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# Social context influences planning ahead in three-year-olds

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ABSTRACT

Children's joint action and advance planning skills are both undergoing development during the preschool years, but little is known about how joint action contexts influence children's advance planning. In the first experiment, three-year-olds (N = 32) were better at planning ahead for a task in an individual compared to a joint condition when playing with a social partner. A second experiment indicated that three-year-olds (N = 32) were as able to plan in advance with a non-social machine as when playing alone, suggesting that the effects found in the first experiment were not a function of different timing or cognitive demands between individual and joint conditions, but were unique to the social context.
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## 1. Introduction

As soon as infants are born, they are immersed into a social world. They are engaged in social interactions almost immediately, and their social environment plays an important role in their development across a variety of domains. The types of social interactions in which children are engaged and the extent of the child's participation in the interactions varies across development. As newborns, infants are engaged in dyadic interactions with their caregivers and other adults that are largely adult-led. Within the first few years of life, however, infants begin to actively engage in triadic interactions (i.e., joint attention) that are essential to language learning and imitative interactions that are central to skill and cultural learning. Collaborative interactions, in which children and their social partners work together to achieve a common goal, emerge later in development and are critical to the uniquely human capacity for higher-order cognition and achievements such as innovation. Although joint actions are beneficial to achieving complex goals, they may also come at a cost due to the difficulty of incorporating another person into one's task. Given the important role that social interactions play in cognitive development, it is important to identify both the benefits (e.g., assistance with carrying out actions) and pitfalls (e.g., the need to take a partner's plans and actions into account) of these interactions. In this research, we investigate the influence of social context on children's advance planning.

## 2. Joint action development

Sebanz, Bekkering, and Knoblich (2006) define joint action as "any form of social interaction whereby two or more individuals coordinate their actions in space and time to bring about a change in the environment" (p. 70). They suggest that

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successful joint actions require prediction of one another's actions, shared representations of goals by both social partners, and integration of the predicted effects of the actions. Without sensitive social partners who adapt their actions to the child's and scaffold the children's planning, children struggle to efficiently and successfully carry out joint actions in the first few years of life (e.g., Brownell, 2011; Gräfenhain, Behne, Carpenter, & Tomasello, 2009; Hunnius, Bekkering, & Cillessen, 2009; Meyer, Bekkering, Paulus, & Hunnius, 2010). For example, at 2.5 years of age, children are not efficient at playing simple turn-taking games with a neutral joint action partner and often make errors in which they perform an action during their partner's turn (Meyer et al., 2010).

## 3. Planning development

One skill that is both crucial to joint actions and important in and of itself is *advance planning*. Planning which ingredient to hand to your friend next is crucial to carrying out an ongoing baking activity with one's partner. Even when acting alone, planning one's actions in advance is important. If a person baking alone adds flour before eggs to a batter, this could disrupt his or her individual action plan. In tasks that involve advance planning, individuals must take future states into consideration when initially engaging in an activity. Planning can be carried out either individually or within a joint action context. A recent study with adults (Meyer, van der Wel, & Hunnius, 2013) measured advance planning of actions that could be performed alone or with another person. In this task, advance planning was not critical to achieve the goal, but planning the initial step of the task in advance with regard for the future step allowed subjects to carry out the task more easily and efficiently. Without explicitly being told to do so, participants learned to initiate actions based on predictions about the subsequent steps (i.e., planned ahead) after they gained firsthand experience acting in the task. This was true in both individual and joint contexts, suggesting that participants were similarly able to use their experience acting alone to predict either their own or adapt to a partner's actions and carry out their actions accordingly. In a developmental adaptation of this task, 3.5-year-old children, but not 2.5- or three-year-olds, were significantly above chance in planning their actions in order to accommodate a partner's action (Meyer, van der Wel, & Hunnius, 2016). Even at five years of age, however, children were still quite variable in their accommodation and, though above chance levels, were not consistently planning with regards for their partners.

A similar advance planning task that can be applied in both social and non-social contexts involves choosing an item that will be needed for a future task. Suddendorf and colleagues (Suddendorf, Nielsen, & von Gehlen, 2011) found that four-year-olds, but not three-year-olds, correctly anticipated an item that would be needed in a future setting. An experiment that examined this type of planning in a joint context was conducted by Warneken and colleagues (Warneken, Steinwender, Hamann, & Tomasello, 2014). They found that five-year-olds were better than three-year-olds at planning which of two tools to act on so that the complementary tool would be available for a social partner to complete a collaborative goal. Thus, five-year-olds can plan in advance in certain joint contexts. This work did not, however, contrast joint planning with individual planning, leaving open the question of the role of social context on advance planning.

In some cases, an interactive social partner benefits children's planning. Radziszewska and Rogoff (1988) used imaginary errand planning to assess 9- and 10-year-old children's ability to plan the shortest route to retrieve all the items from stores on a list. They found that children who engaged in collaborative planning of the errands with an adult partner were subsequently more effective at planning on their own than children who engaged with a peer initially. This is consistent with the general notion first presented by Vygotsky (1978) that sensitive and skilled partners can scaffold children's activities during interactions in order to promote skill acquisition in the child. To be sure, engaging in joint actions with an adult partner has positive consequences on children's planning in the long-term (Bibok, Carpendale, & Müller, 2009; Duran & Gauvain, 1993; Gauvain & Rogoff, 1989; Gauvain, 1992; Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012). The question of how social partners influence action sequences *while* being carried out remains an open question.

## 4. How do interaction partners influence planning?

As discussed above, in certain circumstances, children can plan within joint contexts. They perform at above chance levels in choosing a tool or action that will facilitate a partner's action when they are older than three years (Meyer et al., 2016; Warneken et al., 2014). As of yet, however, the effect of the presence or absence of a social partner has only been investigated with respect to subsequent planning following scaffolded interactions (e.g., Radziszewska & Rogoff, 1988). Measuring the effect of a neutral partner (i.e., a partner who does not help the child in the moment) on advance planning within an action sequence is important because planning during ongoing interactions has implications for the smooth maintenance of social interactions and joint task completion. As described above, if a person is passing a cooking partner ingredients to be added to a batter, it is critical that the receiver plans his or her actions around the action being carried out by the partner. If a cooking partner is expecting to be handed eggs but is handed flour, his or her plans might have to be adjusted to take this into account.

