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BRIEF REPORT

# Sometimes Losing Your Self in Space: Children's and Adults' Spontaneous Use of Multiple Spatial Reference Frames

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Two experiments tested 6- to 11-year-old children's and college students' use of different frames of reference when making judgments about descriptions of social and nonsocial scenes. In Experiment 1, when social and nonsocial scenes were mixed, both children and students ($N = 144$) showed spontaneous sensitivity to the intrinsic and the relative frame of reference for both social and nonsocial scenes. All groups over 7 years old showed a stronger effect of the intrinsic frame of reference for social stimuli. This is the first evidence of sensitivity to more than 1 frame of reference in individual judgments made by children. Experiment 2 tested a further sample of 6- to 11-year-old children and students ($N = 185$) with social and nonsocial scenes in separate blocks. In this study, participants were no longer sensitive to the relative frame of reference—an effect we characterize as "losing your self in space," as this frame is generated by one's own position in the world. Children showed this effect only when the stimuli were social, suggesting that spontaneous use of intrinsic frames of spatial reference may develop out of sensitivity to the perspectives of agents.

*Keywords:* cognitive development, perspective taking, spatial cognition, theory of mind

Many years of research have produced two rather separate bodies of evidence concerning perspective taking in spatial and social contexts (Carlson-Radvansky & Irwin, 1993; Piaget & Inhelder, 1956). In both domains there is evidence that adults' judgments frequently involve the activation of multiple perspectives or reference frames and that inhibition is necessary for selecting one of these for a given judgment (Carlson-Radvansky & Jiang, 1998; Qureshi, Apperly, & Samson, 2010). However, little is known about the relationship between spatial and social perspective taking or about the origins of flexible processing of multiple perspectives in children. This article reports on two experiments that investigated spatial judgments about social and nonsocial scenes in both children and an adult population.

To understand a speaker's intention when referring to the relative positions of people and objects, one must take into account one or more frames of reference (Levinson, 1996). That is, to understand the meaning of a linguistic utterance in light of our perceptual cues, we must map them onto an internal representation of space (Carlson-Radvansky & Irwin, 1993). It is considered that there are three distinct ways in which we can define such spatial relations (Levinson, 1996). The absolute reference frame refers to references related to some (usually invariable) element of the environment (for instance north–south relations). The relative (or egocentric) frame of reference locates the position of objects relative to the viewer. The intrinsic (or object-based) frame of reference locates the position of objects with reference to the plane of one of the objects in the scene (the referent object). These frames of reference can be consistent or inconsistent with each other. For example, in Figure 1 (Panel B), the frames of reference are inconsistent. If we consider only the intrinsic frame of reference, the ball is in front of the boy, in virtue of being on a line extended from *his* front. If we consider only the relative frame of reference, the ball is behind the boy, this time in virtue of being farther from *us* than the boy is. Conversely, in Figure 1 (Panel D) the frames of reference are consistent with one another: From either, the ball is *in front of* the boy.

Adults spontaneously activate multiple frames of reference when making judgments about the positions of objects in relation to each other (Carlson-Radvansky & Irwin, 1993; Carlson-Radvansky & Jiang, 1998). Carlson-Radvansky and Irwin (1993) had participants rate the acceptability of spatial relations between objects using the adverb "above." Ratings of acceptability were

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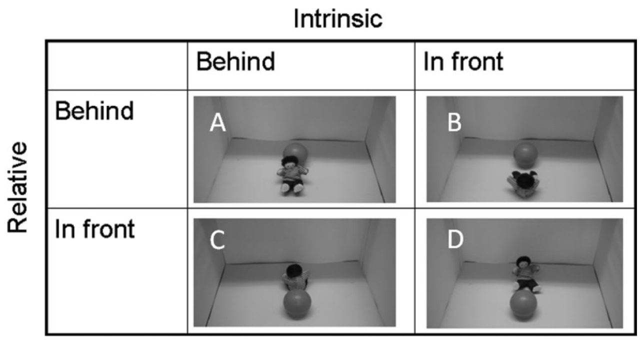


*Figure 1.* Stimuli for social stimulus, illustrates frame of reference manipulation (columns indicate relation of ball to boy with regard to the intrinsic frame of reference and rows with regard to the relative frame of reference).

highest when sentence descriptions were appropriate with reference to the relative and absolute frames (which were not independently varied). Nonetheless, when these effects were controlled for, college students also showed a preference for statements appropriate for the intrinsic frame of reference over those that were inappropriate on this dimension. This implies not only that multiple frames of reference provide acceptable criteria on which spatial relations can be judged but also that college students were spontaneously sensitive to this in the very same stimuli.

