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SHORT REPORT

Children use salience to solve coordination problems

Sebastian Grueneisen, Emily Wyman and Michael Tomasello

Max Planck Institute for Evolutionary Anthropology, Department of Developmental and Comparative Psychology, Leipzig, Germany

Abstract

Humans are routinely required to coordinate with others. When communication is not possible, adults often achieve this by using salient cues in the environment (e.g. going to the Eiffel Tower, as an obvious meeting point). To explore the development of this capacity, we presented dyads of 3-, 5-, and 8-year-olds (N = 144) with a coordination problem: Two balls had to be inserted into the same of four boxes to obtain a reward. Identical pictures were attached to three boxes whereas a unique – and thus salient – picture was attached to the fourth. Children either received one ball each, and so had to choose the same box (experimental condition), or they received both balls and could get the reward independently (control condition). In all cases, children could neither communicate nor see each other's choices. Children were significantly more likely to choose the salient option in the experimental condition than in the control condition. However, only the two older age groups chose the salient box above chance levels. This study is the first to show that children from at least age 5 can solve coordination problems by converging on a salient solution.

Research highlights

- Dyads of children (3-, 5-, and 8-year-olds) were presented with a coordination problem where they had to choose the same of four options as their partner to be rewarded.
- Without communicating or seeing each other's choices, children from age 5 tended to choose the option that was most salient.
- In a control condition where children could retrieve rewards independently, they favored the other, non-salient options.
- From at least 5 years of age, children can coordinate with peers by converging on a salient solution.

Introduction

The need to coordinate our actions with others is ubiquitous in everyday social life. When navigating through traffic, collaboratively working on a project with others, or simply meeting up with friends, the success of our pursuits depends not only on our own, but also other's actions. The ease with which we habitually coordinate suggests that this comes naturally to us, but in fact this facility hides a significant psychological challenge. In order to successfully coordinate, we must form expectations about what others are likely to do. The problem is that our potential partners form simultaneous expectations about our actions. Our expectations are interdependent in ways that have perplexed social theorists for the last half-century or so (e.g. Schelling, 1960; Sugden, 1995). What is required for coordination is thus a kind of 'meeting of minds' that allows us to align our expectations. Indeed, some recent theoretical accounts have proposed that the need to overcome the cognitive perplexities associated with coordination may have contributed substantially to shaping human psychology over the course of evolution (Tomasello, Melis, Tennie, Wyman & Herrmann, 2012).

A key approach to addressing how coordination is achieved has been to place individuals in so-called 'coordination problems' (Lewis, 1969; Schelling, 1960). These are situations in which multiple individuals have a common goal (e.g. to meet), they must – without communicating – converge on one of multiple solutions to achieve this goal (e.g. meeting at location A or B), and

Address for correspondence: Sebastian Grueneisen, Max Planck Institute for Evolutionary Anthropology, Department of Developmental and Comparative Psychology, Deutscher Platz 6, 04103 Leipzig, Germany; e-mail: sebastian_grueneisen@eva.mpg.de

individuals' decisions are interdependent (each person's best decision depends on what others do, and vice versa). In a classic example, Schelling (1960, pp. 54–56) presented participants with a story-scenario in which two parachutists land in foreign territory and try to meet each other using their maps. When asked to take the parachutists' perspective and select a meeting place, most participants chose the same location – a bridge that was prominent due to its centrality – despite the presence of several in principle equally suitable alternatives (a pond, several buildings and intersections). According to Schelling (1960), they achieved this by mutually recognizing a so-called 'focal point'. These are cues in the environment that people perceive as salient and which therefore allow them to converge their expectations of each other's choices.

Research has since shown that adults are proficient at coordinating without communication, despite the fact that there is no rational solution as to which of the multiple solutions ought to be converged upon (Bacharach, 2006; Camerer, 2003). Indeed, people are adept at flexibly using a variety of focal points including perceptual cues (e.g. Mehta, Starmer & Sugden, 1994), social cues (De Kwaadsteniet, Homan, Van Dijk & Van Beest, 2012), or knowledge they share due to their common cultural background (e.g. Bardsley, Mehta, Starmer & Sugden, 2010).[1] While this is not meant to suggest that all coordination problems are solved this way, these findings do indicate that being a competent collaborative partner in situations of interdependence is greatly facilitated by the ability to identify and make use of such focal points.