In the current research, we investigate advance planning during a game that could either be played alone or in a turn-taking sequence with a partner. In order to present a neutral partner who would not facilitate or hinder the child's actions, the partner acted in a predictable, uniform manner throughout the task. Although turn-taking tasks are minimally joint in that they do not necessarily require precise coordination in time and space, they share many of the features of joint actions, including shared goals and interaction space. Previous research indicates that young children represent turn-taking tasks as shared, even when they're not told to take into account the partner's actions (e.g., Milward, Kita, & Apperly, 2014; Saby, Bouquet, & Marshall, 2014). This controlled setting (turn-taking with a neutral partner) will act as a first step toward better understanding more complex interactions with potentially less predictable or reliable peers. Three-year-olds were tested because, as described above, both their planning and joint action abilities are emerging at this age (e.g., Gauvain, 1992; Hamann, Warneken, & Tomasello, 2012), allowing us to examine the malleability of planning during individual versus joint actions.

## 5. Current experiments

To examine the interplay between joint actions and advance planning, we created a color-matching game in which the child was required to plan ahead in order to succeed in the game. If he or she did not plan ahead, the child had the chance to modify the action during a subsequent step of the game. The chance to modify the action allowed a control measure to ensure that all children understood the goal of the game. All children played this game both alone and in alternating turns with a joint partner, a handpuppet named Kip (Dutch for chicken). The use of puppets as social partners and mentalistic agents is well-established with this age-group (e.g., Bartsch, Wade, & Estes, 2011; Rakoczy, Warneken, & Tomasello, 2008) and allowed us to control the partner's actions without giving the impression that the partner was a human adult who might scaffold the child's actions. Across a variety of paradigms, children treat puppets as mentalistic agents who have beliefs and are expected to act in socially normative manners (Beier, Over, & Carpenter, 2014; Rakoczy, 2008; Rakoczy et al., 2008; Schmidt, Rakoczy, & Tomasello, 2012). Research by Bartsch et al. (2011) tested the possibility that puppets were seen as more artificial than human adults and found no differences in three-year-old children's attribution of beliefs to puppets or humans. We examined differences between children's accuracy in advance planning during the individual versus joint conditions.

If collaboration provides advantages for children's advance planning during an ongoing interaction, as it has been shown to do for subsequent planning (e.g., Gauvain & Rogoff, 1989), then children should perform better in the joint than in the individual condition. This would suggest that the presence of a social partner boosts cognitive skills such as planning regardless of the pedagogical or functional role of the partner. If, however, ongoing social interactions disrupt children's performance due to the additional demands of incorporating a social partner (who, in this case, is not helping scaffold the child's behavior), children's advance planning should be better in the individual condition than the joint condition. This would be in accord with theories suggesting that joint actions sometimes disrupt processing due to the extra demands of representing a social partner's actions (see, for example, Milward et al., 2014; Sebanz & Knoblich, 2009). We test this hypothesis in Experiment 1.

## 6. Experiment 1

### 6.1. Method

#### 6.1.1. Participants

Thirty-two three-year-olds (mean age = 37.16 months; range = 36 months to 37.3 months) were included in the final data set for this study (15 females). All children were recruited from a database of families who volunteered to participate in child studies. Children were from a mid-sized European metropolitan area and were largely Caucasian and middle-class. An additional 10 children participated but were not included due to equipment malfunction ($n = 2$), experimenter error ($n = 2$), not completing all trials ($n = 3$), or lack of learning of the rules of the game (as defined by repeatedly and persistently stating that mismatches were "correct") or refusal to play with Kip ($n = 3$).

#### 6.1.2. Stimuli and procedure

Each trial consisted of a set of four balls, four cups, and a clear, plastic tube that held the balls. There were always two cups of one color (e.g., green) and two cups of another color (e.g., yellow). Each cup could only fit one ball. In all but the first training trial, there were two balls of one color (e.g., green), one ball of a second color (e.g., yellow), and one ball that was multicolored (e.g., half green and half yellow). The overall goal of the game was for the child (together with his or her co-actor in the joint condition) to place all four balls in matching buckets (solid colored balls could only go in the directly matching bucket, whereas multicolored balls could go in either bucket). The tube was created to dispense the balls one at a time in a particular order while still allowing participants to see the colors of the upcoming balls (see Fig. 1). The multi-colored ball always came out of the tube in the second position, and the three solid-colored balls were pseudorandomly distributed in the first, third, and fourth positions. Except in the demonstration trial, different color combinations (consisting of red, light blue, dark blue, green, and yellow) were used across trials so as to minimize learning specific rules about colors and to keep the children's attention. In joint play trials, the experimenter wore a hand puppet of a chicken (called "Kip"). The experimenter used a different voice so as to differentiate herself from the puppet so that the child did not expect Kip to scaffold his or her actions.

