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Social orienting predicts implicit false belief understanding in preschoolers

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A B S T R A C T

According to the social motivation theory, orienting toward social elements of the environment should be related to sociocognitive abilities, such as theory of mind (ToM), in both typically developing children and children with autism spectrum disorder. The objective of the current study was to assess whether social orienting skills predict ToM abilities in preschoolers by using two social orienting tasks (biological motion and face preference) and an implicit false belief task. A total of 38 children, aged 2–4 years, participated in this study. As expected, participants showed a social preference on both tasks measuring social orienting. More importantly, children's performance on the face preference task predicted their performance on the false belief task, providing the first evidence for a link between social motivation and ToM in preschoolers.

Introduction

The term *social motivation* has been coined to describe children's psychological dispositions to preferentially orient to the social world (social orienting), to seek and take pleasure in social interactions (social reward), and to invest in maintaining social bonds (social maintaining) (Chevallier, Kohls, Troiani, Brodkin, & Schultz, 2012; Klin, Jones, Schultz, Volkmar, & Cohen, 2002; Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Social motivation has important impacts within atypical populations, such as autism spectrum disorder (ASD), given that deficits in social communication and social interaction are key diagnostic features among individuals with ASD (American Psychiatric Association, 2013).

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Chevallier et al. (2012) recently suggested a social motivation theory to explain the presence of sociocognitive deficits, such as theory of mind (ToM), observed in ASD. They argued that deficits in ToM among individuals with ASD are the result of impairments in social motivation (Chevallier et al., 2012). Theory of mind is defined as the understanding that others have beliefs and thoughts that may be different from one's own (Wellman, 2014). In other words, social motivation theory posits that individuals with ASD fail to attend to and learn from socially relevant information in their environment, and this has downstream effects on their sociocognitive development (Broekhof et al., 2015; Chevallier et al., 2012; Senju & Johnson, 2009). This theory also applies to the natural variance in social motivation and ToM abilities in the neurotypical population. Thus, individual differences in social motivation should be reflected in differences in sociocognitive abilities. The main objective of the current study was to determine whether social orienting skills predict ToM abilities in typically developing preschoolers. To our knowledge, only one study has investigated the relation between social orienting and ToM abilities in young children (Burnside, Wright, & Poulin-Dubois, 2017). This study compared children with ASD with a matched group of neurotypical children on these constructs and found that children with ASD oriented less to social stimuli than did neurotypical children. As expected, children with ASD did not pass an implicit false belief task. However, no link was observed between the preference scores on the social motivation tasks and performance on the ToM task in either group, most likely due to the small sample size in each group.

One way to assess social motivation is by measuring social orienting. This is typically done using the preferential looking paradigm, wherein both social and nonsocial stimuli are simultaneously presented and the proportion of looking time on each picture is measured. If a child looks longer at the social stimulus, then the child is considered to have a social preference. Typical social stimuli include human faces, human motion, and voices, whereas nonsocial stimuli are selected to match the auditory or visual medium used to present the social stimuli (e.g., pictures of objects, scrambled motion, nonspeech sounds) (Annaz, Campbell, Coleman, Milne, & Swettenham, 2012; Curtin & Vouloumanos, 2013; Sasson, Turner-Brown, Holtzclaw, Lam, & Bodfish, 2008). For example, Sasson et al. (2008) presented pictures of human faces and objects in visual arrays to measure the visual exploration of both typically developing children and children with ASD and found that children with ASD explored fewer social images when these images were paired with objects that were of high interest to them (i.e., electronics, trains) as compared with objects that were of low interest to them (i.e., furniture, plants). Other researchers have examined the attentional bias for faces in children with and without a diagnosis of ASD and observed that children without a diagnosis took longer to disengage from the pictures with faces than did children with ASD (Chawarska, Volkmar, & Klin, 2010). These data suggest that typically developing children are more attracted to social stimuli containing human faces. Another goal of the current study was to investigate children's looking behavior when pairs of social and nonsocial images are presented on a split screen, rather than as an array, to measure whether children exhibit a social preference.

Another method used to assess social orienting includes the presentation of biological motion such as a point-light display of a human walking (Johansson, 1973; Pavlova, 2012). This social stimulus is usually contrasted on a split screen with phase-scrambled or random motion (Annaz et al., 2012; Falck-Ytter, Rehnberg, & Bölte, 2013; Klin & Jones, 2008). Annaz et al. (2012) demonstrated that children with ASD fail to show a preference for the biological motion stimulus, whereas typically developing children look significantly longer at the human walking point-light display. In fact, even newborns show a similar preference (Simion, Regolin, & Bulf, 2008). Nevertheless, typically developing children's looking patterns are not consistent across studies; in some cases, they do not show a social preference when biological motion is paired with mechanical motion (e.g., truck or bicycle) (Wright, Kelley, & Poulin-Dubois, 2016). Thus, another goal was to investigate children's social preference with a task contrasting a low-level, abstract social stimulus, a human walking point-light display, with scrambled motion (i.e., phase-scrambled motion of a human walking). Furthermore, because there are no studies comparing different measures of social orienting (e.g., human faces and biological motion) within the same group of children, the current study aimed to assess the construct validity of social orienting through different types of assessment. Inter-task convergence would be expected if both tasks tap into the same construct.

Given that the main purpose of this study was to directly test the social motivation theory in a group of typically developing children, we wished to determine whether preschoolers' performance on two social orienting tasks predicts their ToM abilities. Previous research with adults and older children has analyzed the relation between these two constructs using only one measure of social motivation—biological motion (Miller & Saygin, 2013; Rice, Anderson, Velnoskey, Thompson, & Redcay, 2016). For example, children aged 7–12 years who performed better on a biological motion task (measured using noise dot thresholds, where higher thresholds indicated better detection of the point-light walker when embedded in higher noise levels) were better able to infer mental states from eye gaze or verbal information (Rice et al., 2016). Adults' sensitivity to biological motion was correlated with scores on a self-report measure of empathy as well as their scores on the Reading the Mind in the Eyes test (Miller & Saygin, 2013). To expand on this topic, young children's social motivation was measured using multiple social orienting tasks, and ToM abilities were assessed with an implicit false belief task.

