Planning my actions to accommodate yours: joint action development during early childhood

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The planning and adjusting of one’s actions in relation to an action partner is fundamental to smooth joint action. During their first years of life, children gradually become more engaged in joint actions. Here, we investigated whether and at what age children take their partner into account in their action plans to accommodate the other’s actions. We focused on children’s proactive planning (without prior experience) and flexible adjustment of action plans over time. In a behavioural study, we tested 96 children from four age groups (2½, 3, 3½ and 5 years) in a joint cup-stacking task. Children passed cups to their partner who had only one hand available (alternating over time) to build a tower. Children’s response choices were assessed (i.e. passing the cup on the free or occupied side to their partner). The study yielded two major findings. At all ages, children proactively planned their actions in a way that accommodated their partner’s actions. However, only by 3½ years did children start to flexibly integrate their partner into their action plans. Even at age 5, children only showed minimal adjustments to their action partner. Candidate processes underlying these developmental changes (e.g. inhibitory control, cognitive flexibility, perspective taking) are discussed.

1. Introduction

A fundamental aspect of social interaction is the ability to coordinate our actions with those of others. In such joint actions, adults plan and adjust their own actions to accommodate their action partner, and thereby reach a smooth coordination with the other person. During the first years of life, children gradually become more engaged in joint actions. Yet initially, their eager contribution displays little signs of planning ahead for and adjusting to their action partner. When children’s active engagement turns into a smooth coordination in which they plan ahead to accommodate the other person remains an open question.

(a) Accommodating the other’s actions: evidence from adult joint actions

In everyday life, adults usually plan and adjust their own actions to accommodate the actions of others. For instance, when paying for our groceries at the market the seller might be holding a bag of fruit for us in his left hand. To pay him, we readily pass the money to his free right hand (instead of his occupied left hand). Besides such anecdotal evidence, systematic investigations provide empirical evidence that adults adjust their actions to benefit an interaction partner, and thereby make the joint action progress more smoothly (e.g. [1–3]). Ray & Welsh [1], for example, instructed participants to pass a jug of water to another person who would subsequently use it (e.g. to pour water into a glass). They found that about 90% of the participants passed the jug by holding the jug’s body such that the handle was available for the other person. Instead, when participants were acting alone, they consistently grasped the jug by the handle rather than...
the body to perform the action. Adult participants thus adjusted their actions to accommodate their action partner.

(b) Accommodating the other’s actions: effects on affiliation

Apart from accomplishing observable joint action goals through smooth coordination like passing a jug to serve water, coordinating actions with others also has the potential to establish social bonds. A growing body of evidence shows links between fluent interpersonal coordination and affiliation, both in children [4,5] and adults (see [6] for a review). More specifically, smooth action coordination between people makes them feel more connected to each other [7,8]. Establishing affiliation thus is an integral part of social interaction in addition to achieving observable goals together. During early interactions with children, as in proto-conversation and peekaboo games, observable goals are often less prominent [9]. This feature of early social interactions may make the role of affiliation even more pronounced [9].

(c) Accommodating the other’s actions: asymmetry in early childhood

Still, smooth coordination seems to be a challenge in early childhood. Children have major difficulties in considering the influence their own actions have on others and in acting accordingly, while being well aware of how others’ actions affect themselves and the interaction (see [9] for a review). For instance, if action partners fail to fulfill their part of an interaction, infants and toddlers overtly protest or try to reengage their partner through social bidding [10,11]. This can already be observed in early face-to-face interactions. On the other hand, even beyond infancy, children readily leave their action partner for other activities [12,13]. This suggests an asymmetry in development: whereas young children may take into account how the others’ actions relate to their own actions and goals, the extent to which they plan and adjust their actions with respect to how they affect others’ actions is still limited.