*6.1.2.1. Training.* Children were taught how the game worked via a set of training trials. First, the experimenter placed a set of four solid-colored balls (e.g., brown and black) into matching cups. This short phase was to teach children that balls had to go into matching cups and that only one ball could fit in each cup. Next, one of the solid balls (the one in the second position)

A. B.

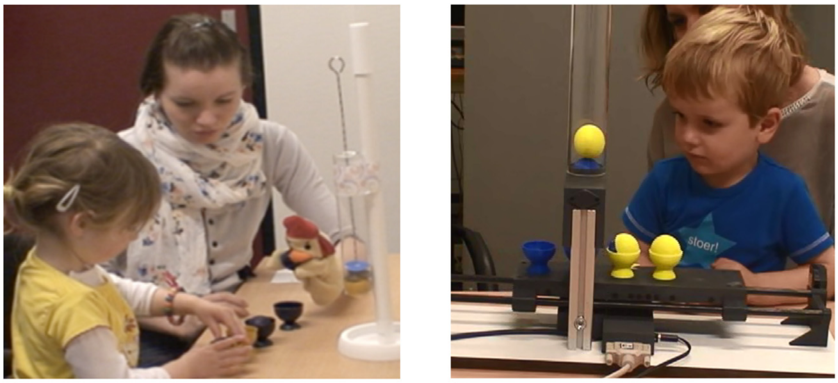
**Fig. 1.** In both experiments, each trial involved three-solid colored balls, a multicolored ball, and two cups in each of two colors. In Experiment 1, the balls were in a manually controlled tube (A). In Experiment 2, they were in a similar tube that allowed machine-control of the bucket placement (B).

was replaced with a multi-colored ball. When the experimenter extracted the multi-colored ball, she showed the child that it could go in either the brown or the black cup. After showing them this, she always left the ball in the inappropriate cup in terms of meeting the end goal. That is, if there were two brown balls in the tube, the multi-colored ball would be placed in a brown cup (and vice-versa if there were two black balls). This "mistake" was made in order to show participants the importance of considering the upcoming balls in the tube (i.e., planning ahead) and to indicate how errors could be modified. The experimenter then placed a black and brown arrow in front of the cup to indicate which cup held the multi-colored ball. After the incorrect placement of the multi-colored ball, the experimenter showed the child that one of the remaining solid-colored balls no longer had an appropriate cup in which to be placed. She talked to the child about how this could possibly be fixed and reminded them about the meaning of the arrow and hinted about a possible solution: "Do you remember what this arrow means? This means that the multi-colored ball is in this cup. And where can the multi-colored ball go?" She then extracted the multi-colored ball and placed it in the opposite colored cup. She moved the arrow to the new cup and then placed the solid-colored ball in the appropriate cup. After having done this, she reminded the child of how the problem had been modified.

Two training trials followed this demonstration in which the experimenter scaffolded the child's actions. These two trials consisted of two different sets of colored balls, randomly assigned. During these trials, the experimenter handed the participant each of the balls and asked him or her to place them in the matching cup. She frequently reminded the child that all the balls had to "fit" in the cups (and pointed to the balls in the tube). If the child encountered a solid-colored ball that had no matching cup, the experimenter first gave him or her time to try to modify the action themselves. Then she gave the participant a series of hints, allowing time for the child to recognize the solution between each hint. As in the demonstration trial, hints increased in detail, ranging from asking what the arrow meant to reminding the child that the multi-colored ball could go in either cup. If the child still did not respond to the hints, the experimenter moved the mixed ball and demonstrated the solution. In this way, the experimenter always ensured that the balls were matched with an appropriate cup at the end of the trial. After these two trials, the experimenter told the child he or she was ready to play without help. Individual or joint play trials then began. All children participated in both conditions (order counterbalanced between participants).

6.1.2.2. *Individual play.* The individual condition consisted of six trials. In each of these trials, the child retrieved each ball from the tube, one at a time, and placed it into a cup. The experimenter did not participate except to ensure that the child did not retrieve the following ball before first placing the one in his or her hand into a cup. If the child encountered a problem (i.e., a solid-colored ball without a matching cup), the experimenter did not interfere unless the child looked to the experimenter for help. If the child expressed uncertainty and enquired for help, the experimenter gave the same hints as during the training trial, again giving the child time to modify the action between each hint. After all of the balls were placed in cups, the experimenter asked the child if they were all correct (regardless of whether or not they were). If the child realized then that there was an error, the experimenter helped (as above) if the child enquired.

6.1.2.3. *Joint play.* At the beginning of joint trials, a small hand puppet was introduced to the child. The child was told that the puppet was named Kip and that Kip wanted to play with him or her and they could take turns (see Fig. 2). The joint play session consisted of nine trials. In the first, fourth, and seventh trial, Kip let the child place the first (and third) ball and Kip placed the second (multi-colored) and fourth ball. Kip always placed the multi-colored ball in the cup that allowed all forthcoming balls to be placed correctly. In the other six trials, Kip placed the first and third balls and the child placed the second and fourth balls. This ensured that the number of trials for which the child had to plan (by placing the multi-colored ball correctly) was matched across the individual and joint conditions. If the child incorrectly placed the multi-colored ball and realized this error when later attempting to place a solid-colored ball, the experimenter followed the same procedure as in the individual play trials as far as waiting for the child to enquire in order to give any hints. Any hints given were



A. B.

**Fig. 2.** In Experiment 1 (A), children alternated turns with Kip during joint action conditions. In Experiment 2 (B), children alternated turns with the machine, which moved the appropriate cup under the tube before the ball was released.

expressed by the experimenter rather than by Kip. If Kip had to place the solid-colored ball that had no matching cup, she would knock on the full cups and say “uh oh—this ball can’t go in this one” and would ask for the child’s help. If the child did not immediately modify the action, the experimenter followed the same pattern for giving hints as in other trials.

#### 6.1.3. Coding

*6.1.3.1. Planning ahead and modifying.* The focal question in this study concerned children’s ability to proactively plan where to place the multi-colored ball so that all following balls could fit in matching cups. For each trial in which the child placed the multi-colored ball (six individual play and six joint play trials), a trained coder watched an offline video of each session and judged whether the child placed the multi-colored ball in the correct cup (for the end goal achievement) without any hints from the experimenter before the following ball was retrieved from the tube. We refer to this behavior as *advance planning*.

A control question was whether children would modify actions if their initial ball placement was incorrect. For this measure, coders judged whether the child removed the mixed ball (in the case of an initial placement error) and placed it in a correct cup. If so, the coder noted whether the child carried out this action with or without needing the assistance of hints from the experimenter. To be clear, if the experimenter gave any hints, the child was scored as incorrect in both planning and modifying. Advance planning and modifying were both, therefore, unrelated to frequency of hints because hints were only given after the child failed to plan or modify on their own and if and when the child looked to the experimenter for help following an attempted modification.