There is a vast literature on the development of ToM understanding from infancy to adulthood (Baillargeon, Scott, & He, 2010; Schneider, Slaughter, & Dux, 2015; Slaughter, 2015). It was first established that false belief understanding develops at around 4 years of age with an explicit version of a false belief task (Wellman & Liu, 2004). A classic example of an explicit false belief task is the Sally–Anne task (Baron-Cohen, Leslie, & Frith, 1985), where a puppet named Sally places her marble in a basket. After Sally leaves the scene, a puppet named Anne moves the marble to the box in the scene. When Sally returns, the participants are asked where Sally will look for her marble. Thus, the children are asked to state explicitly or point to the basket (i.e., where Sally had initially placed the marble, recognizing that she did not see the marble being moved). Success on explicit false belief tasks requires an advanced set of executive functioning skills such as attention, working memory, and inhibitory control (Kimhi, 2014). It has been argued that this is a demanding task because children need to inhibit pointing to the correct location of the marble when they process the "where" in the test question and hastily answer where the marble is actually located (Csibra & Southgate, 2006).

Clements and Perner (1994) were the first to show some form of implicit false belief understanding in young children by measuring this construct using an anticipatory looking paradigm. They tested 2- to 4-year-olds on a false belief task in which a mouse (Sam) hid a piece of cheese in a box. When this mouse was sleeping, another mouse (Katie) moved the piece of cheese to another box. When Sam awoke, Clements and Perner asked the children where he would look for his cheese in order to have an explicit measure of the children's false belief understanding. They also measured the children's implicit false belief understanding by measuring their looking responses during the paradigm to determine whether the children were able to correctly anticipate where Sam would look for his cheese. Using this implicit measure, the authors were able to find evidence of false belief understanding in children as young as 2 years 11 months. Furthermore, they reported a dissociation between implicit and explicit false belief understanding given that 90% of the participants aged 2–4 years passed the implicit version of the false belief task, but only 45% passed the explicit version (Clements & Perner, 1994).

Since then, numerous studies have demonstrated that implicit ToM processing appears to develop prior to explicit ToM reasoning (Grosse Wiesmann, Friederici, Singer, & Steinbeis, 2016; Southgate, Senju, & Csibra, 2007; Thoermer, Sodian, Vuori, Perst, & Kristen, 2012; Yott & Poulin-Dubois, 2012). Researchers have proposed conflicting interpretations of children's performance on implicit false belief tasks (Baillargeon, Scott, & Bian, 2016; Heyes, 2014). To summarize, the "rich" view posits that infants' performance on implicit tasks such as the violation of expectation reflects a mature understanding of false belief, akin to that measured using explicit measures in older children (Baillargeon et al., 2010). In contrast, the lean view proposes that infants' performance reflects lower-level, domain-general abilities, such as perceptual novelty and retrospective interference, or well-learned behavioral rules, such as "a person looks for an object at the last place she saw it" (Heyes, 2014; Ruffman, 2014). As such, it remains unclear whether implicit false belief tasks measure a fully formed ToM or precursor abilities. Importantly, there is currently a debate in the literature centered on the replicability of infants' performance on implicit false belief tasks (see Burnside, Ruel, Azar, & Poulin-Dubois, 2017; Dörrenberg, Rakoczy, & Liszkowski, 2018; Powell, Hobbs, Bardis, Carey, & Saxe, 2017). In addition, there is wide variability in children's performance on the anticipatory looking task, with success rates ranging from 54% to 85% (Grosse Wiesmann et al., 2016; Southgate et al., 2007). This variance indicates that there are individual differences in children's performance on the implicit false belief task that might be accounted for by variability in social motivation. Because the implicit false belief task is known to elicit variable performance across childhood, and because explicit false belief only develops by 5 years of age, an implicit false belief task was chosen for the current study. In doing so, we ensured that inter-individual variability on the task would permit an analysis of individual differences. Furthermore, given that both social orienting tasks (face preference and biological motion preference) used in the current study are implicit measures of social motivation, we opted to assess false belief abilities with an implicit task also based on looking patterns in individuals. Our rationale was that contrasting implicit social motivation measures with an explicit ToM measure may create a methodological confound that would make the interpretation of the findings challenging.

In sum, the objectives of the current study were to (a) determine whether preschoolers' performance on social orienting tasks predicts their performance on an implicit false belief task and (b) examine whether two tasks that are assumed to measure social orienting are related in order to establish construct validity. Given that the social motivation theory posits that the relation between social orienting and ToM abilities should be present as soon as ToM emerges, an implicit ToM task was used with a population of young children. To measure implicit false belief, the version of the anticipatory looking task designed by Thoermer et al. (2012) was used. The two social orienting tasks used were a biological motion task adapted from Annaz et al. (2012) and a face preference measure adapted from Sasson, Dichter, and Bodfish (2012). We expected variable performance across individuals on the implicit false belief task. Furthermore, we expected that children would show social preference (i.e., longer looking at the social stimuli) on both social orienting tasks (face preference and biological motion tasks). We also expected these two measures to be positively correlated with one other. Finally, as predicted by the social motivation theory, we expected performance on each social orienting task to predict children's performance on the false belief task.