Testing of children's frame of reference judgments has generally taken a very different path from that used in the adult literature. Rather than asking for ratings of stimuli in which each frame of reference can be independently manipulated, children have been asked to make single judgments of where an object would be if it were, for example, in front of another object. Such studies have shown that when asked to place an object in front of another object children will use the intrinsic frame of reference if one is present but the relative frame of reference if not (Cox, 1981). When asked to place an object on top of another object, they tend to use the relative frame of reference (Bialystock & Codd, 1987). These studies, as well as illustrating children's preferences, inform us that they are not completely "egocentric" in their judgments, for sometimes they ignore their own position (linked to the relative frame of reference). What they do not illustrate is whether children, like adults, actually activate multiple frames of reference when making single judgments, before using inhibition to select the most appropriate reference frame. An alternative possibility is that children activate only a single reference frame for any given judgment, corresponding to whatever constitutes the most salient "good view" (Light & Nix, 1983) in a given situation. Our studies distinguish between these alternatives by testing children on tasks similar to those used with adults.

A second focus in research on frame of reference judgments has been with using inanimate objects to generate reference frames, with the literature on both adults and children largely ignoring the specific case of agents. A particular question of interest is whether the intrinsic frame of reference due to a *nonsocial object* is in any way different from one due to a *social agent* that has both an intrinsic frame of reference and a psychological perspective. The literature on psychological perspective taking leads to contrasting predictions about the possible influence of the target item's psychological perspective on judgments about its spatial relations. Judging what another person might see from a different spatial position may be an effortful task, requiring us to actively transpose ourselves into the position of others (Michelon & Zacks, 2006). Egocentrism is commonly found in judgments of what others see or know (Nickerson, 1999), suggesting that ignoring one's own perceptions, knowledge, or desires comes at a cost and making it unlikely that unnecessary spontaneous processing of such information might influence participants' judgments on an exclusively spatial task. On the other hand, recent research has suggested that perspective taking may be spontaneous or even automatic in some circumstances. Visuospatial perspective taking may not necessarily require effortful self-projection (Kessler & Thomson, 2010); participants may spontaneously use another's perspective when describing the position of objects (Tversky & Hard, 2009); and simple visual perspective taking may be sufficiently automatic that it causes interference with judgments of one's own perspective in both adult participants (Samson, Apperly, Braithwaite, & Andrews, 2010) and children (Surtees & Apperly, in press). The latter evidence makes it plausible that spatial judgments involving social agents may indeed be influenced by processing of the agent's psychological perspective. In the current studies we therefore manipulated whether the referent object for participants' spatial judgments was social or nonsocial.

We tested children and adult college students on a linguistic frame of reference task in which they had to interpret the appropriateness of statements describing the position of two objects in relation to one another. We used front–back relations because they are understood by relatively young children and because such spatial relations naturally coincide with the psychological perspective of what an agent can or cannot see. Previous findings led us to expect our student sample to be sensitive to multiple frames of reference in their judgments, and a key question was whether children might also show adultlike sensitivity. We tested children between 7 and 11 years old, as acceptability data from a pilot study of younger children ($N = 26$) showed no reliable evidence of their using either frame of reference. Middle childhood may be a critical age for changes in frame of reference processing, due to developments in executive functioning (Davidson, Amso, Anderson, & Diamond, 2006), which is believed necessary for adults' controlled use of multiple reference frames (Carlson-Radvansky & Jiang, 1998).

In Experiment 1, social and nonsocial stimuli were mixed in blocks of trials, corresponding to the way in which we might encounter a mixture of social and nonsocial objects in everyday circumstances. In Experiment 2, processing strategies for social and nonsocial stimuli were examined more independently of one another by presenting these stimuli in separate blocks of trials.

## Experiment 1

### Method

Participants viewed pictures of two objects (like those in Figure 1) placed close to one another. The pictures were paired with a written sentence indicating that the ball was "in front of" or "behind" the other object. Participants had to judge how well the sentence described the picture. By using different arrangements of the ball and the referent object we were able to investigate the importance of different frames of reference on decision making. Figure 1 shows how the intrinsic and relative reference frames can be separately manipulated. For example, if participants rated "the ball is in front of the boy" to be a good description of Panel C in Figure 1 (in comparison to making the same decision about Panel B), then this would suggest they were using the relative frame of reference to help guide judgments.

