The Relation Between Spatial Perspective Taking and Inhibitory Control in 6-Year-Old Children

Andrea Frick[1] & Denise Baumeler

University of Bern

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[1] Andrea Frick is now at the Department of Psychology of the University of Fribourg, Switzerland.

Corresponding address: Andrea Frick, University of Fribourg, Department of Psychology, Rue P.A. de Faucigny 2, CH-1700 Fribourg, Switzerland. Phone: +41 26 300 7483. E-mail: depsy@gmx.net

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Abstract

Developmental research on spatial perspective taking has shown that young children are able to solve perspective-taking problems under favorable circumstances, but they have difficulties succeeding in classic tasks involving a conflict between one's own perspective and that of another observer. To date, little is known about the reasons for young children's difficulties dealing with incongruent perspectives. Based on the assumption that one's own perspective has to be ignored in order to imagine someone else's perspective, it was investigated whether perspective taking is related to inhibitory control in 6-year-olds ($N = 140$). An adapted version of the 'Fruit Stroop Task', appropriate for preschool children, was used to assess inhibitory control. Perspective taking was assessed using the 'Perspective-Taking Test for Children' (PTT-C). Other spatial and nonspatial abilities were assessed to investigate the specificity of the relation. Results showed a significant correlation between perspective taking and inhibitory control, even when controlled for age, verbal-IQ, and socioeconomic status. However, no significant correlations between inhibition and other spatial abilities were found, indicating a specific relation between inhibition and perspective taking. A linear regression analysis showed that, even after accounting for effects of control variables as well as other mental transformation abilities, inhibition accounted for a significant part of the variance in perspective-taking performance. The present findings provide valuable information on what contributes to individual differences in perspective taking, which is an important aspect of everyday cognition and bears relevance for reasoning in technical domains.

Keywords: cognitive development, spatial cognition, perspective taking, inhibitory control

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Visual perspective taking, or the ability to mentally represent a viewpoint different from one's own, has been extensively studied in developmental research, beginning with Piaget and Inhelder's seminal work on *The child's conception of space* (1948/1956). In their *Three Mountains Task*, Piaget and Inhelder presented children with a tabletop model of three mountains. Children's task was to indicate how an observer would see this layout from another position (e.g., from the opposite side of the table). Young children made many errors and often claimed that observers in different positions would see the same view as themselves. Piaget and Inhelder argued that preoperational children are unable to coordinate multiple perspectives, and that it is not until 7–8 years that children begin to understand projective properties of space.

Even though his work has inspired hundreds of subsequent perspective-taking studies, the reasons for children's difficulties remain unclear. The often-heard explanation, that young children are generally egocentric, seems too simplistic. Even though egocentrism served as a descriptive attribute and characteristic in Piaget's theory, no claims were made for its explanatory value, and the term is not defined enough to clarify children's difficulties on perspective-taking tasks (Newcombe, 1989). Furthermore, egocentrism cannot explain children's difficulties up to the age of 8 years (Frick, Möhring, & Newcombe, 2014), in light of findings that under some favorable circumstances even 3-year-olds are able to perform perspective-taking tasks, and thus appear to know that other persons may see other things than themselves (Flavell, Everett, Croft, & Flavell, 1981; Flavell, Omanson, & Latham, 1978; Flavell, Shipstead, & Croft, 1978; Hobson, 1982; Hughes & Donaldson, 1979; Masangkay, McCluskey, Sims-Knight, Vaughn, & Flavell, 1974). For example, when a piece of cardboard is held vertically between the child and an experimenter, with a dog on one side and a cat on the other, 3-year-olds have no difficulty telling which animal the experimenter does or does not see. This type of non-egocentric inference has been termed „Level 1“ perspective taking. Recent research has suggested that Level 1 knowledge may even be present in infancy (Moll & Tomasello, 2006; Sodian, Thoermer, & Metz, 2007) and nonhuman animals (e.g., Bräuer, Call, & Tomasello, 2007; Hare, Call, Agnetta, & Tomasello, 2000; Dally, Emery, & Clayton, 2006). Furthermore, studies with human adults indicated that Level 1 perspective taking may be an automatized low-level process that requires only limited cognitive control (Apperly & Butterfill, 2009; Surtees & Apperly, 2012; Qureshi, Apperly, & Samson, 2010; Samson, Apperly, Braithwaite, Andrews, & Scott, 2010).