Similar asymmetries can be observed in various domains of social development. For instance, Aureli & Presaghi [14] found an asymmetric pattern in their longitudinal study on social engagement in joint play. Observations of mother–child interactions showed that joint play gradually developed from unilateral engagement by the mother to a more symmetric and reciprocal engagement of mother and child between infants’ first and second year of life [14]. Moreover, it has been suggested that in early joint actions, infants might represent mainly their own task and goal while only later representing also their action partner’s task [15–17]. As alluded to before, by 18 months of age toddlers protest when their play partner stops his or her contribution to a joint game (e.g. [11]), whereas it is up to and beyond their third year of life that children readily leave an ongoing joint action for a more attractive game [12] or a reward [13]. With respect to such commitments to a joint action, Hamann and colleagues suggest that a ‘you-to-me’ commitment develops before a reciprocal commitment (i.e. you-to-me and me-to-you) in the third year of life [13].

Together, previous developmental research indicates a major transition in early childhood towards a more reciprocal engagement in joint actions. Apart from this evidence on getting and staying engaged in joint actions, there is little research on the developmental trajectory of when children plan and adjust their actions to accommodate their action partner during a joint action itself. Planning and adjusting one’s action plan to accommodate another person would require young children to take into account how their actions affect their joint-action partner. This goes beyond using their partner as means to achieve their own goal and thus beyond what is called using the other as ‘social tool’ (e.g. [18]).

(d) The current study: hypotheses and design

In a behavioural experiment, we investigated whether and at what age children accommodate an action partner’s actions in their own action planning. More specifically, we focused on two aspects: (i) children’s proactive planning, in the absence of prior experience with how their actions affect those of their partner; and (ii) children’s flexible adjustment of their action plans throughout the course of a joint action integrating changing constraints of their partner’s actions.

The distinction between proactive planning and flexible adjustment of action plans is important, because they reflect different psychological and brain processes. The ability to proactively plan without having prior experience with a particular situation requires taking the action partner’s task and perspective into account, and to make action predictions for the action partner based on that information. In terms of neural activity, this probably involves (pre)motor cortices associated with action prediction (e.g. [19,20]) in combination with the temporo-parietal junction associated with perspective taking [21]. Proactive planning does not require the ability to task switch, as there is no preceding task to switch from yet. Flexible adjustments over the course of trials instead link to a sensitivity to observing another actor’s discomfort and the ability to modify one’s behaviour because of it. Thus, flexibly adjusting action plans may rely on a combination of action perception (associated with the action observation network including the premotor and supplementary motor cortex, inferior parietal lobule and superior temporal sulcus, e.g. [22]) and task-switching mechanisms (associated with the superior prefrontal and posterior parietal cortex, [23]).

Based on previous findings, we expected that both proactive planning and the flexible adjustment to accommodate a joint-action partner would improve between the ages of 2½ and 5 years. Developmental research suggests that compared with 2½-year-old children, 3-year-olds are significantly better at coordinating their actions with a joint-action partner [24], and demonstrate first signs of acknowledging commitment to a joint action [12]. Moreover, young children’s individual planning skills improve significantly between the ages of 3 and 5 years (see [25] for a review). It is also around the same age that children show increasingly more cognitive flexibility and inhibitory control [26,27], both prerequisites for inhibiting prepotent responses and adjusting their own plans to another person. In accordance with this, it was suggested that children’s planning skills and their inhibitory control are closely linked [25]. Although representing distinct aspects of planning, proactive planning and the flexible adjustment of plans to accommodate a joint-action partner might thus show a close interaction.

However, we also expected differences between the two measures. Previous findings suggest that anticipating the effect one’s own actions have for another person and proactively planning one’s own actions accordingly might be
more challenging and emerge slightly later than adjusting one’s action plans in the course of a joint action. In particular, in a study on planning in a collaborative problem-solving context, Warneken et al. found that 3-year-old children needed experience with a task before they planned ahead in a way that integrated the role of their joint-action partner in solving the task. By the age of 5 years, children planned their actions in this collaborative problem-solving context without prior experience [28]. Additionally, Gerson et al. demonstrated that 3-year-old children had more difficulties initially planning their own actions in a joint context than when they acted on their own. Their ability to correct their actions to still reach a common goal, however, was not affected [29]. To what extent children’s action planning as investigated in these studies reflects their efforts to reach their own goal rather than planning their actions to accommodate those of another person remains unclear.

