Journal of Experimental Child Psychology 128 (2014) 201–209

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Brief Report

Young children's agent-neutral representations of action roles

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ARTICLE INFO

Article history:
Received 21 November 2013
Revised 18 June 2014
Available online 26 July 2014

Keywords:
Cooperation
Planning
Action understanding
Action roles
Mental time travel
Social cognition

ABSTRACT

Recent developmental research has shown that young children coordinate complementary action roles with others. But what do they understand about the logical structure of such roles? Do they have an agent-neutral conception of complementary action roles, grasping that such roles can be variably filled by any two agents or even by one agent over time? Accordingly, can they make use of such representations for planning both their own and others' actions? To address these questions, 3- and 4-year-olds were introduced to an activity comprising two action roles, A and B, by seeing either two agents performing A and B collaboratively or one agent performing A and B individually. Children's flexible inferences from these demonstrations were then tested by asking them later on to plan ahead for the fulfillment of one of the roles either by themselves or by someone else. The 4-year-olds competently drew inferences in all directions, from past individual and collaborative demonstrations, when planning how they or someone else would need to fulfill the roles in the future. The 3-year-olds, in contrast, showed more restricted competence; they were capable of such inferences only when planning in the immediate present. Taken together, these results suggest that children form and use agent-neutral representations of action roles by 3 years of age and flexibly use such representations for episodic memory and future deliberation in planning their own and others' actions by 4 years of age. The findings are discussed in the broader context of the

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http://dx.doi.org/10.1016/j.jecp.2014.06.004

development of understanding self–other equivalence and agent-neutral frames of references.

Introduction

Many if not most everyday human activities are complex actions comprising different complementary parts or roles. Making a sauce hollandaise, for example, involves (among other things) the two complementary roles of pouring melted butter into a pot with egg yolk and whipping the resulting mixture. Performing "The Times They Are A-Changin'" involves three roles: singing, playing the guitar, and playing the harmonica.

Children begin to engage in complex activities involving different roles individually from the second year of life onward, particularly in their problem solving where they integrate different action roles (e.g., removing a cloth, grasping the object hidden underneath) in means–ends relations (e.g., Chen & Siegler, 2000; Willatts, 1985, 1999). Similarly, slightly later children also begin to engage in cooperative activities with complementary role structure (Brownell, 2011; Brownell, Ramani, & Zerwas, 2006; Tomasello & Hamann, 2012; Warneken, Chen, & Tomasello, 2006). Examples include joint problem solving in which one person operates one part of an apparatus so that the other person can retrieve some reward (Warneken et al., 2006). At around this time, children also begin to learn about complementary action roles in so-called "role reversal imitation" (Carpenter, Tomasello, & Striano, 2005); when they are shown how to perform one action role, A, in a coordinated activity with a partner performing the complementary role, B, they learn about A by firsthand experience but also learn about B by observation—as indicated in their capacity to imitate both A and B later on.

But what this leaves unclear is what exactly children *understand* about the logical structure of action roles. The studies on early coordination and role reversal might be taken to suggest that even toddlers understand action roles in adult-like ways. However, empirically the situation seems to be more complicated; it is not until much later that children reveal competence in coordinating complementary action roles when the situation is not largely scaffolded by adults (Ashley & Tomasello, 1998; Fletcher, Warneken, & Tomasello, 2012). Relatedly, from a theoretical point of view, what remains unclear is what types of representations underlie children's tracking of action roles. It is an essential feature of such roles that they are *agent neutral;* like variables that can be assigned different values, roles can be filled by different agents such that a role remains the same regardless of who fills it (and thus is neutral regarding its filler). Crucially, for a large class of activities with complementary roles,[1] agent neutrality means not only that each role can be variably filled by any person in the same way but also that two complementary roles can be filled by any set of two different agents *or* by one and the same agent. The three roles of "The Times They Are A-Changin'" can be cooperatively filled by three people playing together (say, by Peter, Paul, and Mary) or by one person filling all roles at the same time (say, by Dylan). Sauce hollandaise can be made by one person (pouring and whipping) or cooperatively by two people (one pouring and the other whipping). Understanding an action role in agent-neutral terms contrasts with an agent-centric, specifically egocentric conception of a role that does not allow for conceiving of the role like a variable that remains the same irrespective of who fills it. An agent with an egocentric conception of an action role can fill the role alone, but the agent cannot conceive of the role as a role equally fulfillable by someone else and, thus, fails to recognize the equivalence between his or her filling the role and someone else's doing so.