The dependent measure for both advance planning and modifying was the proportion of trials within each condition for which the child’s action was correct. That is, for advance planning, the proportion of trials on which the child placed the mixed ball correctly initially was calculated by a trained coder blind to the hypotheses of the experiment. For the modifying stage, we assessed both the proportion of incorrectly planned trials that were then modified without a hint (*proportion modified:* [trials modified]/[total trials − trials modified in advance]) *and* the proportion of trials that were correct following both planning and modifying (*proportion planned or modified:* [trials planned in advance + trials modified]/[total trials]). A second trained coder coded 25% of the videos and agreed on 99% of trials ($\kappa > 0.8$, $p < 0.001$). Because proportion scores are not normally distributed, we report both parametric and non-parametric statistics for analyses using these scores.

*6.1.3.2. Ball order.* In addition to counterbalancing the order of conditions across children, we also pseudorandomly assigned different orders of ball presentation within each trial and across participants. It is possible that children found some orders of presentation more difficult than others (e.g., A(mixed)AB and A(mixed)BA might be easier than B(mixed)AA). In order to account for this possibility, we coded each trial type according to these orders (e.g., A(mixed)AB was ‘0′ and B(mixed)AA was ‘1′) and created an average score of “ball order” for each individual in order to ensure that these factors did not differ between conditions or drive any possible results.

*6.1.3.3. Timing and attention.* In addition to coding children’s behavior on a gross level, we also did a more fine-grained analysis of children’s actions throughout the game. In particular, a trained coder used a software program (ELAN: http://tla.mpi.nl/tools/tla-tools/elan/; Wittenberg, Brugman, Russel, Klassmann, & Sloetjes, 2006) to measure (frame-by-frame) children’s attention to (i.e., number of seconds gazing toward) the experimenter (defined as the experimenter’s face) and Kip (in the joint condition) during each trial. Two children’s videos were unable to be coded because of video errors. A reliability coder coded approximately 25% of the videos and the number of seconds attending to each aspect was highly correlated between the two coders ($r = 0.96$).

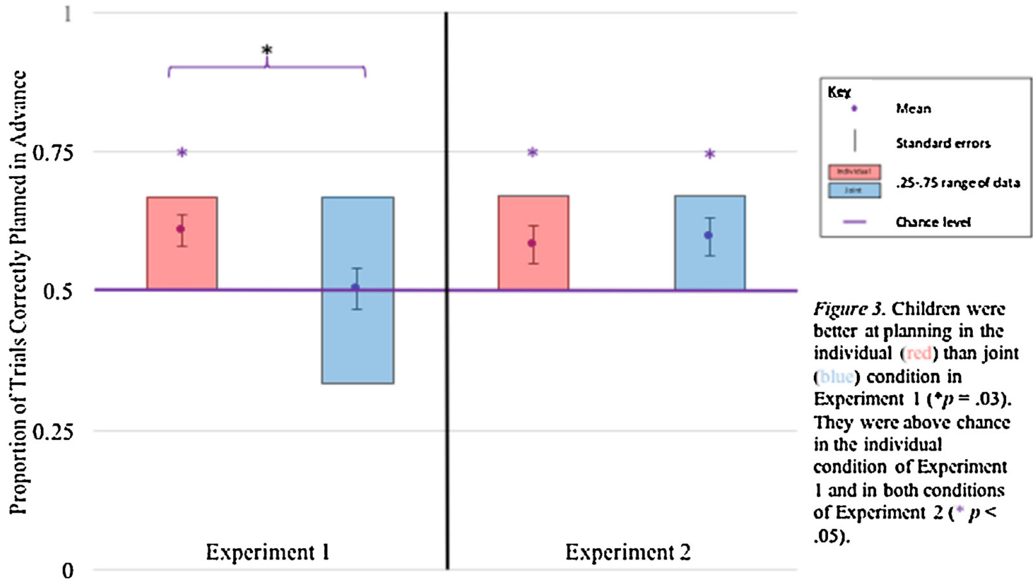



**Fig. 3.** Children were better at planning in the individual than joint condition in Experiment 1 (*p = 0.03). They were above chance in the individual condition of Experiment 1 and in both conditions of Experiment 2 (*p < 0.05).

## 6.2. Results

### 6.2.1. Planning and modifying results

An initial paired-samples *t*-test examined whether children differed in their *advance planning* when playing alone (individual condition) or with Kip (joint condition). This revealed that children were better at planning when playing alone than with Kip, $t(31) = 2.24$, $p = 0.03$, Cohen's $d = 0.57$ (see Fig. 3). A non-parametric, Wilcoxon Signed Rank Test showed a similar pattern, $Z = 2.08$, $p = 0.04$. The proportion of trials for which children successfully planned was greater than chance levels in the individual condition, $t(31) = 3.95$, $p < 0.001$, Cohen's $d = 1.42$ ($M = 0.61$, $SEM = 0.03$), but not in the joint condition, $t(31) = 0.10$, $p = 0.92$, Cohen's $d = 0.04$ ($M = 0.50$, $SEM = 0.04$). As a complementary non-parametric measure, chi square tests were conducted for each condition with number of children performing above, at, or below chance entered as variables. In the individual condition, a significant difference emerged, $\chi^2(2) = 10.75$, $p = 0.005$ (16 above, 14 at chance, 2 below). The difference in number of children above, at, or below chance did not differ in the joint condition, $\chi^2(2) = 1.19$, $p = 0.55$ (11 above, 8 at chance, 13 below).