To investigate whether and from which age on children accommodate their action partner’s actions, we tested children between the ages of 2 to 5 years in a simple joint-action game. In this game, children built four towers together with an adult action partner. For each of the four towers, the action constraints of their partner changed. The joint-action game was designed such that children of all age groups could successfully complete the task. As the task could be completed successfully in any case, we could exclude the possibility that their behaviour would merely reflect that they were using the partner to reach the game’s goal. However, how children chose to pass the building elements of the tower to their partner affected their partner’s action execution.

2. Material and methods

(a) Participants
In this study, we tested 96 children from four age groups (2, 3, and 5 years). The final dataset consisted of 89 children: 2-year-olds 22 (mean age: 31.5 months, ranging from 30 to 32 months; 11 girls), 3-year-olds 23 (mean age: 36.9 months, ranging from 36 to 38 months; 16 girls), 3.5-year-olds 22 (mean age: 42.5 months, ranging from 41 to 43 months; 13 girls), and 5-year-olds 22 (mean age: 60.7 months, ranging from 60 to 61 months; 10 girls). Seven children were excluded because of parental interference (N = 2), technical failure (N = 1), experimenter error (N = 1), because of invalid data (i.e. walking around the table, see Data processing section; N = 1), or unwillingness to participate (N = 2). Children were recruited through a database of the Baby Research Center Nijmegen. This database contains families from Nijmegen (a medium-sized city in the Netherlands) and the surrounding areas who volunteer for participation in developmental research. Parents gave written consent for their child’s enrolment in the study and stayed with their child throughout the laboratory visit. The laboratory visit (including debriefing) took about 30 min and was compensated with either 10 EUR or a children’s book.

(b) Experimental design and materials
A simple joint action task, suitable for all tested age groups, was developed. The task involved two people jointly stacking cups: one person passed cups to a second person, who subsequently stacked the cups on a tower. By means of a custom-made wooden apparatus (height 15 cm, width 74 cm, depth 60 cm) with a hidden turning disc (i.e. a manual carousel-type machine), cups could be presented to the first person one by one in a centred fashion (figure 1). The apparatus was placed on a table and the actors sat opposite each other on either side. The actors were separated by a window frame (height 87 cm, width 80 cm) that was mounted on top of the apparatus and required the actors to reach around the frame on one of its sides to hand over the cups (figure 1). All children were engaged in this joint-action task in a dyadic cooperation with the adult experimenter.

(c) Procedure
Upon arrival at the laboratory, parents and children were invited to a playroom. Parents were informed about the general procedure and asked not to interfere during the testing phase. The time spent in the playroom also served to acquaint the child with the adult experimenter and took no more than 5 min. Then, the experimenter accompanied the parent and child to the testing room. In the testing room, the play setting (i.e. the apparatus with the window-frame) had been arranged on a small table located in the middle of the room. The parent was seated at one end of the play table. The child was invited to sit on the parent’s lap while the experimenter sat down opposite parent and child behind the plexi-glass window. The parent was instructed not to interfere during the experimental session and to minimize interaction with the child as much as possible. On the experimenter’s side of the play setting, out of reach for the child, a red stick (height 18 cm) was located directly in front of and aligned with the centre of the window-frame. Prior to the participant’s arrival, two keys had been placed on the child’s side of the play setting, one on the left and one on the right table edge. Before initiating the joint-action task, the experimenter reached out with her right hand next to the window-frame and asked the child to pass her the key on the child’s left. Analogously, the experimenter repeated the request on the other side. The purpose of this initial phase was to ensure that children experienced that they could pass objects on either side of the window-frame.