Method

Participants

A total of 38 children participated in this experiment (23 boys and 15 girls; M_{age} = 3.68 years, range = 2.08–4.50). Of these participants, 31 spoke English and 7 spoke French. Participants were recruited from a university database. They did not have any reported neurological or developmental disorders (e.g., language delay, epilepsy) and did not have any known first-degree relative with an ASD diagnosis. Participants' chronological ages and verbal and nonverbal age equivalents are listed in Table 1.

Materials and procedure

The implicit false belief task and the two social orienting tasks were administered on a 23-inch monitor. The monitor had an embedded camera that recorded participants' eye gaze during the experiment. To minimize fatigue effects, participants were tested in two separate sessions. During the first visit, each child's caregiver completed a consent form and a demographics questionnaire. Over two visits, participants completed five tasks: the implicit false belief task, two social orienting tasks

Table 1
Mean chronological age, nonverbal mental age, and verbal mental age of the sample.

	Chronological age (years)	DAS–NVMA (age equivalent in years)	PPVT–VMA (age equivalent in years)
Mean	3.68	4.11	4.29
Standard deviation	0.67	0.90	1.22
Range	2.08–4.50	2.58–5.58	1.83–6.92

Note. DAS–NVMA, Differential Abilities Scale–nonverbal mental age; PPVT–VMA, Peabody Picture Vocabulary Test–verbal mental age.

(biological motion preference and face preference), two subtests of the Differential Abilities Scale–Second Edition (DAS-II; Elliott, 2007), and the Peabody Picture Vocabulary Test–Fourth Edition (PPVT-IV; Dunn & Dunn, 2007). The subtests of the DAS-II and the PPVT-IV were administered to assess nonverbal and verbal cognitive abilities. The order of the tasks was counterbalanced across each visit. To maintain an optimal level of attention on the part of the participants, the tasks that required the children to be seated in front of a computer monitor were administered in one block and the cognitive tasks were administered in another block. The order of the tasks within each block was counterbalanced, and the order in which the blocks were presented was randomized.

Biological motion task

This preferential looking task was adapted from Annaz et al. (2012). A split screen featured point-light displays of a walking human on one side and a phase-scrambled human on the other. The human point-light stimulus was provided by Troje (2002). The walking human was composed of 13 point-light dots that were placed on major parts of the human (e.g., one head, two shoulders, two elbows, two hands, two hips, two knees, and two feet). The phase-scrambled display was created by making the motion trajectories play temporally out of phase. Participants viewed 8 trials showing a man walking and phase scrambled motion for a duration of 6 s each. All point-light displays appeared to be moving in one direction (right or left) but they remained stationary with no horizontal translation. Half of the trials displayed motion toward the right. The side of the screen on which the walking human was presented and the direction of the walking (right/left) was counterbalanced. Prior to each trial, a central fixation cross, accompanied by a chime sound, oriented children's attention to the screen. The dependent variable was the mean proportion of looking time at biological motion (i.e., walking human) across the 8 trials.

Face preference task

This task was adapted from Sasson et al. (2012). A split screen displayed a picture of a human (i.e., upper torso) on one side of the screen and a picture of an object on the other. Half of the humans were males, and the humans varied in age (infants to elderly) and ethnicity. Although this study did not test children with autism, the original stimuli used by Sasson et al. (2008) were maintained in order to be comparable to previous research. Half of the pictures of objects consisted of high autism interest (HAI; 10 images: vehicles, road signs, sets of blocks, electronic devices, and clocks), and the other half consisted of low autism interest (LAI; 10 images: clothing, instruments, plants, tools, and furniture). The goal of having these two categories (i.e., HAI and LAI) was to examine whether typically developing children's social preference, when assessed using a split screen, would also vary depending on the salience of the object presented alongside the social stimuli. Participants viewed 20 trials for a duration of 5 s each. The side on which the human was presented, and the order of male/female human and HAI/LAI object, was counterbalanced. Prior to each trial, a central fixation cross, accompanied by a chime sound, oriented children's attention to the center of the screen. The dependent variable was the mean proportion of looking time at the social stimulus (i.e., faces) across the 20 trials.

Implicit false belief task

This anticipatory looking false belief task, known as the autobox task, was adapted from Thoermer et al. (2012). Participants viewed three videos: two familiarization videos (26 s each) and a test video (35 s) assessing false belief understanding. The scene showed a protagonist at the center of the screen, two garages on either side of the screen, and a door above each garage. In the familiarization video, the protagonist watched a toy car move from one garage to the next. One familiarization video had the car moving from left to right, and the other one had the car moving from right to left; the order of these familiarization videos was counterbalanced. Once the car entered the garage on the opposite side of the screen, the protagonist disappeared from the screen. Following this, a chime was played at the same time as the two doors turned bright red. The doors remained red for a total of 3 s, serving as the anticipatory looking period. The protagonist then came out of the door above the garage containing the car and retrieved the object. A passing score was defined as the participant's first look directed toward the door above the garage where the car was located. This indicated that the child understood that the protagonist knew the actual location of the car, thereby correctly anticipating the protagonist's future action. The test trial showed the same car move from one garage to the other except that before the car reached the garage on the opposite side of the screen, a phone ring distracted the protagonist. While the protagonist was looking away, the car reversed and exited the scene on the side where it was at the start of the video. The protagonist then disappeared from the scene as in the familiarization videos, followed by the anticipatory period. To receive a passing score, the participant's first look needed to be directed toward the door above the garage where the car was initially heading. Therefore, a passing score was awarded if the participant was able to correctly anticipate the protagonist's action. Prior to each trial, an attractive attention-getter (a green circle), accompanied by a chime sound, oriented children's attention to the screen. Participants were included if they passed at least one familiarization trial, a criterion that was met by all participants.

