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The relationship between theory of mind and mental rotation ability in preschool-aged children

Jennifer Lehmann[1]* and Petra Jansen[1]

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*Corresponding author: Jennifer Lehmann, Faculty of Psychology, Education and Sport Sciene, Department of Sport Science, University of Regensburg, Regensburg, 93053, Germany
E-mail: jennifer.lehmann@ur.de

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Stefan Elmer, Department Neuropsychology, University of Zurich, Zurich, Switzerland

Additional information is available at the end of the article

Abstract: This study investigates the relationship between two tasks of perspective taking, the social perspective taking ability, namely theory of mind, and the spatial one, namely mental rotation, in preschool-aged children. Both abilities develop during preschool age. We investigated 83 children aged between 3 and 4 years regarding their theory of mind and mental rotation ability. A significant correlation between both tasks was found for those children, who were able to solve the mental rotation task. This relation was no longer significant when analyzing the two age groups separately. Due to the small sample size as well as the performance in the mental rotation test more research is needed to investigate this relationship and its role in development.

Subjects: Cognitive Science; Cognitive Development; Child Development

Keywords: theory of mind; mental rotation; perspective taking; preschool children

1. Introduction

It is the main goal of this paper to investigate if the social ability to impute mental states (theory of mind) relates to the spatial ability to imagine objects in mind (mental rotation) in preschool

ABOUT THE AUTHORS

Dr. Jennifer Lehmann studied sport science at the University of Cologne and obtained her PhD from the University of Regensburg. There she is working as a lecturer and researcher at the Department of Sport Science on projects dealing with the relationship of cognitive and motor abilities

Prof. Dr. Petra Jansen studied biological and social anthropology, psychology and mathematics at the Johannes-Gutenberg University of Mainz. She obtained her PhD and her habilitation in experimental psychology at the Universities of Duisburg-Essen and Düsseldorf. Since 2008, she is the head of the Department of Sport Science in Regensburg. Her research focuses on the relation of motor, cognitive, and emotional processes, gender difference in cognitive abilities, embodiment and mindfulness.

The research of both authors focuses on the investigation of the development of spatial cognition, especially mental rotation. They could show that this development relates to motor development as well as working memory development.

PUBLIC INTEREST STATEMENT

The ability to take the perspective of others is one of the important aspects of social development. It is investigated with the so-called theory of mind paradigm. In the presented study, we could show that this ability relates to the spatial ability to imagine pictures from another point of view. This gives a hint that the development of social and spatial abilities of perspective taking is somehow interwoven in young children. However, more research needs to be done to show the exact interaction between those abilities and in the broader sense the interaction between social and cognitive development.

children. Thereby, the Theory of Mind (ToM) refers to states, such as feelings, wishes as well as beliefs, of oneself or others (Premack & Woodruff, 1978). In former studies, the ability to attribute mental states has often been investigated with the false-belief-tasks (Wimmer & Perner, 1983). In these tasks, the calculation of a wrong false belief is claimed even though one self's knowledge is different (false belief) or in which the belief of another person is in accordance with one's own belief (true belief). One example of a specific task could be the following, where the experimenter presented to the child the story with two toy figures, Maxi and the mother of Maxi. In this story, Maxi places a chocolate in a drawer and leaves the room, when the mother comes into the room and finds the chocolate in the drawer she takes it out and puts it in the fridge. Children who have developed a ToM can answer the question where Maxi would look for the chocolate when he comes into the room again. The crucial development for an explicit understanding of mental processes in children takes place at the age between 3 and 5 years. Wellman, Cross, and Watson (2001) showed in their meta-analysis that the development of the ToM-ability is independent of the kind of the used ToM-tasks as well as of cultural influences. While children at the age of 30 months could only solve 20% of the false belief tasks, children at the age of 44 months were able to solve 50% of those tasks correctly. At the age of 4 years, most of the children can solve ToM-tasks properly, which means that they have an understanding of false beliefs.

