst them. Initially, determining which referent to describe requires switching attention from the "red" occluded object to the "green" target object (and potentially inhibiting attention to the occluded object). Later, deciding what modification is needed requires switching perspective from one's own perspective to an addressee's (and potentially inhibiting one's own perspective on PG trials when the occluded object is irrelevant). One possibility we consider is that a participant's performance reflects strategies optimized for either initial referent determination or subsequent modification decisions. For example, some participants could use a proactive strategy of wilfully ignoring the occluded object. If so, our data are compatible with an account whereby young adults favor this inhibition-driven strategy, and their successful implementation of this shortcut therefore depends on their inhibition capacity. This would explain why young adults' performance is best predicted by inhibition rather than switching.

Nevertheless, such an approach requires continuous goal maintenance, and would likely not be optimal for older adults whose preferences may shift in the direction of utilizing the less cognitively demanding, reactive mode of control (Braver, 2012; Paxton, Barch, Racine, & Braver, 2008). Perhaps, then, the high-performing older adults in our sample relied on a *combination* of proactive and reactive modes, allowing them to partially rely on a stimulus-driven, passive mode of responding to changes while actively refocusing attention. As such, their success would depend on an ability to switch efficiently between occluded and target objects and from their own perspective to the addressee's. Older adults' switching capacity hence would better predict their performance, as we found.

Overall, our results raise intriguing questions regarding a possible shift in EF resources modulating perspective across the lifespan. Future research should therefore address how different aspects of executive function contribute to perspective-taking under different conditions.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2017.09.004.

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