[1] This is the class of so-called "cooperatively neutral" activities (Bratman, 1992)—activities that can, but need not, be performed cooperatively; making a sauce hollandaise together, where one stirs and the other pours in the melted butter (Searle, 1990), is an example. "Cooperatively loaded" activities, in contrast, conceptually require interpersonal cooperation; dancing the tango together and kissing each other are examples.

Empirically, how can one test whether children operate with an agent-neutral conception of action roles in contrast to simpler agent-centric, in particular egocentric ones? The crucial evidence for such an agent-neutral conception is the capacity for flexible inferences as to how roles can be filled. Understanding two roles, A and B, of a potentially cooperative activity in agent-neutral terms means that regardless of how A and B have been introduced—by two people cooperating or by one person filling both roles—one understands that any two people can fill the roles cooperatively as much as any single person can fill them individually. In contrast, an agent might have learned to perform the complex activity comprising Roles A and B, or one of its elements, but remains restricted to egocentric procedural representations of A and/or B that allow only the agent to perform these actions. As a consequence, agent-neutral conceptions allow an inferential generality and flexibility lacking in the case of more egocentric representations. This is analogous to contrasting egocentric and more abstract types of representations in other areas. For example, egocentric spatial representations, in contrast to allocentric ones, specify for an agent the position of objects in space relative to the agent's own body and, thus, are of restricted inferential use; the subject cannot represent the relation of two objects in space to each other or the relation of an object to another agent's body (e.g., Burgess, 2006). The first aim of the current study, therefore, was to test whether children operate with an agent-neutral conception of action roles by testing whether they exhibit the inferential flexibility characteristic of such agent-neutral frameworks.

A second issue that remains unclear from existing studies is how abstract and flexible children's representations of action roles are—not regarding *who* fills the roles but rather regarding *when* the roles are filled. In our adult psychology, representations of action roles are neutral as to when a certain role is filled, allowing us to recognize the equivalence between performances of, say, the harmonica part of the "The Times They Are A-Changin'" in 1970, today, and tomorrow. Accordingly, such representations play a fundamental role in remembering past events and planning for future actions, both individual and cooperative ones. For example, when thinking about how to solve a novel problem in the future—say, cooking a complicated dish for the first time—we flexibly make use of the representation of the different roles involved (e.g., peeling vegetables, stirring sauces) in figuring out how to best orchestrate them. We make use of action role representations for imagining (episodic foresight) what kind of action a future situation would require by oneself or a partner—often on the basis of episodically remembering and reassembling elements of similar past events.

Episodic foresight on the basis of episodic memory has recently been documented in individual problem solving in 4-year-olds. For example, Suddendorf, Nielsen, and von Gehlen (2011) presented children with a novel problem—opening a novel box with a lock of a certain shape (e.g., square) with an unusual "key" (a stick with a square piece of wood attached)—in Room X and then distracted children for 15 min in Room Y, where they were finally told that they could go back and solve the task in Room X and were allowed to select one of three keys (e.g., square, round, or triangle). The 4-year-olds were above chance in their future-directed tool choices. The 3-year-olds, in contrast, failed this future planning version and succeeded only in an immediate present tense control condition with box and keys visible and no delay before the planning.

Whereas this study involved only simple individual actions, another recent study investigated future planning of actions with two roles. Russell, Alexis, and Clayton (2010) had children play a game of "blow football" with a partner. The players stood opposite each other at a table (the pitch) on which they tried to move a ball into each other's goal by blowing it with a straw. The two sides were symmetrical with one exception: On one side (the side that children did not play initially), the floor was lower so that children would need a box to stand on in order to be able to reach onto the pitch. After playing for a while, children were asked what objects would be needed if either they or another child played at the lower side either now or tomorrow (correct: straw + football + box). Both 3- and 4-year-olds found the current version to be easy both for themselves and for others but found the future-directed version to be very difficult (forgetting about the box). Interestingly, there was an asymmetry such that children found the future-directed version to be more difficult when they needed to plan for themselves than when they needed to plan for someone else. Thus, this study suggests that future-directed planning of more complex actions involving different roles might be a cognitive achievement developing only from around 4 years of age (and that different processes might be involved when planning for oneself vs. for someone else). The second aim of the current study, therefore, was to test systematically for children's capacity to use their representations of action roles in temporally flexible ways—to plan for the future (individually or collaboratively) based on past experience.