**Participants.** Child participants attended a school in a lower to middle-class, predominantly White British area of Wolverhampton (United Kingdom). Three age groups were tested: 6- to 7-year-olds ($n = 30$, mean age = 7.17, 14 female); 8- to 9-year-olds ($n = 45$, mean age = 9.08, 24 female); and 10- to 11-year-olds ($n = 31$, mean age = 11.02, 14 female). Age groups are referred to as 7-, 9-, and 11-year-olds herein.

Undergraduate and postgraduate students from the University of Birmingham participated in exchange for course credits ($n = 42$, mean age = 20.93, 35 female). All were native English speakers. Students in this population were generally from middle-class backgrounds.

**Stimuli.** Photographs of 16 arrangements of two objects were taken using a digital camera. Photographs contained a spherical orange ball and another object (a model chair, a doll, or a cup).

Figure 1 shows four picture stimuli from the *social* condition. Four analogous pictures in which the boy was replaced by a model chair made up the *nonsocial* condition. Stimuli showing the ball and the cup and stimuli in which the ball was located relatively to the right or left of the other object were presented to check whether participants used the relative and intrinsic frame appropriately when the other frame of reference was not suitable in decision making. These check stimuli were not used in the final data analysis. A full stimulus set is presented in the Appendix.

A written sentence, either "the ball is in front of the X" or "the ball is behind the X" (X = "cup," "chair," or "boy") was displayed underneath the picture. The design orthogonally varied the appropriateness of the sentence–picture pair from the intrinsic and relative frames of reference.

**Procedure.** College students were first shown an example slide of a picture and sentence. They were told that the sentence under the picture was the attempt of an alien (pictured on the slide) to describe the picture and that their task was to rate how well the alien had done. The scale used to make judgments was made up of five cartoon faces (see Figure 2) ranging from *good* to *bad*. Participants gave responses under no time pressure by marking on a score sheet. Students completed 28 experimental trials and four filler trials, recording their ratings on response sheets.

The procedure for children was identical, except for the following changes. Children made their choices by pointing to one of the faces and completed 14 experimental trials. To avoid confusion and reduce testing time, children did not complete filler trials.

## Results

**Data coding.** As our design was fully orthogonal, we were able to examine the relative and intrinsic frames of reference separately. Each rating of a given picture–sentence pair was analyzed twice: once when the picture–sentence pair was coded in relation to the relative frame of reference, and once when the picture–sentence pair was coded in relation to the intrinsic frame of reference. For example, the stimulus in the left panel of Figure 2 was coded as *appropriate* for the intrinsic frame of reference but was coded as *inappropriate* for the relative frame of reference.

Data from students and children were analyzed separately due to the differences in methods and number of data points. These differences were necessary to make materials developmentally sensitive, but this means that the data from adults should be viewed as defining the qualitative pattern that is the outcome of development, *not* as a basis for statistical comparison with the data from children. For all analyses, an initial analysis of variance (ANOVA) was undertaken with reference frame and stimulus as within-subject factors and age (for child samples) and gender as between-subjects factors. There were no significant main effects or interactions involving gender, $F\text{s} \leq 1.75$, $p\text{s} \geq .178$, and since we had no hypotheses related to gender, data were collapsed across gender for the final reported analyses.

**College students: Intrinsic frame of reference.** A 2 × 2 ANOVA with intrinsic reference frame (appropriate, inappropriate) and stimulus (social, nonsocial) as within-subject factors revealed a significant effect of the intrinsic reference frame, $F(1, 41) = 241.6$, $p < .001$, $\eta_p^2 = .855$, appropriate > inappropriate, and a significant interaction between the intrinsic reference frame and stimulus, $F(1, 41) = 14.64$, $p < .001$, $\eta_p^2 = .263$. There was no main effect of stimulus, $F(1, 41) = .411$, $p = .525$.