For the trials during which children did not successfully plan, we assessed the proportion of this subset of trials that children successfully modified their errors without any hints (*proportion modified)*. The proportion modified did not differ between the individual and joint conditions, $t(30) = 0.42$, $p = 0.68$, cohen's $d = 0.09$ (Wilcoxon Signed Rank: $Z = 0.41$, $p = 0.68$). Overall, following planning and the opportunity to modify their actions (*proportion planned or modified*), children were highly successful in both the individual and joint conditions (mean proportion of trials in which the child had correctly placed all balls [without hints] by the end of the trial: $M = 0.85$, $SEM = 0.03$, and $M = 0.85$, $SEM = 0.03$, respectively).

We then assessed whether children were learning across the six trials within each condition and whether any potential changes differed between conditions. A Repeated-Measures Analysis of Variance (ANOVA) with trial portion (first or second half) and condition (individual or joint) as repeated measures revealed no main effect of trial portion ($F(1,30) = 2.47$, $p = 0.13$, $\eta^2_p = 0.08$) and no interaction between trial portion and condition ($F(1,30) = 1.43$, $p = 0.24$, $\eta^2_p = 0.04$), but a significant main effect of condition ($F(1,30) = 4.70$, $p = 0.04$, $\eta^2_p = 0.14$).

Given the increased planning performance in the individual condition, one might expect that children who engaged in the individual condition prior to the joint condition would perform better during the joint condition. In contrast to this notion, when condition order (i.e., whether the child participated in the individual or joint condition first) was added as a between-subjects (counterbalanced) factor to a repeated-measures ANOVA, the order in which children engaged in the two conditions did not influence their advance planning (main effects and interactions: $ps > 0.85$) and both children who initially engaged in the individual condition and those who initially engaged in the joint condition showed evidence of planning in the individual (one-sample *t*-test from chance: $p = 0.013$ and 0.016, respectively), but not the joint ($p = 0.86$ and 0.97, respectively), condition. Thus, there was no transfer of learning from the individual condition to the joint condition.

In order to verify that presentation order was unrelated to children's success in planning within either condition, we examined any potential correlation between ball order score and advance planning in either condition ($ps > 0.11$). This lack of effect suggests that no ball presentation order was more difficult for children than another. We also assured that the number of these different kinds of trials did not differ between conditions ($p = 0.74$). Therefore, ball presentation order had no influence on children's planning either within or between conditions. Finally, for the approximately 15% of trials on which children may have received hints following unsuccessful planning and modifying (i.e., the trials on which children did not advance plan or modify correctly without a hint; 1.0–0.85; see mean planned or modified above), we assessed whether providing a hint on one trial influenced the child's advanced planning in the subsequent trial. We found that children were equally likely to correctly plan in advance (n = 15 trials in each condition) as to not plan correctly (n = 13 trials in each condition) on trials following hints.

#### 6.2.2. Timing and attention results

We assessed children's attention to (seconds gazing toward) Kip and the experimenter in order to ensure that children were acting as though Kip, rather than the experimenter, was the social partner in the joint condition. In accordance with this hypothesis, children were rated as more attentive to Kip than to the experimenter during joint action trials, $t(25) = 9.29$, $p < 0.001$. Amount of time looking to the experimenter and Kip were both unrelated to planning in the joint condition, $rs < 0.30$, $ps > 0.14$, and amount of time looking to the experimenter was unrelated to planning in the individual condition, $r = -0.08$, $p = 0.71$.

### 6.3. Discussion

In this experiment, children were significantly better at planning ahead when they played alone than when they took turns playing with a social partner. That is, when playing alone, they were more likely to take into account the colors of the remaining balls when initially choosing where to place the mixed ball. When playing with a partner, children's initial placement of the mixed ball was seemingly random (i.e., the placement was correct about half the time). The fact that children did not perform as well in this case suggests that sharing the task with a partner made it more difficult for the children to plan the substeps of the task in advance.

When children did not plan correctly and encountered a proceeding ball for which there was no matching cup, they were equally competent at modifying this action without any hints regardless of whether they were playing alone or with a partner. The fact that children could and did modify the action without hints from the experimenter in both conditions suggests that children understood the goal of the task and what actions were necessary in order to achieve this goal. Thus, it was not a lack of understanding of the task that prevented children from planning appropriately during the joint condition. This is impressive given the complexity of the task carried out by the children.

These findings raise the question of why children's planning differed between individual and joint conditions. As confirmed by our analyses, the order in which the conditions were encountered did not play a significant role in children's planning in either condition; nor did the different presentations of ball order influence children's planning. What was it, then, that made acting with Kip more difficult for planning actions?

On one account, low-level factors such as cognitive load could have interfered with children's planning. The presence of the partner added complexity to the scene, possibly drawing cognitive resources away from the task at hand and causing the child to lose focus. Baron (1986) has suggested that the presence of others causes shifts in cognitive processing. This might be particularly true during early development when attentional control is still developing (Rueda, Posner, & Rothbart, 2005). The lack of relation between attention to Kip and planning during the joint condition suggests that simple attention to Kip was not driving individual differences in the deficits seen in planning. Still, overall, children did have more to process during the joint condition than the individual condition, which may have hindered performance on a group level.

For instance, children may have struggled to maintain attentional control because of the timing differences between the two task conditions. That is, children could play continuously during the individual condition of the task but were required to pause their own play while their partner acted during the joint condition. It is possible that it was not simply the presence of the other, but the fact that the child's play was interrupted that made planning more difficult. The act of flexibly adapting to the timing, rather than controlling the timing oneself, could have also decreased children's focus and hindered advance planning.

Alternatively, the mere presence of a social partner, rather than the pauses in play or attention, may have undermined children's planning. Did the children truly see Kip as a "social partner" and, if so, what was the consequence of this? Anecdotal evidence and attentional analyses suggest that children viewed the puppet, Kip, as a social partner, separate from the identity of the experimenter. Several children were initially shy when Kip was first introduced; others were highly engaged with Kip and talked with her or gave her a high five or a hug after successful trials. Children also looked more toward Kip than to the experimenter during joint condition trials. Thus, consistent with past research suggesting that children can treat puppets as social agents (e.g., Bartsch et al., 2011), it seems that children in this case viewed Kip as social. Given that children viewed Kip as a social partner, the social nature of the interaction may have disrupted the children's planning.