Surprisingly, research on the development of this ability is essentially non-existent. Instead, previous work on coordination in children has mainly focused on action coordination. For instance, Warneken, Chen and Tomasello (2006) showed that 18-month-olds are able to coordinate actions in tasks richly structured by adults (e.g. by waiting for an adult partner and re-engaging them after coordination break-down). With regard to action coordination with peers – e.g. simultaneously pulling a handle to access a toy – children's competence increases around the age of 2 when they start monitoring each other's actions and attention states (Brownell, Ramani & Zerwas, 2006). Around the same age, children also start to understand that they need to coordinate intentional states with collaborative partners to successfully complete cooperative tasks (Warneken, Gräfenhain & Tomasello, 2012). These studies show that from early on children are attuned to engage in collaborative interactions and possess basic cognitive capabilities for doing so. These capacities are very different, however, from the ability to solve formal and tacit coordination problems: In these, individuals are required to converge on one of multiple ways of cooperating with a partner, despite the fact that each solution presents an equally effective way of cooperating (the problem of equilibrium selection; e.g. Harsanyi & Selten, 1988). In addition, in the classic formulation, the problem is tacit, such that individuals must achieve coordination in the absence of communication. This forces individuals to reason about which of the multiple solutions others are likely to choose, and potentially reason about others' reasoning about their own likely actions. To our knowledge, no study so far has examined children's abilities to solve formal coordination problems in general, and more specifically, by using salience as a focal point.

Therefore, we presented dyads of children with a coordination problem: In training, children were presented with four identical boxes, were each given a ball, and learned that inserting these balls into the same box released a gummy-bear for each child. Inserting them into different boxes, however, left them empty-handed. Dyads were then given one test trial in which three of the boxes were marked with identical pictures and one was marked with a different (and therefore, salient) picture. Critically, on this trial, children could neither see their partner's actions nor could they communicate with each other. There were two conditions: In the experimental condition children's decisions were *interdependent* – they each received one ball and therefore had to put their balls into the same box to be successful. In the control condition children's decisions were *independent* – children were given two balls each and could retrieve a gummy-bear irrespective of their partner's decision. We predicted that children would choose the salient box more often in the experimental condition where coordination was required for success than in the control condition where no coordination was needed.

Method

Participants

Forty-eight 3-year-olds (mean age = 3 years, 3 months, 50% females), 48 5-year-olds (mean age = 5 years, 2 months, 50% females), and 48 8-year-olds (mean age = 8 years, 7 months, 50% females) were tested in same-sex dyads. Four additional 3-year-olds were excluded due to shyness (one), experimental error (one), or failure to

[1] For example, when asked to choose the same car manufacturer as an anonymous partner most participants converged on Ford as that seemed to be the prototypical manufacturer in that (British) sample. Probably very different results would have been obtained in other countries.

play the game properly (two). One additional 8-year-old dyad took part but was excluded from the analysis because children communicated their choices before the test trial. Children came mainly from middle-class backgrounds. Five-year-olds were recruited from urban daycare centers and thus were mostly familiar with each other. Eight- and 3-year-olds were recruited from a database of parents who volunteered to take part in child development studies. These children did not know each other beforehand but were familiarized with each other in a warm-up phase prior to the experiment.

Apparatus

Children were presented with four identical sets of apparatus. These were wooden boxes (47 × 40 × 16 cm) with a plastic tube protruding laterally (see Figure 1). Inside each apparatus, a container holding two gummy-bears sat on a platform. If one ball was inserted into the tube, it rolled down a marble run, and became lodged in a hole in the run. When a second ball was inserted, it rolled over the previously inserted ball, and knocked the container off the platform. This triggered a sliding door on the side of the box to hoist upwards, making the gummy-bears retrievable.

Procedure

Introduction

In a demonstration phase dyads were familiarized with the mechanics of a single box. A first experimenter (E1) demonstrated how to extract the gummy-bears, after which children played two practice rounds and collected the rewards in little containers.