Mental rotation describes the spatial ability to mentally rotate two- or three-dimensional objects as fast and as accurate as possible (Linn & Petersen, 1985; Shepard & Metzler, 1971). This ability is often used in daily life (e.g. mathematics (Hegarty & Kozheynikov, 1999)) and develops continuously from 3 to 5 years with huge individual differences (Estes, 1998; Frick, Ferrara, & Newcombe, 2013a; Frick, Hansen, & Newcombe, 2013; Levine, Huttenlocher, Taylor, & Langrock, 1999; Möhring & Frick, 2013; Newcombe, & Frick, 2010). Frick et al. (2013) indicate that children who answer above chance level have an understanding of mental rotation strategy. Thereby one kind of strategy is often a perspective-taking strategy. To solve the mental rotation task one puts oneself into the task to change perspective and to detect which solution is the right one. Estes (1998) stated that the awareness and the conceptual understanding of mental phenomena develop together and seem to influence each other. This means that children develop an awareness of their mind´s activity and can differentiate thinking from other internal processes such as seeing or talking. For both tasks, mental rotation and theory of mind, a deliberated access to mental stimulation is necessary. He concludes that those children, who are not able to perform a mental rotation task properly, do not have a sufficient conceptual understanding of mental phenomenon such as theory of mind (Estes, 1998). Thus, children who have not developed awareness for internal processes do not understand mental rotation and theory of mind. Frick, Möhring, and Newcombe (2014) analysed in a review theoretically the development of mental rotation and theory of mind in kindergartners and argued for a possible common underlying cognitive and developmental mechanism due to the results that some children at the age of 4 years can already solve both tasks whereas others fail in both tasks. This underlying process could be the mental simulation that can be used as a strategy to solve problems. Frick et al. (2014) assumed that an improvement in imaginative power could help children to simulate more complex situations and might be responsible for the developmental progress in the ability of the theory of mind. Additionally, they argue: "...the ability to flexibly change mental representations may even be more fundamental..." (Frick et al., 2014, p.11).

Even though MR and ToM abilities require perspective-taking abilities, namely spatial and social ones, the relation of both abilities has not been systematically investigated until now. Perner and Roessler (2012) argue that perspective taking, which was first investigated by Piaget and Inhelder (1956) in the seminal three mountains task, is required to develop the social perspective taking ability assessed in ToM tasks. Viana, Zambrana, Karevold, and Pons (2016) demonstrated that the ToM abilities of children between 5 and 9 years of age are better predictors of their spatial abilities in a social context than their age, their gender or their spatial abilities assessed in an individual setting. However, in a study with 12 to 50 months infants, Sodian and Kristen-Antonow (2015) provided evidence that "level 1" perspective-taking abilities were not correlated with later false

belief understanding. Level 1 perspective taking abilities demonstrate that children know what others can or cannot see from their own viewpoint.

Thus, the existing scientific evidence is conflicting: Whereas Perner and Roessler (2012) assumed a positive correlation between perspective taking and ToM, Sodian and Kristen-Antonow (2015) did not. However, both studies did not relate mental rotation performance to ToM. For this, this study will characterize the interplay between ToM and mental rotation abilities. According to Frick et al. (2014), we assume a positive correlation between mental rotation and theory of mind.

2. Method

1. Participants

In total, 83 children from two German kindergartens participated in this study with a mean age of M = 3.54 (SD = .52). The sample consisted of 43 girls and 40 boys, which were further divided into the two age groups of 3-year-old children (M = 3.05, SD = .22, 17 girls and 25 boys) and 4-year-old children (M = 4.04, SD = .03, 26 girls and 15 boys). This age range was chosen based on the literature showing an important developmental shift in the explicit understanding of mental processes (e.g. Henning, Daum, & Aschersleben, 2009; Wellman et al., 2001) between 3 and 5 years of age. As most of the 4-year-old children can already differentiate between visual illusion and reality, whereas most of the 3-year-old children are not able to do so, we chose this age range (Perner & Lang, 1999). The groups were separated into those who were 3-year-old and those who were 4-year-old. Thereby, the cut-off-criterion was the age itself. The age range for the 3-year-old children was from 36 month until 47 months and the age range for the 4-year-old children was from 48 month until 59 month. All parents gave their written consent for participation of their child. The experiment was conducted according to the ethical guidelines of the American Psychological Association.

3. Material

3.1. Questionnaire

The questionnaire included demographic data as well as questions regarding the socioeconomic status.