Coding

The videos were coded offline by a female coder who was blind to the location of the stimuli because only the participants' faces were visible. She coded the participants' looking time (i.e., duration of looking to the left of the screen and to the right of the screen) for the biological motion, face preference, and implicit false belief tasks as well as the first look in the false belief task. To establish inter-rater reliability, 30% of the videos were coded by a second blind coder for each task. For the biological motion task, Cohen's kappa inter-rater reliability was .84. The proportion of looking at the social stimulus (walking human) was calculated to determine whether the participants had a social preference. For the face preference task, Cohen's kappa inter-rater reliability was .92. The proportion of looking at the social stimulus (human) was calculated to determine whether the participants had a social preference. For the implicit false belief task, Cohen's kappa inter-rater reliability was .82. Finally, the first look to the correct or incorrect side of the screen during the anticipatory looking period for the two familiarization trials and the test trial was identified.

Results

Participants' chronological age, verbal mental age, and nonverbal mental age all were normally distributed and did not include any outliers. Scores on the biological motion and face preference tasks were normally distributed and did not contain any outliers. Normality was not assessed for the implicit false belief task because it is a dichotomous variable. Four participants were excluded from some of the analyses because they did not complete the tasks (for a final sample of 34).

On the biological motion task, participants looked significantly longer at the social stimuli than at the nonsocial stimuli (see Table 2), thereby displaying the expected social preference. At the individual level, 68% (binomial test, p = .06) of the participants looked more at the human walking. As shown in Table 2, on the face preference task, participants also looked significantly longer at the social stimuli than at the nonsocial stimuli, demonstrating a social preference on a task with higher levels of saliency (i.e., colored pictures of humans and objects vs. point-light displays). Individual looking patterns revealed that on the face preference task 64% of the children tended to display a social preference (binomial test, p = .16). This social preference was observed when the social stimuli were paired with

Table 2
Mean proportion of looking time to the social stimulus in the social orienting tasks and to the correct door during the implicit false belief task.

	M	*SD*	*t* (*df*)	*p*	95% CI	*d*
Biological motion	.56	.12	3.11 (33)	.004	.02–.11	0.53
Face preference	.54	.09	3.32 (32)	.02	.01–.07	0.44
Face preference LAI	.59	.11	4.79 (32)	<.001	.05–.13	0.83
Face preference HAI	.49	.11	−0.30 (32)	.77	−.04 to .03	−0.05
Composite score	.55	.09	3.31 (37)	.002	.02–.08	0.54
Implicit false belief	.39	.33	−1.83 (31)	.08	−.26 to .01	−0.36

Note. CI, confidence interval; LAI, low autism interest; HAI, high autism interest.

the LAI objects, with 73% of children displaying a social preference (binomial test, $p = .01$), but was not observed when the social stimuli were paired with the HAI objects, with only 42% of children displaying a social preference (binomial test, $p = .49$). In addition, children looked longer at the social stimuli when they were paired with LAI objects than when they were paired with HAI objects, $t(32) = 4.39$, $p < .001$, $d = 0.87$. From the children's performance on the face preference task and the biological motion task, a composite social orienting score was calculated (i.e., average proportion of orienting to the social stimuli; see Table 2). At the individual level, 68% (binomial test, $p = .03$) of the participants looked longer at the social stimuli across both social orienting tasks.

A total of 42% of the children correctly anticipated the protagonist's action during the test trial of the false belief task. This proportion was not different from what would be expected by chance (binomial test, $p = .49$). The proportion of total looking at the correct side of the screen during the implicit false belief task was also calculated (total looking to correct side/total looking to both sides; see Table 2) and was also not different from what would be expected by chance.

To compare performance across the two social orienting tasks, and with the false belief task, a series of zero-order correlations was computed. The false discovery rate procedure suggested by Benjamini and Hochberg (1995) was used to correct for multiple comparisons. As expected, the biological motion task was positively correlated with the face preference task (see Table 3). In addition, children's performance on the face preference task when the social stimuli were paired with the LAI objects was positively correlated with their performance on the implicit false belief task. In contrast, there was no such link in the case of the false belief and biological motion tasks. Although the correlation between children's proportion of looking to the correct side of the screen and their performance on the face preference task (LAI condition) was in the expected direction, it was not statistically significant ($r = .32$, $p = .09$). Finally, children's composite social orienting score was not correlated with their performance on the implicit false belief task.

Table 3
Zero-order correlations, as well as bootstrapping confidence intervals, between the social orienting measures and the theory of mind task.

	Biological motion	Face preference	Face preference LAI	Face preference HAI	Social orienting	Implicit false belief
Biological motion	1	.45*	.45*	.27	.90*	.08
N		29	29	29	34	29
95% CI		.09–.73	.10–.69	−.12 to .60	.77–.95	−.22 to .68
Face preference		1	.81*	.82*	.81*	.12
N			33	33	33	29
95% CI			.64–.94	.73–.92	.63–.92	−.33 to .52
Face preference LAI			1	.35^t	.70*	.44*
N				33	33	29
95% CI				.03–.72	.46–.89	.08–.74
Face preference HAI				1	.60*	−.27
N					33	29
95% CI					.36–.80	−.62 to .18
Social orienting					1	.06
N						33
95% CI						−.23 to .59
Implicit false belief						1
N						
95% CI						

Note. An asterisk (*) indicates that the correlation is significant after the false discovery rate procedure (Benjamini & Hochberg, 1995) was applied, where the adjusted alpha is less than .05. A superscript "t" indicates a trend-level correlation. The correlations between the children's performance on the social orienting tasks are Pearson correlations (r), and the correlations between the children's performances on the social orienting tasks and the implicit false belief task (pass/fail) are point-biserial correlations (r_{pb}). LAI, low autism interest; HAI, high autism interest; CI, confidence interval.