Then, the experimenter started the joint-action task by putting on and introducing one of two hand puppets (either a horse or an elephant). Consequently, one of the experimenter’s hands was occupied by holding the puppet. The side with which she started holding the hand puppet was counterbalanced between children. A plastic cup was fixed to each hand puppet and the experimenter introduced the hand puppet by saying, ‘This is a [horse/elephant] and he has a cup’. Simultaneously to this introduction, she pointed to the cup. Following this, the experimenter made the hand puppet balance the cup on top of the red stick. Then the experimenter said, ‘You know what we can do with this? We can build a tower together with cups’. To demonstrate further, the experimenter took a cup from behind the apparatus, lifted it to make it visible for the child, and stacked it onto the first cup. She then said that she had no more cups and asked the child whether he or she had another cup to pass to her so she could put it on top of the tower for them. At the same time, the experimenter operated the turning mechanism of the apparatus such that a cup would appear in front of the child. While awaiting the child’s response, the experimenter rested her free arm alongside her body. The experimenter remained still until the child made a response choice and only then reached out for the cup.

The response choice of the child (i.e. the side on which they passed the cup to the experimenter) affected the experimenter’s subsequent action execution and the smoothness of the joint action: if the child passed the cup on the experimenter’s free-hand side, the experimenter could easily reach for it and subsequently stack it on the tower in the middle (figure 1, middle). If the child passed the cup on the other side, however, the experimenter had to bend over with her free hand and stretch across her occupied arm, with which she balanced the tower on the stick to receive the cup and stack it on top of the tower (figure 1, bottom). Note that either response choice of the child
led to a successful goal accomplishment (i.e. stacking the cups to a tower), but importantly, the child’s action choice differentially affected the execution of their joint-action partner’s action, either by accommodating or by impeding it.

After stacking the cup onto the tower, the experimenter initiated the next trial by asking the child for another cup. To build one tower, children had to pass five cups. Then the experimenter introduced the next hand puppet with the same procedure. With each change of hand puppet, she switched sides by putting the puppet on her previously free hand. Consequently, children now needed to change the side on which they passed the cup to accommodate their joint-action partner. Which of the experimenter’s hands were free was balanced over four blocks. Thus, in total four towers were built, two on each side, adding up to 20 trials per child. A video recording was made during the experimental session to code the child’s response choices offline.

(d) Data processing
Children’s response choices (i.e. the side children chose to pass the cup to their joint-action partner: the partner’s free or occupied hand) were coded per trial offline. Figure 1 illustrates the two possible response choices of the child. Three children did not complete the last of the four blocks. Moreover, individual trials were excluded if the child did not successfully pass the cup to the experimenter (e.g. the cup fell or the parent passed the cup) or if the child stood up or walked around to pass the cup.
Six trials were invalid because of an experimenter’s fault (i.e. counterbalancing error or moving her arm before the children had finished their reaching movement). Together, due to these exclusion criteria approximately 2% of all trials were excluded.

We focused our analysis on two measures of interest: the initial response choice (i.e. the first trial only) and the continuous response choice (i.e. all trials except the first). In their initial response choice, children had to plan ahead without having experienced how their own action would affect their joint-action partner. Thus, the initial response choice reflects whether children proactively planned to accommodate their joint-action partner. One child had to be excluded from further analysis because of walking around the table in the first trial and, therefore, not providing valid data for the initial response choice.

The continuous response choice, on the other hand, reflects the extent to which children flexibly adjusted their action plans to accommodate the other’s action execution over the course of the joint action. To continuously accommodate the actions of the joint-action partner, children needed to flexibly switch the sides on which they passed the cup between blocks. For the continuous response choice, the proportion of trials was calculated in which children chose the joint-action partner’s free-hand side.

The data for both measures were tested for normality. As the assumption of normality was violated, non-parametric statistical tests were used in the subsequent analyses. We tested for main effects and age differences of each measure separately. We hypothesized that with increasing age, children would adjust their action plans more to accommodate their joint-action partner. We expected this development in children’s adjustment of their action plans to slightly precede their development in proactive planning. In addition, both measures were entered in one statistical comparison with test for an interaction of children’s initial and continuous response choices. Both measures assess whether children take the other into account in their action plans, but address different facets of such planning. We thus hypothesized that children who initially planned their action according to their partner’s actions would perform better throughout the subsequent course of the joint-action game.