When performing a task alone, we can create a plan and carry out the task without interruption. When jointly acting with another person, however, we need to take the other's actions into account. According to Sebanz and Knoblich (2009), intentional coordination of actions with another person requires representing both one's own and one's partner's roles in the task. They suggest that adults engaged in joint actions predict a partner's actions in a joint action task by representing the action of a partner and one's own actions in a functionally equivalent way. The incorporation of the partner's task typically leads to a decrease in performance (e.g., slowed reaction time) relative to when carrying out the same task without a partner present or with a non-social machine (Sebanz, Knoblich, & Prinz, 2003; Stenzel et al., 2014). In fact, incorporating a partner's task "affects one's own action planning and performance even when there is no need to take the other's part into account at all" (p. 357; Sebanz et al., 2003). In accord with this, Knoblich and Jordan (2003) observed that groups, relative to individuals, face additional demands that are harder to overcome when planning needs to be extended into the future. Information about others' actions is a necessary condition for groups to effectively learn to extend their plans. Recent developmental research suggests that, at least by four years of age, children similarly co-represent a partner's task during joint actions (Milward et al., 2014; Saby et al., 2014).

Sebanz et al. (2003) suggest that the presence of others influences task performance. They argue that "social facilitation effects are not moderated by the specific actions carried out by others" (p. 12). Instead, they suggest that the presence of another person improves performance on simple tasks but impairs performance on more complex tasks. The current task provides a setting in which this perspective may come to bear in that the planning carried out by children at three years is complex for their developmental stage and is still malleable at this age. As noted by Rogoff, Gauvain, and Gardner (1987), when first emerging, a lack of advance planning may not indicate a lack of skill, "but may instead [reflect] difficulty implementing it appropriately in the many occasions in which the task is hard for them" (p.312).

In a second experiment, we contrasted the above two perspectives to resolve whether attention and timing factors (e.g., executive function) or social factors (e.g., shared representations) better explained why children's planning suffered in the joint condition from Experiment 1. Rather than playing the matching game with a social partner, in Experiment 2, children instead alternated turns with a machine that similarly created cognitive demands and interruptions in play. In contrast to the puppet, however, machines are not seen as social and infants and young children do not see their actions as intentional or goal-directed (Meltzoff, 1995; Moriguchi, Matsunaka, Itakura, & Hiraki, 2012; Woodward, 1998). If the cognitive demands of interacting with the partner or pauses during play decreased children's advance planning in Experiment 1, children should be equally poor at planning ahead when playing with a machine. If, however, children's difficulty in the joint context of Experiment 1 was uniquely the result of playing with a social partner, children playing with the machine should perform just as well as when playing alone.

## 7. Experiment 2

### 7.1. Method

#### 7.1.1. Participants

Thirty-two three-year-olds (mean age = 36.19 months; range = 35.5 months–36.67 months) who had not participated in Experiment 1 were included in the final data set for this study (14 females). All children were recruited from a database of families who volunteered to participate in child studies. An additional six children participated but were not included due to equipment malfunction ($n = 1$), not completing all trials ($n = 4$), or lack of learning of the rules of the game ($n = 1$).

#### 7.1.2. Stimuli, procedure, and coding

The stimuli and procedure in Experiment 2 were identical to those in Experiment 1 with the following exceptions: In both individual and joint trials, the balls came out of a tube that was part of a machine that appeared to move on its own in a mechanical motion (see Fig. 2B). The experimenter used a control box that was out of the child's sight to release balls from the tube and to move the correct cup under the tube during the joint trials for which it was the machine's turn. Instead of introducing the child to Kip at the beginning of the joint trials, the experimenter told the child that he or she would be playing with a machine and had to take turns. As Kip did in Experiment 1, the machine always placed the multi-colored ball in the correct cup during its turn. If the machine was to place a solid colored ball into a cup that was not available, it would move back and forth between the full cups (to indicate hesitation and to best match the knocking of balls that Kip did in Experiment 1) and then would pause and wait for the child to respond. If the child did not modify the action immediately, the machine would drop the ball into an incorrect bucket (because the machine could not vocalize the problem as Kip did in Experiment 1). Coding of planning and modifying was identical to that of Experiment 1 and a reliability coder who coded 25% of the videos agreed with the original coder on 98% of trials ($\kappa > 0.8$, $p < 0.001$). Coding of attention was not conducted for this experiment as there was no social partner and it was not possible to differentiate looks to the machine and the balls or cups because they were within contact at all times (and balls were actually held within the machine).

### 7.2. Results

As in Experiment 1, we first assessed whether children differed in their *advance planning* when playing alone (individual condition) or with the machine (joint condition). This revealed that children did not differ in their planning in the two conditions, $t(31) = 0.29$, $p = 0.78$, Cohen's $d = 0.07$ (see Fig. 3; Wilcoxon Signed Rank Test: $Z = 0.44$, $p = 0.66$). The proportion of trials for which children successfully planned was greater than chance levels in the individual condition, $t(31) = 2.45$, $p = 0.02$, Cohen's $d = 0.88$ ($M = 0.58$, $SEM = 0.03$), and in the joint condition, $t(31) = 2.83$, $p = 0.008$, Cohen's $d = 1.02$ ($M = 0.60$, $SEM = 0.03$). As a complementary non-parametric measure, chi square tests were conducted for each condition with number of children performing above, at, or below chance entered as variables. Significant differences emerged in both the individual, $\chi^2(2) = 6.44$, $p = 0.04$ (15 above, 13 at chance, 4 below). and the joint conditions, $\chi^2(2) = 10.19$, $p = 0.006$ (19 above, 8 at chance, 5 below).