As expected, participants' chronological age was not correlated with their social orienting composite score, $r(38) = -.24$, $p = .14$, or their performance on the implicit false belief task, point-biserial correlation (r_{pb})(33) = −.02, $p = .90$. Participants' nonverbal mental age assessed by the DAS-II was also unrelated to their social orienting composite score, $r(38) = -.16$, $p = .33$, and their performance on the implicit false belief task, $r_{pb}(33) = -.01$, $p = .95$. Similar findings were yielded with participants' verbal mental age assessed with the PPVT [social orienting composite score: $r(36) = -.14$, $p = 43$; implicit false belief: $r_{pb}(31) = -.16$, $p = .38$].

Finally, to directly test the hypothesis that children's performance on the social motivation tasks predicted their performance on the implicit false belief task, a binary logistic regression was conducted given that the outcome (i.e., performance on the implicit false belief task) is a dichotomous variable. Given that only the face preference trials where the social stimuli were paired with the LAI objects were significantly correlated with performance on the implicit false belief task, these scores were entered in the same block of the regression model as the biological motion scores. The logistic regression model was statistically significant, $\chi^2(2) = 6.39$, $p = .04$. The model explained 31% (Nagelkerke R^2) of the variance in implicit false belief performance and correctly classified 72% of the cases. Performance on the face preference task when the social stimuli were paired with the LAI objects significantly predicted performance on the implicit false belief task, $\beta = 12.21$, Wald = 3.97, $p = .05$. However, performance on the biological motion task did not significantly predict performance on the implicit false belief task, $\beta = -2.13$, Wald = .19, $p = .66$.

Discussion

The main objective of the current study was to test the generalization of the social motivation theory, proposed to account for social deficits present in children with ASD, to young neurotypical children. In doing so, we aimed to test whether children's social preference (i.e., social orienting) predicted their implicit false belief understanding. Results show that children who preferred the social stimuli, when they were paired with less interesting nonsocial objects (LAI objects), also directed their first look to the correct door in the anticipatory looking task. Thus, children who demonstrated a stronger preference for social stimuli were more likely to pass the implicit ToM task. The logistic regression analyses corroborated these findings, wherein the combined performance on the face preference with LAI objects and biological motion preference accurately predicted whether children would pass or fail the implicit false belief task and explained 31% of the variance in ToM performance. However, only face preference, but not biological motion, was a significant predictor of implicit false belief. These findings provide support for the social motivation theory, which posits that children's social motivation behaviors, such as orienting toward social stimuli, have downstream effects on the development of sociocognitive abilities, such as ToM (Chevallier et al., 2012). The current findings suggest that the mechanism through which social motivation affects the development of sociocognitive abilities is also applicable for typically developing individuals.

The overall relation between social motivation and implicit ToM, however, was found to be less robust than hypothesized, particularly given that contextual aspects of the face preference measure (i.e., interest level of the nonsocial stimuli) affected the link with implicit false belief performance. That is, when social stimuli were paired with nonsocial images that were of high interest to children, the overall preference for social stimuli was diminished and unrelated to performance on the implicit false belief task. This was also reflected in the significant difference in looking time at the social stimuli between the HAI trials and the LAI trials. These results are in line with Sasson, Elison, Turner-Brown, Dichter, and Bodfish (2011), who reported that the 5-year-olds in their study explored more social images when paired with LAI objects than when paired with HAI objects. As such, children have similar looking patterns when these stimuli are presented in arrays versus in a split screen to measure social orienting. Children failed to show a social preference when the social stimuli were paired with objects that are of high interest for children with ASD. This demonstrates that HAI objects, which were selected because they are considered of circumscribed interests for children with ASD, are also highly salient to typically developing children. As such, we encourage caution when testing social preference because the saliency of artifacts found in atypical populations could also be observed in neurotypical children.

Unexpectedly, children's performance on the biological motion preference task was not related to their performance on the implicit ToM task. Furthermore, when a composite social orienting score was calculated by combining the scores on both the face preference task and the biological motion task, null results were observed. However, it is well established that most species, from domestic fowls to humans, possess primitive neural pathways that make them preferentially attend to biological motion. In addition, biological motion is preferred across a wide range of species that display no sociocognitive skills or primitive ones (Blake, 1993; Dittrich, Lea, Barrett, & Gurr, 1998; Mascalzoni, Regolin, & Vallortigara, 2010; Rosa Salva, Mayer, & Vallortigara, 2015). In adults, a dissociation between sensitivity for form and motion cues in point-light displays of biological motion and social cognition demonstrates that these two mechanisms, while important for biological motion perception, might tap into different aspects of social perception (Miller & Saygin, 2013). Thus, it is possible that visual preference for human-like social stimuli, such as faces and the human body, is uniquely related to children's implicit ToM abilities. Nevertheless, one might speculate that preference for biological motion might be related to simpler building blocks of ToM, such as goal detection.

Another objective of the current study was to assess social orienting across two different tasks and identify potential inter-task convergence of the social motivation construct in preschool children. As expected, children showed a social preference on both the face preference task and the biological motion task, results that replicate those of other researchers using similar stimuli (Annaz et al., 2012; Sasson et al., 2012). Moreover, the biological motion task was positively correlated with the face preference task. This provides evidence that the biological motion task and the face preference task both assess a related construct—social orienting. To the best of our knowledge, previous studies have included only one measure of social orienting, and none has assessed the within-participants convergence of multiple measures of social motivation. Providing evidence for construct validity enriches the extant literature because it permits researchers to treat low-level (biological motion) and high-level (faces) social stimuli as tapping into the same underlying construct. These results indicate that children, spanning from 2 to 4.5 years of age, preferentially orient toward a wide range of socially relevant information in their environment. Nevertheless, despite this significant correlation, only social orienting assessed with the face preference task predicted ToM performance, indicating that the level of social saliency is an important factor when examining this relation.