In contrast, Level 2 perspective taking describes the ability to compute exactly *how* another person perceives things, as for example required in the *Three Mountains Task*. This ability seems to be more cognitively complex, and there is no evidence for Level 2 perspective taking in infants or non-human animals, nor for automatic or involuntary processing of Level- 2 perspectives (Apperly & Butterfill, 2009; Surtees, Butterfill, & Apperly, 2012). In fact, Level 2 perspective taking develops comparatively late, being first evident only at around 4 or 5 years of age (Masangkay et al., 1974; Flavell, Flavell, Green, & Wilcox, 1980; Pillow & Flavell, 1986), and improving considerably between 6 and 8 years of age (Frick et al., 2014; Salatas & Flavell, 1976). However, the question remains why young children have difficulties with Level 2 perspective-taking tasks, and why they often fall back to egocentric choices (cf. Aebli, 1967).

In order to shed light on this question, Liben (1978) used a task in which she built an array at the child’s eye level, from back to front, either using increasingly larger or increasingly smaller objects. In the ‘hidden’ condition, the front object hid the back objects from the child’s view. In the ‘visible’ condition, the child saw all the objects, but the larger object in the back hid the rest of the objects for an observer sitting at the opposite side of the table. Children performed better in the 'hidden' condition and responded that the observer would see the objects that they could not see themselves (but knew were there). A later study (Liben & Belknap, 1981) showed that performance was notably different when children watched the construction of arrays and thus had knowledge of blocks that were eventually out of sight, as compared to when they were presented with finished arrays. The authors argued that the reason for these results might lie in what Luquet (1991/1927) termed ‚intellectual realism' – the tendency for conceptual knowledge to be dominant over perceptual experience. Children may thus have difficulties ignoring what they know to exist. Similar mechanisms have been assumed to be responsible for children's difficulties with Theory of Mind tasks (cf. "curse of knowledge" Birch & Bloom, 2003; "reality bias" Southgate, Senju, & Csibra, 2007).

Aside from conflicts between conceptual and perceptual information, the grounds for children's difficulties may also be a conflict between perceptual input and the to-be-imagined view. Walker and Gollin (1977) found that covering the stimulus array in a perspective-taking task reduced egocentric errors among 4-year-olds, suggesting that an incongruence of what the children saw and what the choice alternatives showed may have kept them from selecting the correct view. Huttenlocher and Presson (1973) allowed children to physically move to the position of the observer after the initial viewing of an array, which led to significantly better performance. The authors postulated that the continuous experience of the changing appearance of the hidden array when moving to the new position resolved the incongruence between the ego-perspective and the to-be-imagined perspective. On a slightly different note, findings with adult participants are also supportive of a *sensorimotor interference account* (May, 2004), positing that difficulties in imagined perspective switches might arise from conflicts between sensorimotor information (i.e., the participants' actual body/head orientation) and cognitive codes of the object locations as defined by the to-be-imagined perspective, which lead to interference effects during response selection.

Based on these findings, it seems reasonable to assume that the real challenge in Level 2 perspective-taking tasks is not only the mental transformation that underlies imagining a different perspective per se, but ignoring conflicting information. Complex forms of perspective taking typically present a conflict between two perspectives, between two spatial frames of reference, or between what children perceive and know to exist. This conflicting information has to be ignored in order to be successful at imagining another perspective, which begs the question of whether perspective-taking ability is associated with executive functioning, more specifically with inhibitory control.

Inhibitory control is a key component of executive functions, which refers to high-level cognitive control processes that underlie flexible goal-directed responses to novel or difficult situations (Best & Miller, 2010; Hughes & Graham, 2002; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000). Such skills are thought to be important in non-routine tasks that require a considerable amount of deliberate attentional resources, such as planning and decision-making, troubleshooting, initiating novel actions, overcoming strong habitual responses, or resisting temptation (Norman & Shallice, 1986). According to Best and Miller (2010), most theories describe the development of executive functions as involving an increasing ability to resolve conflict, for example between rules (Zelazo, Müller, Frye, & Marcovitch, 2003), between latent and active representations (Munakata, 2001), or between current representations and prepotent mental sets or behaviors (Diamond, 2006).