For the trials during which children did not successfully plan, we again assessed proportion modified and proportion planned or modified. The proportion modified did not differ between the individual and joint conditions, $t(27) = 0.16$, $p = 0.88$, Cohen's $d = 0.03$ (Wilcoxon Signed Rank Test: $Z = 0.17$, $p = 0.86$). Overall, children were highly successful in both the individual and joint conditions in proportion planned or modified (mean proportion of trials in which the child had correctly placed all balls [without hints] by the end of the trial ($M = 0.85$, $SEM = 0.03$, and $M = 0.85$, $SEM = 0.04$, respectively).

A repeated measures ANOVA with trial portion and condition as repeated measures showed no effect of trial portion ($F(1,31) = 0.37$, $p = 0.35$), condition ($F(1,31) = 0.04$, $p = 0.84$), or interaction between these two factors ($F(1,31) = 0.24$, $p = 0.63$). We also confirmed that the different types of ball order presentation did not differ between conditions, $p = 0.88$, and that ball presentation order was unrelated to planning in either condition, $ps > 0.32$. Further, we confirmed that the ball order presentation did not differ between experiments 1 and 2 for either condition, $ps > 0.16$. Additionally, we found that the number of trials directly following potential hints that children planned correctly (n = 11 and 10 in the individual and joint conditions, respectively) and did not plan correctly (n = 9 and 13, respectively) did not differ systematically.

#### 7.2.1. Results across Experiments 1 and 2

Finally, in order to compare advance planning between conditions, we conducted a repeated measures ANOVA with condition as a repeated measure and experiment as a between subjects measure. This revealed no main effects (condition: $F(1,62) = 1.81$, $p = 0.18$, $\eta^2_p = 0.03$; experiment: $F(1,62) = 1.08$, $p = 0.30$, $\eta^2_p = 0.02$) but a marginal interaction between condition and experiment, $F(1,62) = 3.10$, $p = 0.08$, $\eta^2_p = 0.05$. Following up on the estimated marginal means of this interaction revealed that participants' advanced planning did not differ between experiments for the individual condition (estimated marginal mean = 0.02 [SEM = 0.04], $p = 0.57$). The difference between experiments was marginal for the joint condition (estimated marginal mean = 0.09 [SEM = 0.05], $p = 0.07$) such that individuals in the first experiment (puppet) were worse at advance planning in the joint condition than participants in the second experiment (machine).

### 7.3. Discussion

In Experiment 2, the cognitive and inhibitory demands of the joint condition with the machine were matched to the cognitive and inhibitory demands required for interaction with the puppet in Experiment 1 in terms of the pauses between turns for the child and the novelty of the puppet or machine during the joint phase. Nevertheless, children in Experiment 2 performed equally well in planning ahead in the individual and joint conditions when the joint "partner" was a non-social machine. The fact that children's advance planning was significantly above chance level in the joint condition and did not differ from performance in the individual condition suggests that the pauses between turns and necessary inhibitory control was not a significant source of difficulty for the participants. The marginal difference between joint conditions in the two experiments, however, indicates that this should be interpreted with caution.

Further, the new context (relative to training) and the added novelty of the machine did not disrupt children's proactive problem-solving. Anecdotally, the majority of children were intrigued by the machine and were interested in uncovering the source of the movement (and sometimes even tried to push the machine themselves). Despite the avid attention children paid to the novel contraption, they were able to overcome this distraction in order to plan ahead. The matching of these factors across experiments and differential advance planning of children in the joint condition indicates that, rather than cognitive limitations such as attention switching or inhibition, the social context that the puppet provided specifically challenged children's advance planning in Experiment 1. The possible reasons for the unique detriment in advance planning when playing with a social partner are expanded upon in the General Discussion.

## 8. General discussion

The current findings shed new light on the difficulties encountered when first attempting to incorporate predictions of a partner's actions with one's own advance planning. They suggest that proactive planning for two individuals, even when they share a common goal, is more difficult than planning ahead solely for oneself. They further highlight differences between interactions with a non-social versus a social partner.

### 8.1. Implications for joint action development

The unique challenge of planning actions with a social partner is consistent with prior research indicating that taking another individual into account when carrying out joint actions adds complexity beyond that added by the novelty of a non-social agent. Sebanz and Knoblich (2009) have pointed out that planning in joint actions may be more difficult than during individual actions because joint actions involve integrating two action plans – one's own and one's partner's. Given that planning of others' actions might happen in a functionally equivalent manner to planning one's own actions (as described by the simulation account, e.g., Wilson & Knoblich, 2005), it is understandable that the effort of separating plans for the other from those of your own might hinder optimal performance. As noted in the introduction, recent evidence suggests that children, like adults, represent a partner's actions when in a social interaction (Milward et al., 2014; Saby et al., 2014). In some instances, a social partner's actions interfere or alter the effects of one's own actions. These instances make planning one's own actions more difficult and stress the importance of creating complimentary actions in joint action (Bekkering et al., 2009). In the current research, the partner's actions should not have interfered with the child's in any way (as the partner always acted correctly and there was no need to coordinate actions on a fine timescale). An interesting avenue of future research will be to explore how less predictable or reliable social partners influence children's advance planning and modifications.

The joint action conditions in these experiments were minimally joint in that they involved a turn-taking task during which the partner always performed correctly. Turn-taking reduces timing and coordination demands that are common to other joint action tasks. Still, the difficulty in planning ahead for the children in the joint condition of Experiment 1 indicates that this minimal interaction made the task more difficult than playing alone. These findings suggest that the added difficulty of engaging in joint actions with social partners is robust early in development, in that errors can be seen in minimally joint contexts and without the need to time and coordinate actions carefully. The effects likely become more subtle with further development (e.g., evident in reaction time differences for particularly complex tasks). Future research should consider the differential influences of more or less complex interactions with social and non-social partners across development.