3. Results

(a) Initial response choice

To test whether children differed in their initial response across different ages, we submitted the initial response choice values to a Pearson’s $\chi^2$-test. No significant association between children’s initial response choices and their age was observed, $\chi^2(3) = 1.048$, $p = 0.79$. Figure 2 illustrates that 64% of the 2½-year-olds, 70% of the 3-year-olds, 77% of the 3½-year-olds and 73% of the 5-year-olds passed the cup on the first trial in such a way that their joint-action partner could easily reach for the cup with her free hand.

As no age differences were observed, we collapsed data across age to test whether children were more likely to pass the cup to their joint-action partner on her free-hand side on the first trial. Overall, children significantly planned their actions proactively in a way that accommodated their partner’s actions, as indicated by the fact that 71% of all children chose to pass the first cup to their joint-action partner on her free-hand side ($p < 0.01$).

(b) Continuous response choice

The second question we examined was to what extent children of different age groups would flexibly adjust their action plans over the course of the experiment to accommodate the actions of their partner. For this purpose, we tested with a Kruskal–Wallis test and Jonckheere’s trend test whether children flexibly adjusted their continuous response and whether this improved with age. The results are shown in figure 3. Continuous response choice values can range from 0 (i.e. making the partner’s actions more difficult on all trials) to 1 (i.e. accommodating the partner’s actions on all trials). If children continuously passed the cup on one side it resulted in a continuous response choice value of 0.5.

Children’s continuous response choices differed significantly between age groups, $H(3) = 7.9$, $p < 0.05$. Jonckheere’s test revealed a significant trend in the data: the continuous response choice values increased with age, $F(2, 1799.5) = 7.22$, $p < 0.01$, $z = 2.62$, $r = 0.28$. To test children’s performance against chance, we entered the data in a one-sample Wilcoxon signed-rank test, separately per age group. The 2½-year-olds ($M = 0.51$, s.d. = 0.03) and 3-year-olds ($M = 0.54$, s.d. = 0.12) did not differ from chance (i.e. 0.5) in their averaged continuous response choices ($p > 0.05$); they equally often passed the cup to the side of their joint-action partner’s free and occupied

Figure 2. Percentage of children from the four age groups who made the initial response choice in a way that was accommodating (green) or not (blue) their joint-action partner’s actions (i.e. reaching and grasping the cup on the free-hand side).

Figure 3. Continuous response choices throughout the joint-action task in proportion (1 representing flexible adjustment to the joint-action partner in all trials; 0 representing always choosing the opposite response, not comfortable for the joint-action partner). Error bars represent 95% confidence interval. *$p < 0.05$, **$p < 0.01$. 
hands. Whereas the 3-year-old children show more choices towards the free-hand side of their partner, their variability in performance was relatively high. By the age of $3_2$ years, children did pass the cup significantly more often to their joint-action partner’s free-hand than to the occupied-hand side ($M = 0.53, \text{s.d.} = 0.07, p = 0.04$). By the age of 5, children then showed a further increase in their tendency to accommodate their action partner flexibly ($M = 0.56, \text{s.d.} = 0.1, p = 0.005$). The findings thus indicate that with increase in age, children adjusted their action plans more flexibly to accommodate the other’s action execution. Yet although 5-year-old children significantly adjusted their action plans, the extent to which they did so is still very limited. On average, they handed the cup over on the side their partner could easily retrieve it only in 56% of all trials.