The interaction was explained by the effect of the intrinsic frame of reference being present for both social and nonsocial stimuli but

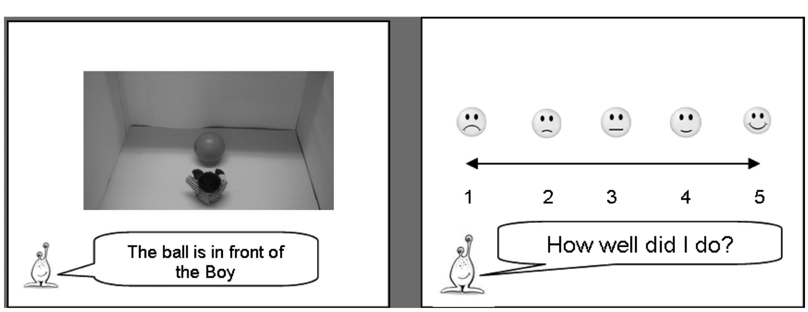


*Figure 2.* Event sequence, as experienced by participants. At the start of the experiment, participants were introduced to the alien and told that he was trying to learn how to describe pictures. They then saw pictures paired with a sentence (as above). The sentence was read by the experimenter, and then the participant was asked to rate how well the alien had done at describing the picture.

being greater when the stimulus was social, $t(41) = 15.876$, $p < .001$, than when it was nonsocial, $t(41) = 11.996$, $p < .001$ (see Figure 3).

**College students: Relative frame of reference.** A 2 × 2 ANOVA with relative reference frame (appropriate, inappropriate) and stimulus (social, nonsocial) as within-subject factors revealed a significant effect of the relative reference frame, $F(1, 41) = 91.41$, $p < .001$, $\eta_p^2 = .525$, appropriate > inappropriate, and a significant interaction between the relative reference frame and stimulus, $F(1, 41) = 30.096$, $p < .001$, $\eta_p^2 = .423$.

The interaction was explained by the effect of the relative frame of reference being present for both social and nonsocial stimuli but being greater when the stimulus was nonsocial, $t(41) = 10.704$, $p < .01$, than when it was social, $t(41) = 6.441$, $p < .01$. This was the opposite pattern from that found with the intrinsic frame of reference.

**Children: Intrinsic frame of reference.** A 2 × 2 × 3 ANOVA with intrinsic reference frame (appropriate, inappropriate) and stimulus (social, nonsocial) as within-subject factors and age (7, 9, 11) as a between-subjects factor revealed a main effect of the intrinsic reference frame, $F(1, 105) = 320.41$, $p < .001$, $\eta_p^2 = .757$, appropriate > inappropriate. There was a trend toward an effect of stimulus, $F(1, 105) = 3.06$, $p = .086$, nonsocial > social, and a main effect of age, $F(2, 105) = 4.02$, $p = .021$, $\eta_p^2 = .072$; 7 > 9 = 11. There was a significant interaction between age and intrinsic reference frame, $F(2, 105) = 30.61$, $p < .001$, $\eta_p^2 = .373$, but not between intrinsic reference frame and stimulus, $F(1, 105) = .2.36$, $p = .128$. The interaction between intrinsic reference frame, stimulus, and age, $F(2, 105) = 5.13$, $p < .01$, $\eta_p^2 = .091$, was significant.

To investigate the three-way interaction, separate 2 × 2 ANOVAs with intrinsic reference frame (appropriate, inappropriate) and stimulus (social, nonsocial) were conducted for each age group. Seven-year-olds did not show an interaction between intrinsic reference frame and stimulus, $F(1, 29) = 2.197$, $p = .149$, but this interaction was observed in 9-year-olds, $F(1, 44) = 5.590$, $p < .023$, $\eta_p^2 = .113$, and in 11-year-olds, $F(1, 30) = 6.423$, $p = .017$, $\eta_p^2 = .176$. For both 9-year-olds and 11-year-olds, like the college students, the effect of the intrinsic reference frame was greater when the stimulus was social: 9-year-olds, $t(44) = 12.871$, $p < .001$; 11-year-olds, $t(30) = 14.916$, $p < .001$, than when the stimulus was nonsocial: 9-year-olds, $t(44) = 9.764$, $p < .001$; 11-year-olds, $t(30) = 8.246$, $p < .001$.

**Children: Relative frame of reference.** An 2 × 2 × 3 ANOVA with relative reference frame (appropriate, inappropriate) and stimulus (social, nonsocial) as within-subject factors and age (7, 9, 11) as a between-subjects factor revealed a main effect of the relative reference frame, $F(1, 105) = 38.091$, $p < .001$, $\eta_p^2 = .270$, appropriate > inappropriate. There were no significant interactions, $Fs(1, 105) < .767$, $ps > .383$.