Interestingly, in the current study there was no link observed between children's chronological age, nonverbal mental age, or verbal mental age and their scores on the social orienting and ToM tasks. Similar stimuli to those used in the face preference task were presented to 9-year-olds in a study comparing children diagnosed with ASD with neurotypical controls, and no age effect was reported (Sasson et al., 2008). Annaz et al. (2012) used a biological motion task similar to ours on both an ASD group (M_{age} = 5.50 years) and a typically developing control group (M_{age} = 5.58 years), and verbal mental age was not a significant covariate. The results of the current study indicate that even younger children are able to process the same images and point-light displays and exhibit a social preference. This suggests that such social preference might develop early and remain stable across age groups. Similarly, we failed to find an age effect on the ToM task, as measured by anticipatory looking. This would be expected because this type of behavior (i.e., anticipatory looking) is typically observed in infants and toddlers (Southgate et al., 2007; Thoermer et al., 2012). Some researchers have suggested that behaviors observed in implicit tasks might not be based on the reasoning observed in older children and adults but rather reflect a separate ToM system altogether that develops independently (Apperly & Butterfill, 2009; Low, Apperly, Butterfill, & Rakoczy, 2016). Specifically, they proposed an "efficient mindreading system [that] is evolutionarily and ontogenetically ancient, operates quickly, and is largely automatic and independent of central cognitive resources" (i.e., implicit ToM) and a "flexible mindreading system [that] develops late, operates slowly, and makes substantial demands on executive control processes" (i.e., explicit ToM) (Low et al., 2016, p. 2). Implicit ToM, therefore, is thought to develop early in infancy and remains stable throughout the lifespan (Low et al., 2016), which would explain why we failed to find an age effect when measuring implicit false belief in preschoolers. According to this view, when measured concurrently, implicit false belief and explicit false belief should be dissociated; a few studies have reported such a dissociation in 3- and 4-year-olds (Burnside et al., 2017; Grosse Wiesmann et al., 2016; Low & Watts, 2013). In contrast, one longitudinal study found that 18-month-old infants' anticipatory looking in the current false belief task predicted explicit false belief at 4 years of age, showing some support for the two constructs not being entirely dissociated (Thoermer et al., 2012).

Implicit ToM has been argued to emerge during the second year of life when low task demands are used (e.g., violation of expectation and anticipatory looking paradigms) (Scott & Baillargeon, 2017; Slaughter, 2015). For example, Wang and Leslie (2016) directly compared high- and low-demand anticipatory looking tasks in adults and in young children aged 2–4 years. The researchers reported a difference in performance between the low-demand and high-demand tasks in both the preschoolers and the adults, showing that task demands affect participants' performance on anticipatory looking tasks measuring the same construct. The implicit false belief task used in the current study was adapted from the one used by Thoermer et al. (2012). In the original study, 55% of the 18-month-olds passed this implicit false belief task. Interestingly, children's performance on the implicit false belief task in the current study was not different from what would be expected by chance. Previous research with children in the same age range has shown that children succeed on implicit false belief tasks based on anticipatory looking (Grosse Wiesmann et al., 2016; Low, 2010; Schuwerk, Jarvers, Vuori, & Sodian, 2016; Southgate et al., 2007). However, throughout the implicit false belief literature, a variable proportion of participants across a wide age range pass this task (with success rates ranging from 54% to 85%). It has been suggested that slight methodological changes across anticipatory looking tasks measuring implicit false belief affect participants' performance (Low et al., 2016).

A recent study revealed similar poor performance in young children on the same implicit false belief task, suggesting that this task is a conservative test of implicit false belief understanding because of higher task demands (e.g., inhibit looking where the car disappeared; Burnside et al., 2017). Despite the relatively poor performance of the current sample, the nearly balanced distribution of children who passed versus failed allowed for an analysis of stability, that is, whether individual differences in implicit false belief performance were related to individual differences on the social orienting tasks. Further research should examine the relation between social motivation and various implicit ToM tasks because some of these tasks have been found to be difficult to replicate (see Burnside et al., 2017; Dörrenberg et al., 2018; Poulin-Dubois & Yott, 2017; Powell et al., 2017).

Relatedly, there is an ongoing debate surrounding the construct validity of implicit ToM tasks. Most researchers participating in the ongoing debate adopt either a rich view (i.e., the tasks measure a mature ToM understanding) (Baillargeon et al., 2016; Scott, 2017) or a lean view (i.e., the tasks measure domain-general abilities such as novelty preference) (Heyes, 2014, 2017) of young children's performance on implicit ToM tasks. As such, it is possible that the construct measured by these implicit tasks is leaner than a mature ToM understanding. If so, the current results could indicate that social orienting is positively related to *precursor* abilities to false belief reasoning. It is possible that these precursors are infants' ability to track behavioral rules (Ruffman, 2014). As such, the observed relation with social orienting could reflect that children who are more attentive to social regularities (e.g., faces) are also more attentive to behavioral rules/regularities.

Chevallier et al. (2014) investigated the role of the audience effect (e.g., having an experimenter present vs. absent) when completing an explicit forced-choice ToM task. The researchers found a difference between children with ASD and typically developing children on the ToM task when the experimenter was present. Specifically, the typically developing children outperformed the children with ASD in this condition. The researchers did not find this group difference when the experimenter was absent during the administration of the ToM task. Although these findings provide preliminary evidence that social motivation might also be related to explicit ToM understanding, this paradigm examined the audience effect, which is more a reflection of social reward (i.e., pleasure from social interactions) than social orienting (Chevallier et al., 2012). Future studies examining both false belief and social orienting longitudinally (with both assessed implicitly and explicitly) will be needed to help elucidate the nature of the relation between these constructs.