(c) Linking initial and continuous response choice
Finally, we investigated the relationship between initial and continuous response choice to determine whether children who accommodated their action partner from the start would also show greater adjustments to their partner over the course of the experiment. To test for this possibility, we computed an independent samples test (Mann–Whitney) with the initial response choice as independent and the continuous response choice as dependent variable. Thus, we assigned children who did display accommodating behaviour on the first response choice as independent and the continuous response choice to determine whether children also show greater adjustments to their partner over the course of the experiment. Please note that children’s initial response choice is excluded from their subsequent continuous response choice. Children who initially chose to pass the cup on the joint-action partner’s free-hand side tended to show more accommodating behaviour throughout the joint-action task ($p = 0.08$). In addition, children who started out passing the cup on the joint-action partner’s occupied side did not significantly adjust their behaviour throughout the task to accommodate their joint-action partner. Error bars represent 95% confidence interval. *$p < 0.05$, **$p < 0.01$.

Figure 4. Continuous response choice throughout the joint-action task separated by children’s initial response choice accommodating (green) or not (blue) to their joint-action partner initially. Please note that children’s initial response choice is excluded from their subsequent continuous response choice. Children who initially chose to pass the cup on the joint-action partner’s free-hand side tended to show more accommodating behaviour throughout the joint-action task ($p = 0.08$). In addition, children who started out passing the cup on the joint-action partner’s occupied side did not significantly adjust their behaviour throughout the task to accommodate their joint-action partner.

4. Discussion
Smooth joint coordination between two actors requires the planning and adjusting of one’s own actions to those of a joint-action partner. In the current experiment, we studied the behaviour of $2_1$- to 5-year-old children in a simple joint-action game to investigate whether and at what age children plan their own actions to accommodate a joint-action partner. In particular, we assessed two aspects of children’s action planning: their proactive planning in the absence of prior experience with a particular joint action (i.e. initial response choice); and their flexible adjustment of their action plans to accommodate their joint-action partner when the constraints of their partner’s but not their own actions changed throughout the joint play (i.e. continuous response choice, measured over the course of the experiment).

This study yielded two major findings. First, we found evidence that young children proactively planned their actions such that they accommodated the actions of their joint-action partner. Second, our findings suggest developmental increase in children’s ability to flexibly adjust their action plans to accommodate their joint-action partner. Moreover, $2_1$- and 3-year-old children did not differ from chance in the way they planned their actions with respect to their joint-action partner across the joint-action game. At the age of $3_2$ years, children showed flexible adjustment to the partner’s constraints as their performance differed from chance. By 5 years, children were clearly above chance levels, reflecting that they flexibly accommodated to their action partner. However, even 5-year-olds only did so in less than 60% of the trials.

(a) Accommodating the other’s actions: children’s proactive action planning
At the very start of the joint-action game, 70% of all children passed the cup to the joint-action partner on her free-hand side. Doing so assured that the adult partner could easily reach for and subsequently stack the cup onto the tower. The lack of developmental differences in this regard was somewhat unexpected as we had hypothesized an age-related increase in children’s proactive planning and a potentially delayed onset of proactive planning skills compared with flexible adjustment of their action plans. It also contradicts some of the previous developmental research [12,13,28]. For instance, Warneken et al. [28] found that 3-year-olds fail to plan their actions ahead in relation to another person’s actions in a collaborative problem-solving task. Based on this research, we had expected that especially the younger children in our study would have greater difficulties planning their actions to accommodate
children adjusted their plans to the other person in less than 60% of the trials. In other words, children adjusted their response on average only on 2 of the 10 trials that differed from their initial response. It therefore remains an open question when children reach adult levels in flexible adjustment of their action plans to accommodate others. It is important to mention, however, that we found in a previous study on joint-action planning that adults adjust their actions less consistently to their action partner if the joint action requires higher-order planning [3]. At first glance, our findings seem at odds with previous findings demonstrating prosocial behaviour already in infancy and early childhood (e.g. [40,41] for a review). For instance, at the age of 18 months, toddlers open a door for another person or hand objects that are out of reach for the other. Most of these studies, however, assess whether infants and young children engage in an interaction to assist another person in reaching his or her goal, rather than examining how children adjust their action plans for another person when already engaged in a joint action (as was the case in the current study). Flexibly adjusting action plans for a joint-action partner during an ongoing joint action might be far more demanding and thus develop only during and beyond early childhood. A combination of higher cognitive abilities, such as inhibitory control, cognitive flexibility and perspective taking, might be needed to adjust one’s plans flexibly to accommodate the joint-action partner. While children’s early proactive planning to accommodate others’ actions is in line with findings of early prosocial behaviour, the dynamically changing constraints for the other person might put more demands on their higher cognitive abilities to achieve flexible adjustment in action plans.