Inhibitory control is therefore likely to be involved in Level 2 perspective-taking tasks, because such cognitive control may be a necessary precondition to ignore conflicting information and inhibit one's dominant own perspective or conceptual knowledge in order to imagine a counterfactual view (cf., Diamond, Kirkham, & Amso, 2002; Miyake et al., 2000; Nigg, 2000). Moreover, the protracted developmental time course of perspective taking and inhibitory control, with both abilities showing developmental progression well into later childhood (Davidson, Amso, Anderson, & Diamond, 2006; Diamond, 2002; Röthlisberger, Neuenschwander, Michel, & Roebers, 2010), suggests that they might rely on similar processes.

Inhibitory control has previously been associated with performance on appearance-reality and false-belief tasks (e.g., Carlson, Moses, & Claxton, 2004; Leslie & Polizzi, 1998; Leslie, German & Polizzi, 2005), pretense (Carlson, White, & Davis-Unger, 2014) or judgment of emotional states (Bull, Phillips, & Conway, 2008), suggesting that it is conductive to suppressing one's current knowledge about reality or known facts. However, the role of inhibitory processes in perspective taking has rarely been investigated. Qureshi and colleagues (2010) found that executive functions are not crucial for adults' Level 1 task performance, which they took as a possible explanation for the success of infants on 'indirect' measures of perspective taking that do not require selection of the relevant perspective, as opposed to the more complex Level 2 tasks that require such selection. A case study of an adult stroke patient (Samson, Apperly, Kathirgamanathan, & Humphreys, 2005) showed that impaired inhibitory abilities were associated with low performance in a false-belief task, but only if task demands for self-perspective inhibition were high. The patient also showed an interesting dissociation, in that performance in a Level 2 visual perspective-taking task was impaired, whereas mental rotation skills seemed unaffected.

Despite some evidence that inhibition may be crucial for false-belief and perspective-taking task performance in adults, the role of inhibitory processes in the development of Level 2 perspective taking and their contribution to individual differences remain unclear. Therefore, the present study focused on the question of whether children who have better inhibitory skills perform better on a perspective-taking task, as compared to children with low inhibitory control, who presumably would have more difficulties ignoring their own perspective or knowledge. Furthermore, effects of spatial complexity and angle of perspective were investigated. High inhibition skills were expected to be especially helpful on trials that require a perspective change, but less crucial on trials that do not require a change in perspectives. For spatial complexity it could be hypothesized that inhibition skills help on spatially complex trials because these are more difficult to solve, or on spatially simple trials because in these cases the own perspective may be even more pervasive and difficult to reject.

As a second research question, we tested whether this relation is specific, or whether inhibition is generally related to performance on other kinds of spatial tasks. Such a general relation could be assumed based on the fact that spatial tasks are typically complex tasks that afford a high level of selective attention and often present choice alternatives among which the correct response has to be selected while inhibiting choosing the distractor items (or the item chosen on the previous trial). Therefore, we expected correlations between inhibitory control and all spatial tasks tested. However, if inhibition is specifically helpful for perspective taking, we expected larger correlations between inhibitory control and perspective taking as compared to the other spatial task. Six-year-olds were tested in this study, based on previous findings (Frick et al., 2014) that children predominantly respond above chance at this age, while still showing pronounced difficulties and large individual differences.

Method

Participants

The data was collected in the context of the first assessment of a larger longitudinal study investigating how spatial skills in kindergarten are related to later school achievement. Children were recruited in 24 different rural and urban kindergartens in Switzerland during their last kindergarten year. Children's verbal assents and signed parental consent forms were obtained prior to the study from 140 children (62 girls, mean age = 6.49 years, *SD* = 0.27, range = 6.01 – 6.99; 78 boys, mean age = 6.46, *SD* = 0.34, range = 5.99 – 7.01). Procedures followed ethical guidelines and were approved by the Institutional Review Board of the University.

Procedure

Data collection took place at the end of children's last kindergarten year. There were two test sessions, each lasting about 30 minutes, with approximately 1-2 weeks in between (*M* = 10.4 days; *SD* = 8.5 days). Children were tested individually in a separate room. Materials were presented on a table, and the experimenter was sitting orthogonally to the side of the participant. Children were given six tasks that assessed spatial mental transformation abilities, and five nonspatial tasks that assessed inhibitory, verbal (passive and active), basic arithmetic, and gross-motor skills. Furthermore, socio-economic status (SES) was assessed via parent questionnaires. Table 1 shows the order in which the tests were administered across the two sessions. Children were praised irrespective of their performance and given a small snack or toy after each session. In the following, the perspective-taking task and the inhibitory control task will be described in more detail, as they were at the focus of the present paper. The additional spatial and nonspatial measures are described only briefly, as they were less central to the present research question.