In the current study, children were introduced to an apparatus whose operation required the consecutive performance of two action roles, A and B (each with a specific tool), and saw the two roles either filled by one person individually or filled by two people cooperatively. Children were allowed to perform Role A and were then asked the crucial test question about the future continuation of the activity. Children were asked which tool they themselves (Self condition) or a partner (Other condition) would need to finish the activity (fill Role B). In Experiment 1, testing for children's temporally flexible memory-based planning, the test question was asked after a 15-min delay and distraction period. In Experiment 2, without delay, children were asked the test question immediately after having performed A.

The logic is as follows. If children have an agent-neutral, temporally flexible conception of action roles, they should be able to remember the past in such agent-neutral terms and plan for the future accordingly; if remembering A had been done as part of the bigger activity, they should plan ahead for the completion through the performance of B—regardless of by whom. If, in contrast, children operate with only an egocentric conception of action roles, they might be able to complete their own bigger activity by performing B after having performed A but would be unable to plan analogously for another agent. In addition, if children have an agent-neutral conception of action roles yet are limited in temporal flexibility, they might be able to plan for the immediate future (for both themselves and someone else) but might be restricted in their episodic memory and foresight concerning the representation of A or B performances.

Both 3- and 4-year-olds were tested because previous studies found that an understanding of more complex forms of cooperation and future planning seem to emerge at around this age.

Experiment 1

Method

Participants

A sample of 96 children comprising 48 3-year-olds (M = 39 months, range = 36–43, 25 girls and 23 boys) and 48 4-year olds (M = 51 months, range = 48–56, 15 girls and 33 boys) was recruited from a databank of children whose parents had previously given consent to experimental participation and came from mixed socioeconomic backgrounds. Children were tested by one of two pairs of female experimenters in the laboratory. An additional 7 children were tested but excluded from data analysis due to experimental error (n = 5) or failure to cooperate (n = 2).

Design and procedure

Children were randomly assigned to one of four conditions differing in type of demonstration (Individual or Collaborative) and addressee of tool choice (Self or Other). Children were tested by two female experimenters in the laboratory. The session, which lasted approximately 30 min, consisted of three phases: demonstration, distraction, and testing.

Demonstration phase. Experimenter 1 (E1) first introduced children to the "pling machine," a cardboard box with a small tube opening containing a toy xylophone, while Experimenter 2 (E2) positioned herself by a "marble track" hidden from children's view behind a room divider. E1 showed children that dropping marbles into the tube made a "pling" sound, and children were given five marbles to drop into the box. She then remarked that all of the marbles were now gone and that the only way to get new marbles was by operating the marble track, an apparatus that required problem solving and consecutive performance of two action roles, A and B, in order to obtain a marble (see Fig. 1). E1 and children then joined E2 behind the room divider, and E1 began introducing the marble track. The main part of the marble track consisted of a ramp. Alongside the tall end of the ramp, there was a Plexiglas chute with a small platform at the bottom holding a marble that could be moved up and down the chute. At the other end of the ramp was a small compartment in which marbles