The ongoing development of executive function skills, such as inhibitory control and cognitive flexibility, probably plays an important role in the developmental pattern we found. Notably, the current joint-action game was designed with inherent inhibition and flexibility demands which are typical but not necessary for joint-action tasks. The change between blocks required children to refrain from choosing the same side and to switch to the other side to account for where their joint-action partner’s free hand was. The ability to inhibit a prepotent response and to flexibly adjust a previously established response pattern underlies top-down processes associated with frontal brain areas. These areas, which are still in maturation up to adolescence, are thought to be involved in inhibitory control and cognitive flexibility [42–45]. Improvement in the performance of tasks requiring inhibitory control (such as the gift delay task) and cognitive flexibility (such as the Stroop or the dimensional change card-sorting task) is consistently found between the ages of 3 and 5 years [26,45,46]. It is around the same ages that we observed flexible adjustment emerging in children’s action plans with respect to the changing constraints of their joint-action partner. Although far from conclusive, the increased variability of the 3-year-old children’s behaviour is consistent with this developmental change. As a group, however, they still performed at chance level.

As discussed in the context of proactive action planning, we assume that in addition to and possibly intertwined with inhibitory control and cognitive flexibility, perspective-taking skills might play an important role in adjusting one’s action plans to another person. This holds true especially for the flexible adjustment needed to account for the other’s changing task constraints. In order to plan their own actions to accommodate the actions of their partner, children might...
need to take the other’s perspective and track potential changes in the constraints of the other’s actions (like holding the tower on different sides). The observation that children in our study flexibly adjusted their actions to the action partner to an increasing degree parallels children’s emerging epistemic perspective-taking skills. Still, future research is required to test direct links between the development of perspective-taking and children’s action planning to accommodate their joint-action partner.

(c) Relationship between children’s proactive planning and their flexible adjustment of action plans

We also found a marginally significant effect indicating a potential relationship between the two measures of proactive planning and flexible adjustment of their action plans: the children who at the very beginning of the joint action proactively planned their actions in a way that accommodated the actions of their partner tended to be more flexible in adjusting their actions over the course of the experiment. Although the two measures reflect distinct aspects of how children plan their actions to accommodate their partner’s actions, they might build upon each other.

Potentially, children’s detection of the other’s action affordances forms the basis for their initial planning and a prerequisite of their adjustment to accommodate their partner. On top of detecting the other’s action affordances, however, ongoing dynamic changes during the joint action put additional demands on higher cognitive abilities, such as inhibitory control and cognitive flexibility, which leads to the delayed development of children’s flexible adjustment. This might explain why children who detect the affordances of the other’s actions initially plan their actions accordingly and also show a higher performance in flexibly adjusting their plans.

5. Summary

Together, the current findings indicate that children proactively plan their actions in a way that accommodates the actions of their partner early in childhood. By contrast, the flexible adjustment of their action plans to their partner only begins to develop in the fourth and fifth year of life. Notably, even at the age of 5 children only adjusted their action plans to a surprisingly small degree. To our knowledge, this is the first study on when children begin to plan and adjust their actions beyond the purpose of reaching a goal to accommodate their partner’s actions. As this is the first study on the development of planning own actions to accommodate others, complementary findings from additional experimental settings are required to draw general conclusions about the developmental trajectory. Underlying processes, such as inhibitory control, cognitive flexibility and perspective taking, may play a crucial role in learning how to plan one’s own actions in a way that accommodates the actions of a joint-action partner and brings about smooth joint-action coordination. Further research is needed to examine the precise contributions of each of these processes.

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