## Discussion

We identified evidence of spontaneous sensitivity to the intrinsic and relative frames of reference in both children and a population of college students. College students showed a greater effect of the intrinsic frame of reference for social stimuli compared with nonsocial stimuli, and this was observed in 9- and 11-year-olds but was not significant in 7-year-olds. Conversely, college students showed an enhanced effect of the relative frame of reference for

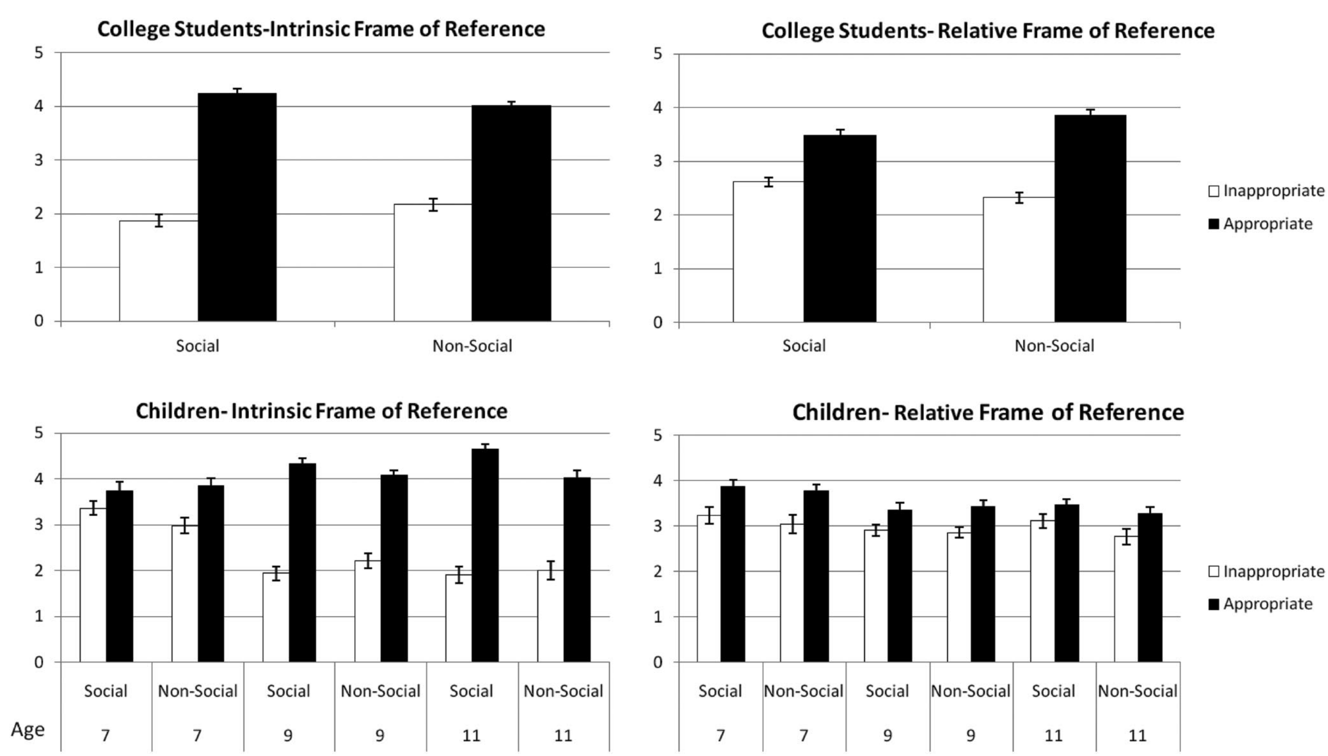


*Figure 3.* Graphs showing average acceptability ratings in Experiment 1. Effect of each frame of reference is shown through differences between appropriate and inappropriate conditions.

nonsocial stimuli; this was not shown in children at any of the ages tested. By testing sensitivity to frames of reference in a mixed block design, we matched the everyday requirement to spontaneously evaluate spatial relations to more than one type of object. However, such a design also affords the possibility of carry-over effects between trials. Experiment 2 avoided this by presenting social and nonsocial stimuli in separate blocks.

## Experiment 2

### Method

Stimuli and procedure were identical to those used in Experiment 1, except that social and nonsocial stimuli were presented in separate blocks. Half of participants completed the social block of trials first. Preliminary analysis revealed that the order of blocks had no effect on judgments, *F*s $< 1.425$, *p*s $> .234$, so data were combined for further analysis.