3.2. Theory of mind test

The Theory of Mind (ToM) was measured with the German translation of the Theory of Mind scale for 3- to 5-year-old children form Wellman, Phillips, Dunphy-Lelii and Lalonde (2004) (in the German version: Hofer & Aschersleben, 2007). The test consists of five different independent tasks and one additional task with increasing difficulty. While the first and second task addresses the distinction on oneself wish (belief) from others, the third task is about access to knowledge, the fourth and fifth tasks are about false believes regarding places and contents. The additional task captures whether children can differentiate between pretended and real feelings. All tasks are presented in short stories and with “playmobil figures”, accordingly to the age of the children. Each task is tested with two questions regarding the aim as well as control and memory. Only if both questions are answered correctly the task will be interpreted as solved. This results in a maximum score of 5. Additionally, a false belief score can be calculated out of the tasks 4 and 5, with a maximum score of 2. Due to inconsistence in the literature (Aschersleben, Hofer, & Jovanovic, 2008; Henning, Spinath, & Aschersleben, 2010; Wellmann, et al., 2004), both scores are used here. The unit of measurement of the ToM as well as the false belief tasks were integral numbers with the maximums reported above. Due to the use of this scale in earlier studies (Liu, Wellman, Tardif, & Sabbagh, 2008; Wellman et al., 2001), we used this scale.

3.3. Mental rotation test

The ability of mental rotation was assessed with the Picture Mental Rotation Test (BIRT) (Quaiser-Pohl, Rohe, & Amberger, 2010), which is approved for the age range of our study. This no-time-limit

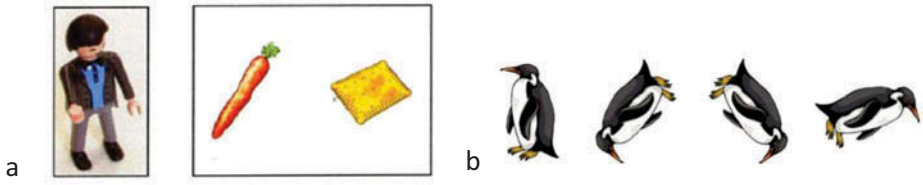

Figure 1. Examples for the theory of mind task (a) and the mental rotation task (b)

In the Theory of mind Task (a) it is assessed, if the child can distinguish between the own wish (I`d rather like to eat the biscuit) and the wish of another person (Mr. Miller likes to eat a carrot). The child is

paper and pencil test consists of two examples as well as 16 test items. Each item is composed of one standardized picture on the left side of the paper and three repeated pictures on the right side of the paper, rotated 45°, 90°, 135°, or 180° in relation to the standardized object on the left side. Only one of the three comparison pictures is identical to the standard item, while the other two pictures are mirror-reversed. Children have to mark which one of the three rotated pictures is identical to the standard item. Split-half reliability is .74 and the maximum score is 16, with the unit of measurement of integral numbers. Figure 1 shows an example of the Theory of Mind and the Mental Rotation Task. The task has been already used with kindergarten children in former studies (Jansen & Heil, 2010; Lehmann, Quaiser-Pohl, & Jansen, 2014).

4. Procedure

Each child was tested separately in a quiet room in two kindergartens. The order of the tasks was counterbalanced across the children. At the beginning of the tests, it was explained to the child that some new games were going to be played to avoid a situation in which the children felt under pressure. At the end of the test session, the children received small presents for their participation. One female examiner collected data.

4.1. Statistical analysis

For all measurements, we used the number of correct solved items as an indicator. For the analysis of the mental rotation task, we only included those children, who did not guess and answered at least 50% of the task correctly. Based on this criterion, we had to exclude 37 children from the analysis resulting in a sample of N = 46 (M = 3.66, SD = .49, 27 girls and 19 boys; 3 years: M = 3.05, SD = .02, 6 girls and 12 boys; 4 years: M = 4.04, SD = .03, 21 girls and 7 boys). We then conducted a multivariate analysis for the performance in the BIRT, ToM and False-Believe Task with age as an independent variable. Due to the fact that the multivariate box-test was not significant, the hypothesis of the equality of the variance-covariance matrices is not rejected (p = .054) and therefore the requirements to perform a multivariate analysis are fulfilled. Additionally, a correlation analysis between mental rotation and ToM performance was conducted. We alpha-corrected the correlational analysis in line with Bonferroni (according to Field (2009)), resulting in a corrected significance level of $p < .017$. All results for the tests are presented in table 1.