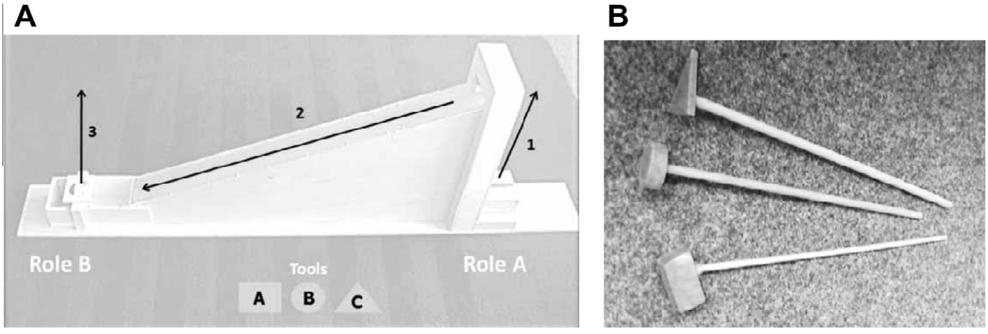

Fig. 1. (A) The marble track used in Experiments 1 and 2 with a schematic depiction of roles and tools: (1) Role A: one player lifts a marble up the elevator with the help of Tool A; (2) the marble runs down the ramp; (3) Role B: one player lifts the lid to retrieve the marble with the help of Tool B. (B) The three tools from which children needed to choose.

terminated once they had rolled down the ramp. The chute, ramp, and compartment were enclosed in Plexiglas so that children could see the marble and follow its course but could not reach it without performing the required steps. E1 first showed children the individual parts of the marble track by tracing the hypothetical course of the marble with her finger (up the chute, down the ramp, and into the compartment) without actually setting the marble into motion. While doing so, the experimenter emphasized that she could not reach the marble and encouraged children to try in order to ensure that they understood the basic problem-solving situation. She then introduced the tools (see Fig. 1). In the Individual condition both Roles A and B were performed by E1, whereas in the Collaborative condition A was performed by E1 and B was performed by E2.

Role A consisted of inserting Tool A, a stick with a rectangular block at the end, into a corresponding rectangular opening at the bottom end of the chute and pushing up the platform until it reached the top end and the marble rolled down the ramp into the compartment. Role B consisted of inserting Tool B, a stick with a magnetic round disc at the end, into a corresponding round opening in the roof of the compartment and lifting it, thereby giving access to the marble. After both roles had been performed, E1 encouraged children to throw the marble into the pling machine on the other side of the room divider. Meanwhile, E2 inserted a new marble into the chute and hid all tools except Tool A. When children returned, they were shown the new marble on the platform and were told that they could perform Role A, sending the marble down the ramp into the compartment. Children were then told that all other tools had been misplaced and that E2 would need to go look for them.

Distraction phase. The demonstration and testing phases were separated by a 15-min distraction phase during which children performed another task together with E1 on the other side of the room divider (i.e., marble track and E2 were out of view). The distraction phase ended with E1 calling to E2, asking whether she had found the tools.

Testing phase. During the testing phase, E2 emerged from behind the room divider with a box of three tools that she placed on a table: Tool A, Tool B, and Tool C (i.e., a distraction tool; see Fig. 1). Children were then asked the test question; children in the Self condition were asked which tool they would need to get the marble *themselves,* whereas children in the Other condition were asked which tool E2 would need to get the marble. Importantly, the marble track was out of sight during administration of the test question. After selecting the tool, children were free to run to the marble track to operate it themselves (Self condition) or to hand the tool to E2 (Other condition) so that she could operate it.

Results and discussion

The target-dependent measure was children's tool selection (A, B, or C) in response to the test question. To test for effects of age and condition type, we analyzed children's tool choice data in binary form (correct [Tool B] vs. incorrect [Tool A or C]; see Fig. 2A and B) and conducted a four-way log–linear analysis (Tool Choice × Age × Demonstration Type × Addressee Type). The log–linear analysis produced a model that retained the main effects and two- and three-way interactions. The likelihood ratio of this model was $\chi^2(0) = 0$, $p = 1$. There was a main effect of tool choice. Overall, children were more likely to choose the correct tool versus an incorrect tool, $\chi^2(1) = 22.97$, $p < .001$. The main effect of tool choice was driven mainly by 4-year-olds' choice behavior, indicated by a significant two-way interaction of Tool Choice × Age. Across demonstration type and addressee type, 4-year-olds (88%) were more likely to choose the correct tool compared with 3-year-olds (60%), $\chi^2(1) = 9.79$, $p < .005$. The odds ratio as a measure of effect size indicated that the odds of choosing the correct tool were 4.57 times higher for 4-year-olds than for 3-year-olds. We found no other two-way interactions. There was a three-way interaction of Tool Choice × Age × Addressee Type, $\chi^2(1) = 3.90$, $p < .05$. Follow-up analyses showed that across demonstration type, 4-year-olds were significantly better at choosing correctly for the other player compared with 3-year-olds, $\chi^2(1) = 11.10$, $p < .001$. There was no age difference in tool choice when children chose for themselves, $\chi^2(1) = 0.95$, $p = .33$. The odds ratio as a measure of effect size indicated that the odds of choosing the correct tool for the other player were 19.49 times higher for 4-year-olds than for 3-year-olds.