**Participants.** A new sample of 6- to 11-year-old children who attended a school in a lower to middle-class, predominantly White British area of Wolverhampton completed Experiment 2. Three age groups were tested (6- to 7-year-olds, $n = 51$, mean age = 7.2, 24 female; 8- to 9-year-olds, $n = 43$, mean age = 8.7, 21 female; 10- to 11-year-olds, $n = 47$, mean age = 10.7, 26 female). College students from the University of Birmingham were again used for our mature sample ($n = 44$, average age = 20.57, 36 female).

### Results

As in Experiment 1, gender contributed to no significant main effects or interactions, *F*s $\leq .316$, *p*s $\geq .730$, so data were collapsed for this factor in our final reported analyses.

**College students: Intrinsic frame of reference.** A 2 × 2 ANOVA with intrinsic reference frame (appropriate, inappropriate) and stimulus (social, nonsocial) as within-subject factors revealed a significant effect of the intrinsic reference frame, $F(1, 43) = 329.43$, $p < .001$; $\eta_p^2 = .887$, appropriate > inappropriate, and a significant effect of stimulus, $F(1, 43) = 5.981$, $p = .019$, $\eta_p^2 = .125$, social > nonsocial, but no interaction, $F(1, 43) = 1.007$, $p = .321$ (see Figure 4).

**College students: Relative frame of reference.** A 2 × 2 ANOVA with relative reference frame (appropriate, inappropriate) and stimulus (social, nonsocial) as within-subject factors revealed no significant effect of the relative reference frame, $F(1, 43) = .722$, $p = .40$, and no interaction, $F(1, 43) = 1.007$, $p = .321$.

With the social and nonsocial stimuli presented in separate blocks, students no longer showed an effect of the relative frame of reference. This was the case for both social and nonsocial stimuli.

**Children: Intrinsic frame of reference.** A 2 × 2 × 3 ANOVA with intrinsic frame of reference (appropriate, inappropriate) and stimulus (social, nonsocial) as within-subject factors and age (7, 9, 11) as a between-subjects factor revealed a main effect of the intrinsic reference frame, $F(1, 140) = 211.795$, $p < .001$, $\eta_p^2 = .605$, appropriate > inappropriate. There was no