Measures

Perspective Taking was assessed using an adaptation of the *Perspective-Taking Test for Children*, PTT-C (Frick et al., 2014). In this test, children saw A4 color printouts showing toy photographers taking pictures of objects from different angles. On each trial, children were asked to choose which one of four pictures the toy photographer could have taken from a particular angle. One of the pictures showed the correct view and three were foils, in which the orientation or spatial relations among the objects would not match the photographer's perspective. Trials varied in the angular difference between the photographer's and the child's perspectives (0°, 90°, or 180°) and in the number of objects (1, 2, or 4). There were two parallel test halves with 9 items each. Between the test halves, 4 items were added in which foils did not include the ego perspective (all with 4 objects, at 90° and 180°) in order to disrupt possible egocentric response tendencies. The test took about 5 to 7 minutes. The PTT-C score was calculated as the percentage of items (out of 22) that were solved correctly.

Five different mental transformation abilities other than perspective taking were assessed in the present study. *Mental Rotation*, the ability to imagine an object in a different orientation, was assessed with a Ghost Puzzle Task (Frick, Hansen, & Newcombe, 2013). Children saw cutouts of two ghosts that were mirror images of each other, and were asked to pick the ghost that would fit into a hole. There were 21 items with varying ghost shapes in 7 different orientations. The *Spatial Scaling Test* (SST, Frick & Newcombe, 2012) presented small maps showing a target, and children were asked to locate the target in a larger field. The test consisted of 24 items that varied in scaling factor and shape of the fields. The *Diagrammatic Representations Test* (DRT, Frick & Newcombe, 2015) showed pictures of 3D objects that had to be matched with 2D line drawings, or vice-versa. This test consisted of 24 items, and children chose among four choice-alternatives. The *Cross-sectioning for Children* (Ratliff, McGinnis, &

Levine, 2010) showed pictures of 3D geometric solids, and children were asked to select the cross-section that would result, if the object were cut apart where a cardboard piece intersected it. This test had 12 items showing different objects and intersection angles, and children chose among four choice-alternatives. The *Children's Mental Transformation Task*, CMTT (Levine, Huttenlocher, Taylor, & Langrock, 1999) showed two black 2D shapes and children were asked to point to one of four shapes that would result if the two pieces were moved together. We used an abbreviated version with 24 items. All tests were scored with one point per correctly solved item, except for the spatial scaling test on which children received 1/3, 2/3, or 1 point per item, depending on how close the responses were to the target (within 2 cm, 1.5 cm, or 1 cm, respectively). Scores were translated into percentages in order to better compare performance. Scores were then *z*-transformed and averaged across all five mental transformation tasks, in order to obtain a composite score of children's mental transformation performance (other than perspective taking).

Inhibitory control was measured with the *Fruit Stroop* task (Archibald & Kerns, 1999), in an adapted version by Röthlisberger and colleagues (2010). This task is appropriate for preschool or kindergarten children, as in contrast to the classic Stroop task, it does not require reading skills (MacLeod, 1991). Children were presented with four A4 pages, each showing 25 images. The first page showed 25 colored squares (blue, red, green, yellow), and children were asked to name the colors (baseline). The second page showed colored fruits and vegetables and children were again asked to name the colors (congruent). Page 3 showed the same fruits and vegetables in black-and-white (neutral), and page 4 in wrong colors (incongruent), and children were asked to name the colors they *should* have (e.g., a banana was shown in blue with the correct response being "yellow"). Children were instructed to go through the items row by row and name the colors as fast as possible. An interference score was calculated after a formula suggested by Archibald and Kerns (1999), which calculates costs in response times when seeing incongruent colors, taking into account children's baseline response times. Higher scores indicate stronger interference (and lower inhibitory control). The task took approximately 6-7 minutes.

Verbal IQ was assessed using the active and passive vocabulary subtests of the HAWIVA-III (Ricken, Fritz, Schuck, & Preuss, 2007). On the passive vocabulary subtest, children saw four pictures and were asked to point to a particular picture that the experimenter named. On the active vocabulary test, children were presented with a single picture and asked to name it. Each subtest took about 3-4 minutes to complete. Scores were aggregated across both subtests to obtain an overall vocabulary score, which was then transformed into a verbal IQ score based on norm tables.