### 8.2. Developmental links between planning, social cognition, and social interaction

Ontologically, developments in advance planning skills and increased participation in joint actions emerge around the same period (De la Ossa & Gauvain, 2001; McCormack & Atance, 2011; Meyer et al., 2010). More broadly, the similar timing in development of several executive functioning (EF) skills (including planning, inhibitory control, and working memory) and social cognition (e.g., theory of mind) have been thoroughly studied (refs?). One reason many researchers are interested in the similar timing of EF skill emergence and improvements in social cognition is because of the bidirectional relations between these domains and their effects on later social functioning. For example, greater EF skills have been associated with better theory of mind reasoning in children during development of both of these skills (e.g., Carlson, Mandell, & Williams, 2004; Frye, Zelazo, & Palfai, 1995; Hala, Hug, & Henderson, 2003; Hughes, 1998; Müller, Liebermann-Finestone, Carpendale, Hammond, & Bibok, 2012), and individual differences in performance on theory of mind tasks, in turn, are predictive of later social competence (e.g., Diesendruck & Ben-Eliyahu, 2006; Lalonde & Chandler, 1995; Razza & Blair, 2009). Riggs, Jahromi, Razza, Dilworth-Bart, and Mueller, (2006) suggest that EF likely has direct, mediational and moderational influences on social functioning. As shown in this research, social context can have an influence on executive functioning (i.e., planning) during an ongoing interaction, thus supporting the possible mediational role of social interactions on relations between social cognition and executive functioning.

Interestingly, children responded differently to social and non-social partners, and the incorporation of another social agent into the task was uniquely challenging. The challenge of incorporating social cognitive skills into joint action tasks likely influences the efficiency and effectiveness of carrying out joint actions throughout development. In fact, in a review of joint action development, Brownell (2011, p. 193) suggested that "a key mechanism underlying the dramatic changes in joint action over the second year of life is the ability to reflect consciously on oneself and one's behavior and volition and correspondingly, on the behavior, goals, and intentions of others". As noted in the introduction, engagement in joint actions with a social partner requires a variety of social cognitive abilities. The prerequisite abilities of prediction, shared representation, and integration emerge at different timepoints in development. Children of the age in the current research (3 years) have the ability to view a partner as an intentional agent (see Woodward et al., 2009, for a review), predict another person's actions (e.g., Falck-Ytter, Gredebäck, & von Hofsten, 2006), and plan ahead when carrying out their own actions (individual conditions in this research). They understand and predict others' actions specifically for social agents (e.g., hands, characters, puppets, biological motion) but not for non-agentive objects (e.g., claws, machines, mechanical movement; e.g., Falck-Ytter et al., 2006; Meltzoff, 1995; Woodward, 1998). Meyer and colleagues (Meyer, Bekkering, Haartsen, Stapel, & Hunnius, 2015) recently found direct evidence that individual differences in 2.5-year-olds' ability to accurately anticipate others' actions in an eye-tracking task was directly related to effectively carrying out joint actions in a turn-taking task. This suggests that the ability to predict actions accurately outside of a joint action context (in place to varying degrees in the third year of life) plays a role in a child's ability to adapt to a partner within a joint action.

Although it is likely that three-year-old children *could* make predictions about a partner's actions, the extent to which they integrated and differentiated their own and their partner's plans cannot be defined in the current experiment. Recognition of a shared representation between oneself and one's partner and differentiation between oneself and one's partner is likely a function of full-fledged theory of mind that is not solidified until the fourth or fifth year of life. Consistent with this notion, Milward and colleagues (Milward et al., 2014) recently found that children four years and older represented a partner's task during a joint activity, but younger children did not. It is possible, however, that children's developing understanding of others' mental states at this age could interfere with processing by adding an increased cognitive load when interacting with a social partner. That is, attempting to identify a social partner's mental states, even if not fully formed or accurate, could interfere with other task demands. This possibility presents an alternative to the hypothesis put forth by Sebanz and Knoblich (2009), though not orthogonal or in complete contradiction, in that an accurate and complete internal representation of the partner's action would not be necessary in order to interfere with processing in joint actions. The current research cannot differentiate these possibilities, but future research should investigate how changes in theory of mind influence the way in which children represent and interpret a partner's actions and alter how they interact with that partner.

### 8.3. Limitations and future directions

The relative complexity of the planning task in this research may have provided the ideal setting in which to examine differences across social contexts at this age. It is likely that, given a less demanding task (or this task at an older age), children would have performed similarly in the individual and joint conditions in Experiment 1. On the other hand, a more difficult task may have created floor effects in which children would not have performed at above chance levels in either condition. The variability in advance planning across conditions in this research was likely due to an interplay between task difficulty and developmental period. Whether and how individual versus joint planning differs in different developmental periods and at different levels of task complexity should be explored further.

The specific context and knowledge about the individual with which the child is engaged may alter how children interact with the joint action partner. In the current experiment, it is unknown whether children viewed the puppet as a similarly skilled peer, an adult who was not helpful in scaffolding, or a play companion who was pretending to be naïve. Better defining how children view the interaction partner and how different partners alter their behavior will help define the constraints and generalizability of the current findings. For example, whether performance differs when playing with parents, who may scaffold their actions, or with peers, who are less predictable in their actions, is an interesting avenue of future work. In the current research, we do not know whether children perceived Kip as more or less predictable than the machine in Experiment 2.

One possible explanation for the current findings is that children perceived the social agent (Kip) as less predictable than the machine and thus found the presence of the social other more distracting during their own actions. Although we controlled the actual predictability of Kip's and the machine's actions, humans are typically less systematic and consistent in their responses than are machines, and this knowledge could have accordingly influenced children's interactions with Kip. Another alternative is presented by the on-line simulation account (e.g., Wilson & Knoblich, 2005), which proposes that it is more difficult to separate one's own action plans from a human agent compared to a non-human agent because of the functionally equivalent format in the former, but not the latter, case. A better understanding of how actions of others are represented and influence advance planning within joint action development is critical for further exploration of potential educational consequences and atypical developmental patterns.

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