The investigation of the social motivation theory in typically developing children is a necessary step toward testing the hypotheses generated by this theory. Crucially, understanding how theories of atypical development extend or apply to typically developing populations allows for a basis for interpreting the results of research with atypical populations. In a recent study, Burnside et al. (2017) compared children with ASD with typically developing children on these same measures of face preference, biological motion preference, and an implicit false belief understanding. Results of the current study are helpful in interpreting the pattern of results in Burnside et al. (2017) because the older typically developing children in that study also showed a pattern of diminished preference for faces within the context of high-interest objects but not low-interest objects. Moreover, consistent with the social motivation theory, typically developing children were found to outperform children with ASD on both social orienting tasks and the implicit false belief task. In the current study, the preschoolers' performance on the implicit false belief task is also in line with the typically developing children in the study conducted by Burnside et al. (2017).

It is hoped that the current findings will stimulate continued investigation of the relation between social motivation and the development of sociocognitive abilities. Future studies using a longitudinal design will be crucial in determining whether social orienting during infancy predicts later ToM understanding. Unlike a correlational design, it would provide direct evidence for the social motivation theory and, thus, further inform the assessment of early signs of atypical development. In addition, a longitudinal design would also be helpful in determining whether lower-level social stimuli are stronger predictors of ToM understanding in younger age groups, whereas higher-level social stimuli are stronger predictors of ToM understanding as children develop more advanced sociocognitive abilities. This research may combine both implicit and explicit measures of ToM, such as the traditional explicit ToM task, which is not typically passed by children under 5 years of age. Such an investigation may also shed light on the possible reasons why in the current study biological motion, although efficacious in measuring social motivation, did not predict implicit false belief understanding.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jecp.2018.05.015.

References

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, DC: Author.

Annaz, D., Campbell, R., Coleman, M., Milne, E., & Swettenham, J. (2012). Young children with autism spectrum disorder do not preferentially attend to biological motion. *Journal of Autism and Developmental Disorders, 42*, 401–408.

Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological Review, 116*, 953–970.

Baillargeon, R., Scott, R. M., & Bian, L. (2016). Psychological reasoning in infancy. *Annual Review of Psychology, 67*, 159–186.

Baillargeon, R., Scott, R. M., & He, Z. (2010). False-belief understanding in infants. *Trends in Cognitive Sciences, 14*, 110–118.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition, 21*, 37–46.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, 57*, 289–300.

Blake, R. (1993). Cats perceive biological motion. *Psychological Science, 4*, 54–57.

Broekhof, E., Ketelaar, L., Stockmann, L., Zijp, A., Bos, M. N., & Rieffe, C. (2015). The understanding of intentions, desires, and beliefs in young children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 45*, 2035–2045.

Burnside, K., Ruel, A., Azar, N., & Poulin-Dubois, D. (2017). Implicit false belief across the lifespan: Non-replication of an anticipatory looking task. *Cognitive Development*. https://doi.org/10.1016/j.cogdev.2017.08.006. Advance online publication.

Burnside, K., Wright, K., & Poulin-Dubois, D. (2017). Social motivation and implicit theory of mind in children with autism spectrum disorder. *Autism Research, 10*, 1834–1844.

Chawarska, K., Volkmar, F., & Klin, A. (2010). Limited attentional bias for faces in toddlers with autism spectrum disorders. *Archives of General Psychiatry, 67*, 178–185.

Chevallier, C., Kohls, G., Troiani, V., Brodkin, E. S., & Schultz, R. T. (2012). The social motivation theory of autism. *Trends in Cognitive Sciences, 16*, 231–239.

Chevallier, C., Parish-Morris, J., Tonge, N., Le, L., Miller, J., & Schultz, R. T. (2014). Susceptibility to the audience effect explains performance gap between children with and without autism in a theory of mind task. *Journal of Experimental Psychology: General, 143*, 972–979.

Clements, W. A., & Perner, J. (1994). Implicit understanding of belief. *Cognitive Development, 9*, 377–395.

Csibra, G., & Southgate, V. (2006). Evidence for infants' understanding of false beliefs should not be dismissed. *Trends in Cognitive Sciences, 10*, 4–5.

Curtin, S., & Vouloumanos, A. (2013). Speech preference predicts autistic-like behavior in 18-months-olds at risk for autism spectrum disorder. *Journal of Autism and Developmental Disorders, 43*, 2114–2120.

Dittrich, W. H., Lea, S. G., Barrett, J., & Gurr, P. R. (1998). Categorization of natural movements by pigeons: Visual concept discrimination and biological motion. *Journal of the Experimental Analysis of Behavior, 70*, 281–299.

Dörrenberg, S., Rakoczy, H., & Liszkowski, U. (2018). How (not) to measure infant theory of mind: Testing the replicability and validity of four non-verbal measures. *Cognitive Development*. https://doi.org/10.1016/j.cogdev.2018.01.001. Advance online publication.

Dunn, L. M., & Dunn, D. M. (2007). *Peabody picture vocabulary test* (4th ed.). Bloomington, MN: Pearson.

Elliott, C. D. (2007). *Differential abilities scale* (2nd ed.). Bloomington, MN: Pearson.

Falck-Ytter, T., Rehnberg, E., & Bölte, S. (2013). Lack of visual orienting to biological motion and audiovisual synchrony in 3-year-olds with autism. *PLoS ONE, 8*, e68816.

Grosse Wiesmann, C., Friederici, A. D., Singer, T., & Steinbeis, N. (2016). Implicit and explicit false belief development in preschool children. *Developmental Science, 20*, e12445.

Heyes, C. (2014). False belief in infancy: A fresh look. *Developmental Science, 17*, 647–659.

Heyes, C. (2017). Apes submentalise. *Trends in Cognitive Sciences, 21*, 1–2.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics, 14*, 201–211.

Kimhi, Y. (2014). Theory of mind abilities and deficits in autism spectrum disorders. *Topics in Language Disorders, 34*, 329–343.