Socio-economic Status (SES) was determined on the basis of parent's present occupations, which were classified according to the 'International Standard Classification of Occupation' (ISCO-88, International Labor Office, 1990) and transformed into an 'International Socio-Economic Index' (ISEI: Ganzeboom, De Graaf, Treiman, & De Leeuw, 1992). The higher ISEI of the mothers or fathers was used. If neither mothers nor fathers indicated a present occupation, we used the ISEI of the occupation they were trained for. This procedure allowed us to determine the SES of 136 children (97.14%).

Results

Preliminary and outlier analyses

Each variable was analyzed for outliers and values that were more than 2.5 standard deviations above or below the mean were excluded (1 to 5 values, 0.7% to 3.6% per variable).

To test for possible sex differences, a MANOVA was calculated with all variables in Table 2 as dependent variables and sex as a between-participant variable. The analysis showed no significant sex difference (all Fs < 1.6, all ps > .21). Therefore, sex was not considered in subsequent analyses.

Relation between Perspective Taking and Inhibitory Control

To investigate the relation between perspective taking and inhibitory control, Pearson[1] correlations were calculated. Table 2 shows that there was a significant correlation between perspective taking and inhibitory control, even when controlled for age, verbal IQ, and SES. This significant negative correlation indicates that the lower the value of the interference measure in the *Fruit Stroop* test was (indicating higher inhibitory abilities), the better they performed in the perspective-taking task. In contrast, no significant correlation was found between inhibitory control and the composite score of the other mental transformation abilities assessed in this study. Fisher's r-to-z transformation showed that the correlation between inhibitory control and perspective taking (r = -.22) was significantly different from the correlation between inhibitory control and the mental transformation composite score (r = -.06, z = -2.23, p < .05). Inhibitory control was also not significantly correlated to any of these mental transformation abilities if analyzed separately (all rs between -.03 and -.14, all p's >.20).

A linear regression analysis with perspective-taking performance as the predicted variable showed that after accounting for the control variables of age, verbal IQ, and SES, as well as other

[1] Kolmogorov-Smirnov tests suggested that normal distributions could not be assumed for all variables. Therefore, correlation and regression analyses were also run using the bootstrapping method (Efron & Tibshirani, 1993), which yielded the same significant results at the α-level of 5%.

mental transformation abilities ($R^2 = .20$, $p < .001$), inhibition accounted for an additional 4% of the variance in perspective-taking performance ($\beta = -.20$, $p < .05$).

Detailed Analysis of PTT-C Performance

To further characterize the relation between perspective taking and inhibition, more detailed analyses were conducted that tested possible differential effects of inhibitory control on the various items in the perspective-taking task. If inhibitory control facilitates ignoring one's own perspective, good inhibition skills should be especially helpful on trials that require a perspective change (90° and 180° trials), but less so on trials that do not require a change in perspectives (0° trials). Inhibition skills could also have differential effects depending on the spatial complexity of the layout. Therefore, an analysis of variance (ANOVA) was carried out, with percentage correctly solved regular items in the PPT-C as dependent variable, and number of objects in the displays (1, 2, or 4) and angle (0°, 90°, or 180°) as within-participant variables. Inhibition performance was dichotomized (low vs. high) by means of a median-split and added as a between-participants variable[2]. The analysis showed significant main effects of objects, $F(2, 266) = 78.42$, $p < .001$, $\eta^2 = .37$, angles, $F(2, 266) = 694.31$, $p < .001$, $\eta^2 = .84$, and inhibition, $F(1, 133) = 8.80$, $p < .01$, $\eta^2 = .06$. These effects were qualified by significant interactions between inhibition and objects, $F(2, 266) = 3.32$, $p < .05$, $\eta^2 = .02$, between objects and angles,

[2] We also calculated an analysis of covariance (ANCOVA) with inhibition performance added as a continuous variable. This analysis showed the same main effects of objects, $F(2, 266) = 13.03$, $p < .001$, $\eta^2 = .09$, angles, $F(2, 266) = 44.29$, $p < .001$, $\eta^2 = .25$, and inhibition, $F(1, 133) = 8.84$, $p < .01$, $\eta^2 = .06$, as well as interactions between objects and angles, $F(4, 532) = 6.81$, $p < .001$, $\eta^2 = .05$, and between objects, angles, and inhibition, $F(4, 532) = 4.29$, $p < .01$, $\eta^2 = .03$. There was a trend for an interaction between inhibition and objects, $F(2, 266) = 2.55$, $p = .08$, $\eta^2 = .02$.