Next, we tested in each condition whether children chose correctly more often than expected by chance (i.e., 1/3 given three tools). The 4-year-olds chose correctly significantly above chance in all conditions (binomial tests, $ps < .001$), whereas the 3-year-olds did so only when choosing for themselves following an individual demonstration (binomial test, $p < .001$). The 4-year-olds showed clear signs of the capacity to form agent-neutral representations of action roles and to use these for future

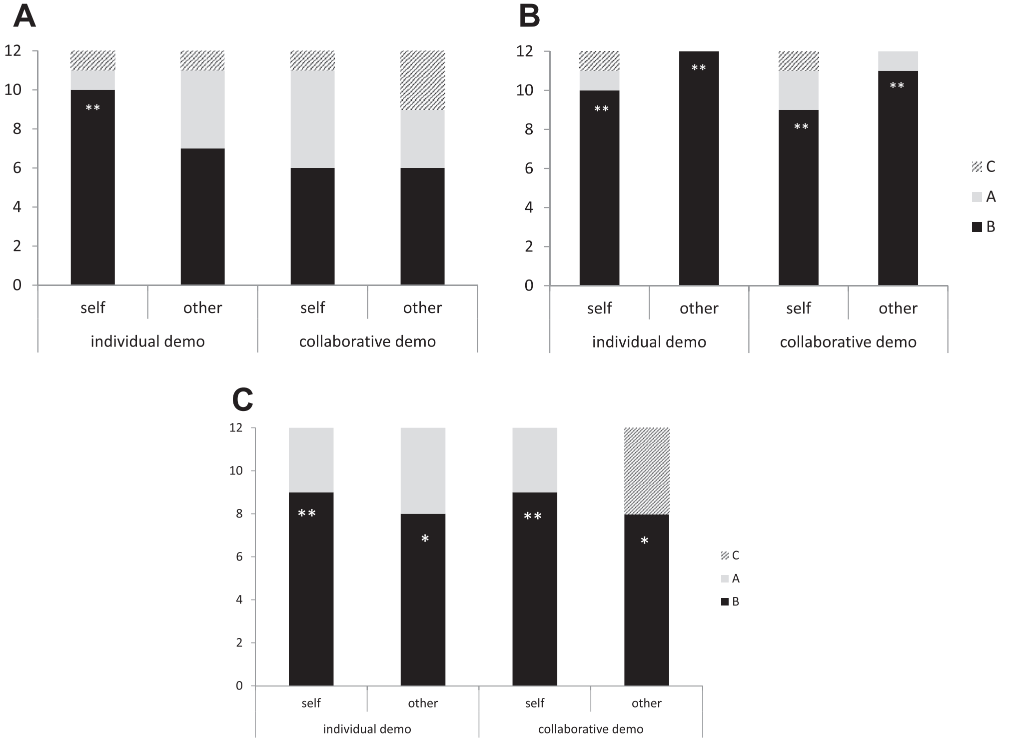

Fig. 2. (A,B) Percentages of 3-year-olds (A) and 4-year-olds (B) correctly choosing Tool B versus the distracter A or C as a function of condition in Experiment 1. (C) Percentages of children correctly choosing Tool B versus the distracter A or C as a function of condition in Experiment 2. Asterisks indicate a significant difference from chance (binomial tests against .33: $^{*}p < .05$; $^{**}p < .01$).