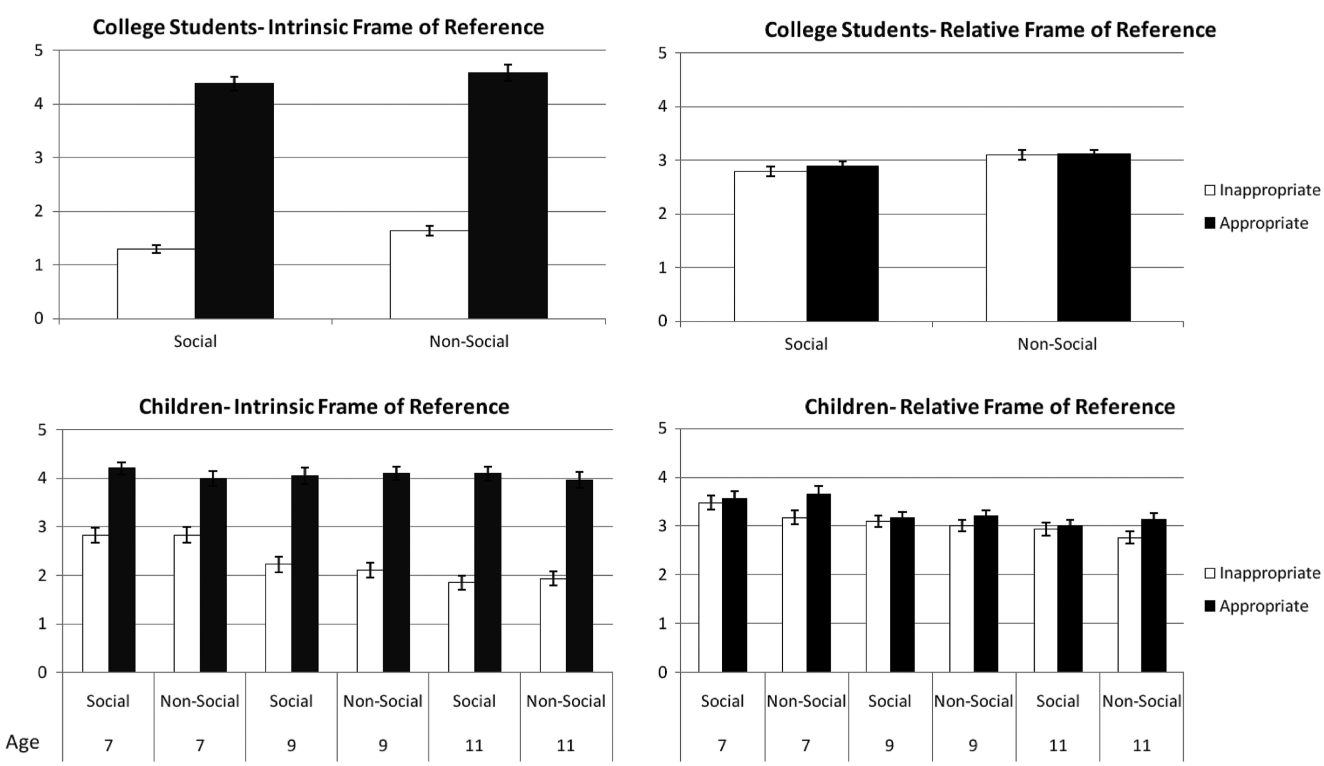


*Figure 4.* Graphs showing average acceptability ratings in Experiment 2. As with Experiment 1, differences between appropriate and inappropriate conditions show effects of each frame of reference.

significant effect of stimulus, $F(1, 140) = .853$, $p = .357$, but there was an effect of age, $F(2, 140) = 10.204$, $p < .001$, $7 > 9 = 11$. There was a significant interaction between age and intrinsic reference frame, $F(2, 140) = 4.788$, $p = .01$, $\eta_p^2 = .065$, but no other significant interactions, $F$s$(1, 140) < 1.235$, $p$s $> .294$.

All age groups independently showed the effect of the intrinsic reference frame: 7-year-olds, $t(50) = 6.325$, $p < .001$; 9-year-olds, $t(42) = 8.260$, $p < .001$; 11-year-olds, $t(46) = 10.60$, $p < .001$. The interaction between age and the intrinsic reference frame was the result of 7-year-olds showing a significantly smaller effect of the intrinsic reference frame than 9-year-olds, $F(1, 93) = 4.382$, $p = .039$, $\eta_p^2 = .045$, and 11-year–olds, $F(1, 97) = 9.291$, $p = .003$, $\eta_p^2 = .088$. Nine- and 11-year-olds showed statistically equivalent intrinsic reference frame effects, $F(1, 89) = .574$, $p = .451$.

**Children: Relative frame of reference.** A $2 \times 2 \times 3$ ANOVA with relative reference frame (appropriate, inappropriate) and stimulus (social, nonsocial) as within-subject factors and age (7, 9, 11) as a between-subjects factor revealed a significant main effect of the relative reference frame, $F(1, 140) = 5.876$, $p = .017$, $\eta_p^2 = .041$, appropriate > inappropriate. There was a significant interaction found between the relative reference frame and stimulus, $F(1, 140) = 4.413$, $p = .037$, $\eta_p^2 = .031$, but no other significant interactions, $F$s$(1, 140) < .409$, $p$s $> .665$.

The data were split by stimulus type to investigate the interaction between the stimulus and the relative reference frame. The relative reference frame had a significant effect on judgments involving nonsocial stimuli, $t(140) = 3.349$, $p < .001$, but not for judging those involving social stimuli, $t(140) = .683$, $p = .496$.

Children still showed effects of the intrinsic frame of reference for both social and nonsocial objects. However, there was a significant effect of the relative frame only when the stimulus was nonsocial.

## General Discussion

Results from Experiment 1 converged with previous findings (Carlson-Radvansky & Irwin, 1993; Carlson-Radvansky & Jiang, 1998) that adults spontaneously activate both intrinsic and relative frames of reference when evaluating spatial descriptions of a scene. Importantly, this experiment extended this literature by finding similar effects in children as young as 7 years old. This fits with previous evidence that young children are capable of using intrinsic and relative frames of reference (Bialystok & Codd, 1987; Cox, 1981; Harris & Strommen, 1972). Critically, though, the data suggest that children are not dominated by one or the other frame of reference in a situation-specific manner (Light & Nix, 1983). Instead the data suggest that children, like adults, can spontaneously activate both intrinsic and relative frames of reference, with both influencing their evaluation of spatial descriptions of scenes.