Klin, A., & Jones, W. (2008). Altered face scanning and impaired recognition of biological motion in a 15-month-old infant with autism. *Developmental Science, 11*, 40–46.

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry, 59*, 809–816.

Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year-olds with autism orient to non-social contingencies rather than biological motion. *Nature, 459*, 257–261.

Low, J. (2010). Preschoolers' implicit and explicit false-belief understanding: Relations with complex syntactical mastery. *Child Development, 81*, 597–615.

Low, J., Apperly, I. A., Butterfill, S. A., & Rakoczy, H. (2016). Cognitive architecture of belief reasoning in children and adults: A primer on the two-systems account. *Child Development Perspectives, 10*, 184–189.

Low, J., & Watts, J. (2013). Attributing false beliefs about object identity reveals a signature blind spot in humans' efficient mind-reading system. *Psychological Science, 24*, 305–311.

Mascalzoni, E., Regolin, L., & Vallortigara, G. (2010). Innate sensitivity for self-propelled causal agency in newly hatched chicks. *Proceedings of the National Academy of Sciences of the United States of America, 107*, 4483–4485.

Miller, L. E., & Saygin, A. P. (2013). Individual differences in the perception of biological motion: Links to social cognition and motor imagery. *Cognition, 128*, 140–148.

Pavlova, M. A. (2012). Biological motion processing as a hallmark of social cognition. *Cerebral Cortex, 22*, 981–995.

Poulin-Dubois, D., & Yott, J. (2017). Probing the depth of infants' theory of mind: Disunity in performance across paradigms. *Developmental Science*, e12600. https://doi.org/10.1111/desc.12600.

Powell, L. J., Hobbs, K., Bardis, A., Carey, S., & Saxe, R. (2017). Replications of implicit theory of mind tasks with varying representational demands. *Cognitive Development*. https://doi.org/10.1016/j.cogdev.2017.10.004. Advance online publication.

Rice, K., Anderson, L. C., Velnoskey, K., Thompson, J. C., & Redcay, E. (2016). Biological motion perception links diverse facets of theory of mind during middle childhood. *Journal of Experimental Child Psychology, 146*, 238–246.

Rosa Salva, O., Mayer, U., & Vallortigara, G. (2015). Roots of a social brain: Developmental models of emerging animacy-detection mechanisms. *Neuroscience and Biobehavioral Reviews, 50*, 150–168.

Ruffman, T. (2014). To belief or not belief: Children's theory of mind. *Developmental Review, 34*, 265–293.

Sasson, N. J., Dichter, G. S., & Bodfish, J. W. (2012). Affective responses by adults with autism are reduced to social images but elevated to images related to circumscribed interests. *PLoS ONE, 7*, e42457.

Sasson, N. J., Elison, J. T., Turner-Brown, L. M., Dichter, G. S., & Bodfish, J. W. (2011). Brief report: Circumscribed attention in young children with autism. *Journal of Autism and Developmental Disorders, 41*, 242–247.

Sasson, N. J., Turner-Brown, L. M., Holtzclaw, T. N., Lam, K. L., & Bodfish, J. W. (2008). Children with autism demonstrate circumscribed attention during passive viewing of complex social and nonsocial picture arrays. *Autism Research, 1*, 31–42.

Schneider, D., Slaughter, V., & Dux, P. (2015). What do we know about implicit false-belief tracking? *Psychonomic Bulletin & Review, 22*, 1–12.

Schuwerk, T., Jarvers, I., Vuori, M., & Sodian, B. (2016). Implicit mentalizing persists beyond early childhood and is profoundly impaired in children with autism spectrum condition. *Frontiers in Psychology, 7*. https://doi.org/10.3389/fpsyg.2016.01696.

Scott, R. M. (2017). The developmental origins of false-belief understanding. *Current Directions in Psychological Science, 26*, 68–74.

Scott, R. M., & Baillargeon, R. (2017). Early false-belief understanding. *Trends in Cognitive Sciences, 21*, 237–249.

Senju, A., & Johnson, M. H. (2009). The eye contact effect: Mechanisms and development. *Trends in Cognitive Sciences, 13*, 127–134.

Simion, F., Regolin, L., & Bulf, H. (2008). A predisposition for biological motion in the newborn baby. *Proceedings of the National Academy of Sciences of the United States of America, 105*, 809–813.

Slaughter, V. (2015). Theory of mind in infants and young children: A review. *Australian Psychologist, 50*, 169–172.

Southgate, V., Senju, A., & Csibra, G. (2007). Action anticipation through attribution of false belief by 2-year-olds. *Psychological Science, 18*, 587–592.

Thoermer, C., Sodian, B., Vuori, M., Perst, H., & Kristen, S. (2012). Continuity from an implicit to an explicit understanding of false belief from infancy to preschool age. *British Journal of Developmental Psychology, 30*, 172–187.

Troje, N. F. (2002). Decomposing biological motion: A framework for analysis and synthesis of human gait patterns. *Journal of Vision, 2*, 371–387.
Wang, L., & Leslie, A. M. (2016). Is implicit theory of mind the "real deal"? The own-belief/true-belief default in adults and young preschoolers. *Mind & Language, 31*, 147–176.
Wellman, H. M. (2014). *Making minds: How theory of mind develops*. Oxford, UK: Oxford University Press.
Wellman, H. M., & Liu, D. (2004). Scaling of theory-of-mind tasks. *Child Development, 75*, 523–541.
Wright, K., Kelley, E., & Poulin-Dubois, D. (2016). Biological motion and the animate–inanimate distinction in children with high-functioning autism spectrum disorder. *Research in Autism Spectrum Disorders, 25*, 1–11.
Yott, J., & Poulin-Dubois, D. (2012). Breaking the rules: Do infants have a true understanding of false belief? *British Journal of Developmental Psychology, 30*, 156–171.