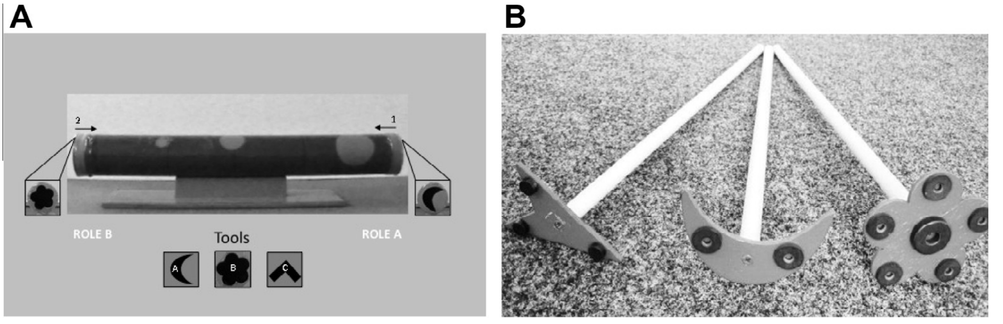

Fig. 3. (A) The tube apparatus used in Experiment 2 with a schematic depiction of roles and tools. To obtain the marble, Tool A needed to be inserted into a crescent-shaped opening on one end of the tube to push a platform holding a small magnetic box (1 cm^3) containing a marble toward the other end of the tube (Role A). Tool B could then be inserted into a flower-shaped opening at the other end of the tube to fetch the box (Role B). (B) The three tools from which children needed to choose.

planning, as indicated by their flexible inferences in all directions. The 3-year-olds, in contrast, showed restricted competence, planning appropriately only when they did so for themselves after individual demonstrations. This restricted inferential flexibility is consistent with a merely egocentric representation of Roles A and B. So, are 3-year-olds restricted to the use of egocentric role representations in principle, or do they have a framework of agent-neutral action role representations yet are limited in its temporal flexibility? In Experiment 2, we investigated children's representations of action roles without the temporally demanding delay between demonstration and planning.

Experiment 2

Method

Participants

A total of 24 different 3-year-old children ($M = 39$ months, range = 36–41, 13 girls and 11 boys) were included in the final sample. An additional 9 children were tested but excluded from data analyses due to experimental error ($n = 6$), equipment failure ($n = 1$), or uncooperativeness ($n = 2$).

Design and procedure

The design was similar to that of Experiment 1 with two exceptions: We removed the distraction phase and changed the design to a 2×2 one with demonstration type (Individual or Collaborative) as a between-participants factor and addressee type (Self or Other) as a within-participants factor. Children participated in two consecutive trials[2] with different apparatuses. In addition to the marble track from Experiment 1, a second apparatus similar to the marble track in structure and function was used (see Fig. 3), with assignment of apparatus to condition and order of presentation counterbalanced across children. Because there was no distraction phase, children performed Role A and were simply told that the box containing the other tools was now on the table behind the room divider. Again, children were asked the test question only after the apparatus was out of view.

Results and discussion

The proportions of children choosing the correct tool as a function of condition are depicted in Fig. 2C. Because preliminary analyses did not reveal any effects of the order of Self/Other trials or of Trial 1 versus Trial 2, these factors were skipped from subsequent analyses. The main analysis revealed

[2] Because there was no distraction period in Experiment 2, the session was much shorter than in Experiment 1 and allowed testing two trials rather than only one trial.

that there were no differences in children's tool choice between the Self and Other conditions overall (McNemar's test, $p = .75$) or between the Individual and Collaborative demonstration conditions: Self, $\chi^2(1) = 0$, $p = 1$; Other, $\chi^2(1) = 0$, $p = 1$. In addition, children chose correctly more often than expected by chance (1/3) in all conditions (binomial tests, $ps < .05$). These findings suggest that 3-year-olds can use agent-neutral action role representations in their individual and collaborative planning when the temporal structure of the tasks is suitably simplified.