$F(4, 532) = 14.97$, $p < .001$, $\eta^2 = .10$, and between objects, angles, and inhibition, $F(4, 532) = 4.28$, $p < .01$, $\eta^2 = .03$. Pairwise comparisons (Sidak corrected) showed that these interactions were mainly due to lower PPT-C scores for children with low as compared to high inhibition on trials that required a change in perspective and showed only one object (for 90° trials, mean difference = 19 %, $p < .01$; for 180° trials, mean difference = 16 %, $p < .01$, all other *p*s > .11; see Figure 1, left panel: dotted vs. solid lines). No further effects were found ($F < 1$).

Egocentric Responses

A last analysis focused on effects of inhibitory control on how often children chose their own view on trials that required a change in perspective. Overall, children chose the egocentric perspective on 70% of the trials. An ANOVA[3] was carried out with inhibition (low, high) as between-participants variable, objects (1, 2, or 4) and angles (90°, 180°) as within-participant variables, and percentage of egocentric responses on the regular items of the PPT-C as dependent variable. The analysis showed main effects of objects, $F(2, 266) = 51.01$, $p < .001$, $\eta^2 = .28$, and angles, $F(1, 133) = 8.79$, $p < .01$, $\eta^2 = .06$, as well as an interaction of inhibition and objects, $F(2, 266) = 5.43$, $p < .01$, $\eta^2 = .04$. Sidak corrected pairwise comparisons indicated that this interaction was especially due to more egocentric responses for children with low as compared to high inhibition performance on trials with only one object ($p < .01$, mean difference = 16%; all other *p*s > .22; see Figure 1, right panel: dotted vs. solid lines). No other effects were found (all *F*s < 3.50, all *p*s > .06).

Discussion

[3] An ANCOVA with inhibition as covariate showed a main effect of objects, $F(2, 266) = 12.94$, $p < .001$, $\eta^2 = .09$, as well as an interaction between inhibition and objects, $F(2, 266) = 3.36$, $p < .05$, $\eta^2 = .03$.

Results showed a significant correlation between perspective taking and inhibitory control, even when controlled for age, verbal-IQ, and socioeconomic status. However, no significant correlations between inhibition and other spatial mental transformation abilities assessed in the present study were found. A regression analysis further revealed that children's inhibitory control explained a significant proportion of the variance in perspective-taking performance, even after effects of age, verbal IQ, SES, and other spatial transformation abilities were accounted for. Thus, the present findings indicate that there is a specific and exclusive relation between inhibition and perspective taking, above and beyond possible effects of task format. These results extend previous findings on associations between inhibitory control and false-belief tasks (e.g., Carlson, Moses, & Claxton, 2004; Leslie & Polizzi, 1998; Leslie, German & Polizzi, 2005), by showing that inhibitory control can account for individual differences in Level 2 perspective taking in children as young as 6 years old.

The fact that no correlations were found between inhibitory control and any of the other spatial tasks, such as mental rotation, is somewhat surprising. Correlations between inhibition and other tasks that use a multiple-choice format could have been expected, due to the general necessity to inhibit choosing distractor items. On the other hand, the result is in line with previous findings from a case study (Samson et al., 2005) showing impaired inhibition skills along with low performance on a Level 2 perspective-taking task, but unaffected mental rotation skills. These findings thus further corroborate the notion that perspective taking and mental rotation are dissociated processes (cf. Hegarty & Waller, 2004; Huttenlocher & Presson, 1973, 1979; Zacks, Mires, Tversky, & Hazeltine, 2000; Zacks, Rypma, Gabrieli, Tversky, & Glover, 1999).

Detailed analyses of children's PPT-C performance further clarified that the relation between perspective taking and inhibition was mainly due to children with low inhibitory abilities performing worse on trials that required a perspective change than children with high inhibitory abilities. Furthermore, children with low inhibitory control made more egocentric errors than children with high inhibitory control, especially on trials of low spatial complexity (i.e., showing only one object). This suggests that children with low inhibitory control had difficulties rejecting their own perspective if it showed a single fronted object, whereas on this spatially simple task high inhibition skills helped children to perform well. These results are in line with previous research showing young children's difficulties in dealing with conflicting perspectives (Huttenlocher & Presson, 1973; Newcombe & Huttenlocher, 1992), but better performance for spatially less complex layouts with only one object (e.g., Fishbein, Lewis, & Keiffer, 1972; Frick et al., 2014; Gzesh & Surber, 1985). Importantly, the present results extend these findings by showing that these effects are accentuated in children with low inhibitory control.