Table 1. Demographic and performance data of the children

	Total sample (n = 46)	3-year old (n = 18)	4-year old (n = 28)	p
Mean age (SD)	3.66 (.49)	3.05 (.02)	4.04 (.03)	
Sex	27 girls 19 boys	6 girls 12 boys	21 girls 7 boys	.238
BIRT (SD)	9.24 (1.32)	8.94 (.99)	9.43 (1.48)	.229
ToM (SD)	2.57 (1.41)	1.39 (.92)	3.32 (1.12)	.000
False Believe (SD)	.80 (.86)	.22 (.43)	1.18 (.86)	.000

5. Results

The analysis of variance revealed more correct solved items for the 4-year-old children in the ToM-scale ($F(1,44) = 37.21$, $p < .01$, $\eta = .458$) as well as the false belief task ($F(1,44) = 18.99$, $p < .01$, $\eta = .301$), but no significant differences in the BIRT ($F(1,44) = 1.49$, *n.s.*).

When calculating correlational analyses between the BIRT, ToM and the False-Belief Task we found significant correlations between the BIRT score and the ToM score ($r(46) = .356$, $p < .017$) as well as the BIRT and the False-Belief task ($r(43) = .395$, $p < .017$). Additionally, we calculated a correlational analysis for the two age groups. We neither found correlations for the 3-year-old children (BIRT and ToM: $r(18) = .282$, $p= .257$, and BIRT and False-Belief task: $r(18) = .444$, $p= .065$) nor for the 4-year-old children (BIRT and ToM: $r(28) = .338$, $p = .079$, and BIRT and False-Belief: $r(28) = .345$, $p = .072$).

6. Discussion

To our knowledge, this is the first study investigating the relationship between mental rotation and ToM in children between three and 4 years of age. While it seems that mental rotation and ToM have common underlying processes (Estes, 1998; Frick et al., 2014), these processes could be the ability to perform mental simulations and transformations (Estes, 1998; Frick et al., 2014). The presented study expected to deliver first hints not only in a theoretical but also in a practical way on this relationship between the two abilities.

We found a significant correlation between mental rotation performance and theory of mind for the sample of those children who were able to solve the BIRT (N = 46). For this, our results can confirm the assumption of Perner and Roessler's regarding the relation of spatial and social perspective taking in young children. Moreover, the results of the study are in line with the theoretical review of Frick et al. (2014) and we assume that the ability to mentally imagine something might be the underlying relevant mechanism. Nevertheless, more research is needed to investigate, if the ability to mentally simulate or the flexibility to change mental representations or, for example, the development of executive functions is the relevant underlying mechanism for the relation between MR and ToM.

However, there was no correlation when analyzing the two age groups, which might be due to the small number of children in each age group. It seems that in this context age is more relevant for the cognitive performance in the mental rotation than the ability to impute mental states. Additionally, we only found age effects for the theory of mind ability but no such effects for the mental rotation ability. While it seems that at the age of 3- and 4-years no differences in the mental rotation are present, as least in our sample, there are age effects for the theory of mind. This is in line with former studies showing that most children at the age of four are able to solve a ToM task, but children at the age of three often fail (Wellman et al., 2001). The fact that we did not find any age effects in the mental rotation might be due to the test applied. Although this test has been constructed for the relevant age group it might not be sensitive enough to differentiate the age groups tested. To conclude, a relation between spatial and social perspective taking was found. This is important due to the fact that the results show that at least some aspects of social and cognitive development should not be treated separately. This result provides evidence that social training in kindergarten might enhance cognitive abilities, as well as a cognitive training, might improve social development. Confirmation of a common mechanism between false belief task and visual perspective taking comes from a meta-analysis of fMRI studies showing a common activation of false belief reasoning and visual perspective taking in the left dorsal temporal parietal junction (Schurz, Aichhorn, Martin, & Perner, 2013).

7. Limitations and further research

The study is limited by the fact that only 46 out of 83 children were able to solve the mental rotation task above chance level successfully. The BIRT was chosen because it has been successfully applied in the study of Lehmann et al. (2014) with children as young as three and 4 years of age. However, this has to be considered carefully in further studies and it has to be reconsidered if other mental rotation

test should be applied. Due to the fact that the coefficients for the separate sample had high values, and at least one had a larger value than the complete sample, this might indicate, that the analysis lacked statistical power. Additionally, it might be that the tests we used lead to floor effects. Therefore, the study should be replicated with an increased sample size to have a more detailed look into the relationship between the two abilities for the different age groups.

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Competing Interests
The authors declare no competing interests.

Author details
Jennifer Lehmann[1]
E-mail: jennifer.lehmann@ur.de
Petra Jansen[1]
E-mail: petra.jansen@ur.de
[1] Faculty of Psychology, Education and Sport Sciene, Department of Sport Science, University of Regensburg, Regensburg, 93053, Germany.

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.

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