Notably, although we found evidence for spontaneous activation of intrinsic and relative frames of reference, our findings also suggest that activation of both reference frames is not obligatory but varies according to the context in which judgments are made and the nature of the reference object. When social and nonsocial stimuli were presented in separate blocks (Experiment 2), student participants no longer showed any influence of the relative frame of reference. We suggest that, when the reference object's identity was the same from trial to trial, participants no longer needed to calculate its intrinsic frame of reference afresh for each judgment, and in these circumstances they no longer activated the relative frame of reference. Because the relative frame of reference arises from participants' own "self" perspective, we describe this phenomenon as "losing one's self in space." This finding is striking because it suggests that the effects of egocentric anchoring, though pervasive in judgments of spatial and social perspectives (e.g., Nickerson, 1999), are in fact sensitive to context.

The nature of the reference object also modulated the effects of intrinsic and relative reference frames. Most strikingly, in Experiment 2, children 7 to 11 years old showed the same effect as college students of "losing one's self in space" when the reference object was social (the boy) but not when it was nonsocial (the chair). Similarly, in Experiment 1, all but the youngest age group showed a larger effect of the intrinsic frame of reference when the reference object was social rather than nonsocial. These results indicate that processing of the object's intrinsic, spatial frame of reference is influenced by something that is specific to social stimuli. We suggest that this influence may be due to processing of the perspective of the social stimulus, which is aligned with the front–back intrinsic spatial reference frame. This suggestion fits with recent evidence that processing of social agents' visual perspectives may be spontaneous or even automatic (Samson et al., 2010; Tversky & Hard, 2009).

In sum, the current findings suggest that by 7 years of age, children evaluate spatial language in terms of both intrinsic and relative frames of spatial reference that are activated spontaneously and in parallel in much the same way as has been observed in adults. That this is the case for children as well as adults significantly advances our knowledge of the development of frame of reference processing: Multiple reference frame activation and selection are not limited to adults with fully developed executive control. It remains for further research to determine the age at which such effects first occur. One possibility is that spontaneous activation of multiple spatial reference frames has its origins in infants, who, in different studies, show evidence of sensitivity to both intrinsic and relative frames of reference (Bremner, Bryant, & Mareschal, 2006; Bremner, Bryant, Mareschal, & Volein, 2007). Another is that spontaneous sensitivity to the intrinsic frame of reference during spatial judgments about fronted objects may be a phenomenon that has its origins in children's initial spontaneous sensitivity to social perspectives. Our experiments take the first step toward examining this by testing the development of frame of reference judgments about social agents as well as nonsocial objects. In doing so, we found interesting cases where treatment of agents was somewhat different from treatment of fronted objects. Future research should look to integrate these two literatures, which have until now been surprisingly separate.

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## Appendix

## All Pictures Used Within Both Experiment 1 and Experiment 2

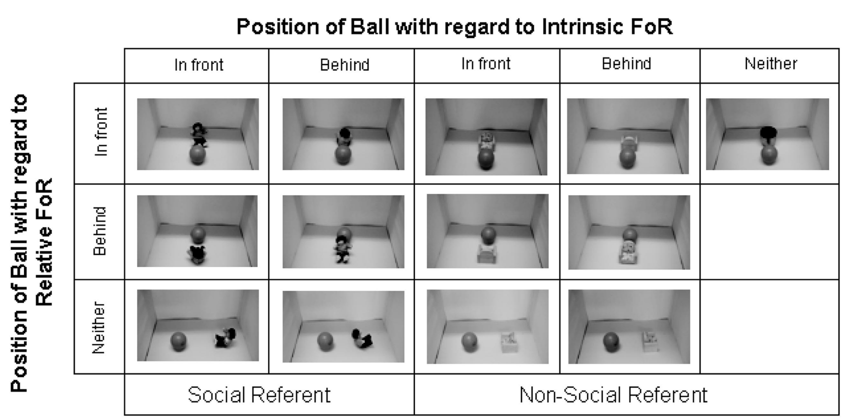


*Figure A1.* Pictures where the ball was neither in front nor behind the other object with regard to a given frame of reference (FoR) were used to check participants' use of the alternative frame of reference.

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