There are two possible ways how inhibitory control could be conductive to perspective taking. First, as discussed in the introduction, inhibition may be necessary to ignore predominant or conflicting information. Level 2 perspective-taking tasks typically are spatially complex and present a conflict between the current and the to-be-imagined spatial frame of reference. Inhibitory control may thus be crucial to ignore such conflicting information and suppress one's own current visual input or body orientation. Moreover, especially young children may benefit from good inhibitory skills, because they also help them ignore their conceptual knowledge about what they know to exist.

A second possibility is that inhibition is used to suppress motor output and may prevent us from *physically* moving to another location in space while *mentally* simulating a perspective change. According to some researchers, processes underlying motor imagery and motor execution rely on similar neural mechanisms, with the major difference that during imagery motor output is suppressed (Decety, 1996; Jeannerod, 1994; Schwoebel, Boronat, & Coslett, 2002; Wilson, 2003). In a similar vein, proponents of simulation theories posit that we use mechanisms that have its original purpose in imitating observed behavior, and run those "offline", detached from physical in- and output, in order to simulate unobserved events (e.g., Wilson, 2002). Inhibition may thus be a crucial precondition for suppressing overt responses while running such mental simulations.

If inhibition processes were indeed recruited to suppress motor output during mental simulations, the question arises why no correlation was found to other mental transformation abilities, such as mental rotation, which presumably also require mental simulation. In fact, studies have shown that motor areas are sometimes – yet not always – activated during mental rotation (for a review, see Kosslyn, Thompson, Wraga, & Alpert, 2001), suggesting that at least two different strategies can be used in mental rotation: one that recruits processes that prepare motor movements and another one that does not. That is, participants may either imagine themselves physically manipulating the object, or they could imagine how an external force moves the object. According to Wilson (2001) the likeliness that motor simulations are executed may vary as a function of imitability of the stimuli (i.e., the degree of isomorphism between the imitator and the imitated). This idea is supported by findings of substantial activation in motor areas of the brain during mental rotation of hand stimuli, but not during mental rotation of cube objects (Kosslyn, DiGirolamo, Thompson, & Alpert, 1998). Thus, the propensity to run an internal simulation of the movement – and with it the need for inhibiting the overt execution of motor programs – may be stronger for body movement as opposed to object movement. This could explain why inhibitory control was only related to perspective taking but not to mental object rotation in the present study. Nevertheless, we deem the first alternative to be more likely, based on numerous findings that reducing conflicts between visual input and the to-be-imagined view improved performance (e.g., Huttenlocher & Presson, 1973; Liben & Belknap, 1981; Walker & Gollin, 1977). In line with these findings, our results suggest that individual differences in inhibitory control affected children's ability to inhibit visual input rather than motor output.

Finally, another alternative is that perspective taking facilitates inhibitory control. Whereas this possibility cannot be ruled out due to the correlational nature of the present data, it seems more likely that inhibitory processes are foundational for perspective taking, as perspective taking can be considered a higher-level cognitive process. Future research may help to clarify the functional role of inhibition for perspective taking and training studies might shed light on the question of whether improving inhibitory abilities can have positive effects on the development of perspective-taking abilities.

The present results are of high relevance in light of the fact that perspective taking is not only an integral aspect of everyday cognition, the ability to coordinate perspectives and reference frames also bears importance to many other spatial tasks in adults (Hegarty & Waller, 2004, 2005). Furthermore, the ability to reason about spatial configurations and their properties is important for reasoning in technical domains (Zacks et al., 2000) and may facilitate children's understanding of academic content (Newcombe, 2010). The present findings indicate that young children's difficulties in classic perspective-taking tasks are related to their inhibitory skills, and thus provide valuable information on what may be an important factor contributing to individual differences in perspective taking.

Compliance with Ethical Standards

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent: Informed consent was obtained from all individual participants included in the study.