General discussion

This study explored the developing capacity to form and use agent-neutral representations of complementary action roles. Both 3- and 4-year-olds saw an activity comprising complementary Roles A and B demonstrated either collaboratively by two agents or individually by one agent. After they had completed Role A themselves, and after some distraction (Experiment 1), children were asked which tool an agent would need to fulfill Role B in the future—where this agent was either the children themselves or someone else. The 4-year-olds performed competently in all conditions—revealing true agent-neutral representations of action roles flexibly usable for future-directed deliberation. The 3-year-olds, in contrast, performed poorly in Experiment 1 (competent only in drawing narrow inferences from an individual demonstration to a future individual decision for themselves). However, when the delay before planning, and thus the need for memory-based foresight, was removed in Experiment 2, the 3-year-olds competently drew broad inferences in all directions—just like the 4-year-olds in Experiment 1.

What these findings suggest is that at 3 years of age children do indeed have agent-neutral representations of action roles at their disposal but are still limited in their flexible temporal use of these representations. In fact, such a picture would fit closely with much other research on the development of temporal cognition. Quite generally, the capacity for mental time travel and foresight has been found to develop in the very age range between 3 and 5 years (Atance & O'Neill, 2001; McColgan & McCormack, 2008; Moore, Barresi, & Thompson, 1998; Suddendorf & Corballis, 2007). More specifically, the results of the current study are highly consistent with other recent findings of future tool choice as a measure of action planning; these studies converge on finding competence already in 3-year-olds when the planning is for the here and now, without much need to episodically remember a specific past event, but only from around 4 or 5 years of age when future-directed deliberation based on episodic memory is required (Russell et al., 2010; Suddendorf et al., 2011).

Although generally consistent with previous tool choice planning studies, the current study goes beyond these previous findings in two important ways. First, Experiment 2 suggests that 3-year-olds are not confined to individual and egocentric planning but can think about action roles in agent-neutral terms—understanding them as roles that can be filled by any one or two persons alike. Second, Experiment 1 suggests that although 3-year-olds are limited in their memory-based future planning of such abstract action roles, they seem to be competent at planning for themselves at least under some conditions (when the two roles of an action, one of which needs to be planned, have been introduced by one individual performing both roles and when children themselves perform both roles). How robust this finding is, and how it relates to recent findings suggesting a more fundamental deficit in future planning in 3-year-olds (Suddendorf et al., 2011), remains to be clarified in future research.

Regarding the cognitive underpinnings of self/other planning, one previous study found a striking asymmetry such that 4-year-olds were slightly better in future-directed planning for someone else than for themselves (Russell et al., 2010). One possible explanation is that 4-year-olds made use of their newly emerged and still fragile capacity for episodic future thinking in the first-person case and just general semantic thought about the future in the third-person case where the former was still more error prone than the latter (Russell et al., 2010). In contrast to this single previous finding, there was no such asymmetry whatsoever in the current experiments; if anything, the results point in the opposite direction given that the only condition in which 3-year-olds in Experiment 1 performed competently was when they planned for themselves. Why the results of these two studies diverge in this respect is currently not known. One plausible possibility is the following: Children in Russell and colleagues' (2010) study played an exciting game in one role for quite a while and, thus, were more engaged in this own role and had difficulty in disengaging from it when planning for themselves in another role. In our experiments, in contrast, there was no such intensive engagement in a role, meaning that disengagement was not an issue. Future research will need to explore, first, how robust and replicable the two patterns of findings are and, second, whether differential engagement might in fact explain their divergence.

An interesting open question for future research, finally, concerns the relation of the developing planning capacities for oneself or someone else studied here to prospective memory development. These phenomena seem to be closely linked and partly overlapping yet conceptually distinct. On the one hand, self-directed, memory-based planning seems to be intimately related to, and to build on, prospective memory (McDaniel & Einstein, 2007). On the other hand, the planning for another agent goes beyond what is standardly subsumed under "prospective memory" (usually understood as memory for one's own past *individual intentions to perform an action oneself*). Thus, it is a fundamental challenge for future work to explore the conceptual and empirical relation of the kinds of memory-based planning for one's own and others' actions studied here, and mental time travel more generally, to prospective memory more systematically.

Acknowledgments

This work was supported by the German Initiative of Excellence. Thanks go to Alexander Ball, Nina Coy, Ronny Fehler, Anja Granitza, Karina Joppa, Marina Josephs, Nora Pulz, and Kira Sagolla for help with testing and coding.

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