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Table 1

Overview of assessment sessions and measures

Session	Ability Tests (References)
1	Inhibition: *Fruit Stroop* task (Röthlisberger, Neuenschwander, Michel, & Roebers, 2010)
	Perspective-Taking Test for Children, PTT-C (Frick, Möhring, & Newcombe, 2014)
	Mental Rotation: *Ghost Puzzle* (Frick, Hansen, & Newcombe, 2013)
	Diagrammatic Representations Test, DRT (Frick & Newcombe, 2015)
	Passive vocabulary, HAWIVA-III (Ricken, Fritz, Schuck, & Preuss, 2007)
2	*Cross-sectioning for Children* (Ratliff, McGinnis, & Levine, 2010)
	Spatial Scaling Test, SST (Frick & Newcombe, 2012)
	Active vocabulary, HAWIVA-III (Ricken, Fritz, Schuck, & Preuss, 2007)
	Children's Mental Transformation Task, CMTT (Levine, Huttenlocher, Taylor, & Langrock, 1999)
	Basic arithmetic: adding and subtracting marbles (single digit, natural numbers)
	Balance: standing on one leg
Parents	Socio-economic status (SES): ISCO-88 (International Labor Office, 1990); ISEI (Ganzeboom, De Graaf, Treiman, & De Leeuw, 1992)

Table 2

Pearson correlations between Inhibition, Perspective Taking, Mental Transformation (composite score), as well as the control variables of Age, Verbal IQ, and SES

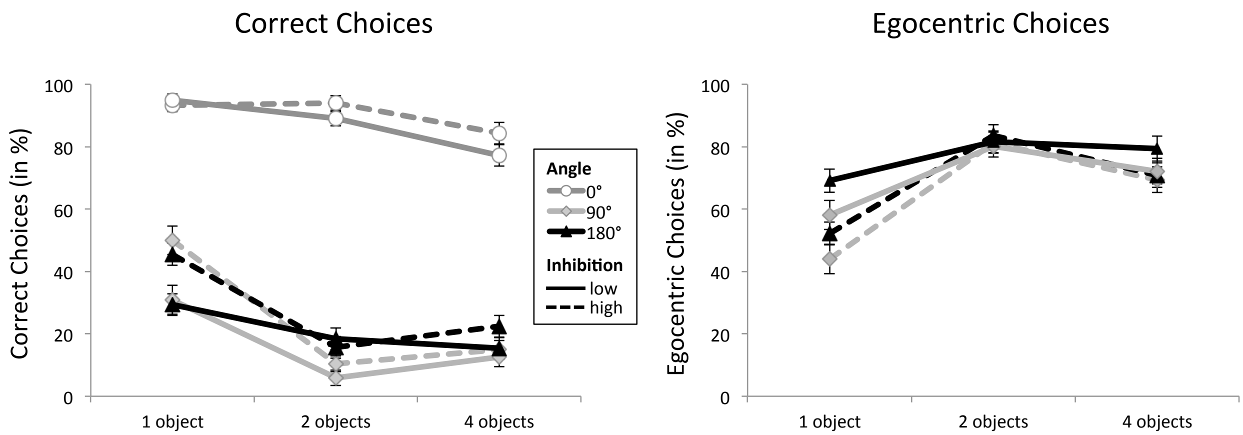
	1.	2.	3.	4.	5.	6.
1. Inhibition	-	-.26**	-.10	-.19*	.01	-.14
2. Perspective Taking	-.22**	-	.33***	.11	.31***	.27**
3. Mental Transformation	-.06	.21*	-	0.09	0.32***	0.22*
4. Age in Days				-	.21*	-.04
5. Verbal IQ					-	.27**
6. SES						-

Note. Above diagonal: zero-order correlations. Below diagonal: partial correlations controlled for Age, Verbal IQ, and socio-economic status (SES). Missing values due to outliers, excluded pairwise (df = 126 - 138). * $p < .05$, ** $p < .01$, *** $p < .001$.

Figure Captions

Figure 1. Percentage of correct choices (left) and percentage of egocentric responses in the PPT-C (right), by number of objects in the layout and angle of perspective change, for children with high (dotted lines) and low (solid lines) inhibitory control. Error bars indicate standard errors.

Figure 1


Correct Choices
Correct Choices (in %)
100
80
60
40
20
0
1 object
2 objects
4 objects
Angle
0°
90°
180°
Inhibition
low
high
Egocentric Choices
Egocentric Choices (in %)
100
80
60
40
20
0
1 object
2 objects
4 objects