Training

Here children were presented with all four boxes at once. Different pictures were attached to each box whereby the boxes could be easily distinguished from each other. The pictures (e.g. four different fruits or pieces of clothing) were changed on all four training trials.

At the start of each trial, a second experimenter (E2) took one child (C2) out of the test room while the other child (C1) was positioned opposite the four boxes (which child played first alternated on every trial). E1 then asked C1 to choose a box to insert his/her ball in, do so, and then leave the room and tell C2 which box he/she had chosen (e.g. 'I chose the box with the apple on it'). C2 then entered the room, was positioned opposite the boxes, and was asked to insert his/her ball into one of the boxes. After C2 had done so, E2 re-entered with C1, whereupon both children shared the rewards and went behind individual cardboard barriers where they received a drawing task. Meanwhile, E1 refilled the emptied box and changed the pictures for the subsequent trial. Training procedures were close to identical for all age groups. However, on the last training trial most 3-year-olds were asked to point out which box their partner would have to choose after they had inserted the first ball. This gave an indication of whether they had thoroughly grasped their interdependence.

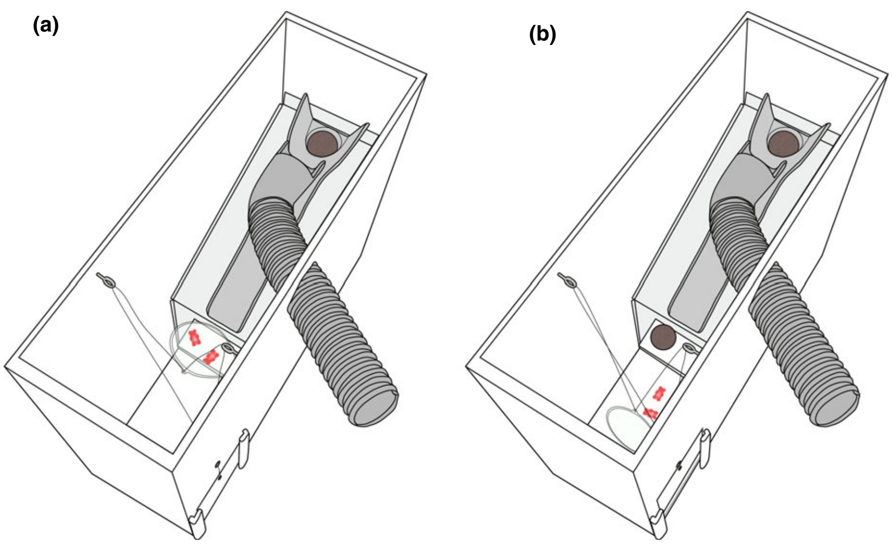

Figure 1 *Apparatus*
(a). Apparatus after one ball has been inserted.
(b). Apparatus after two balls have been inserted and gummy-bears are retrievable.

Test

Dyads were given one test trial that was identical to training trials except for three critical changes: First, children were instructed that they would not be allowed to communicate anymore; second, three of the boxes were marked with identical pictures whereas one box was marked with a different and, therefore, salient picture (the salient picture – a piece of celery – was less attractive than the identical pictures – ice-cream cones – to reduce the chances of children choosing the salient option simply because they liked it more). Lastly, children's starting position was placed furthest from the box with the salient picture (see Figure 2). Hence, going for the salient box required an additional – albeit small – physical effort.

In the experimental condition, C1 was positioned at the start mark while C2 waited outside with E2. E1 first told C1, 'You will get one ball and your partner will get the other ball – so you have to work together for it to work', after which E1 asked two comprehension questions ('Are you allowed to tell your partner which box you have chosen?' and 'Do you need to think about which box your partner will choose?', with corrective feedback given by E1). E1 then handed over a ball to C1 whereupon C1 inserted it into one of the boxes. In order to prevent communication between children, C1 was then taken behind his/her barrier whilst C2 was brought into the room and positioned behind his/her respective barrier. Only after C1 had been escorted out of the testing room was C2 positioned at the start mark, and given the same instructions as C1 (adjusting for the fact that C1 had already played).

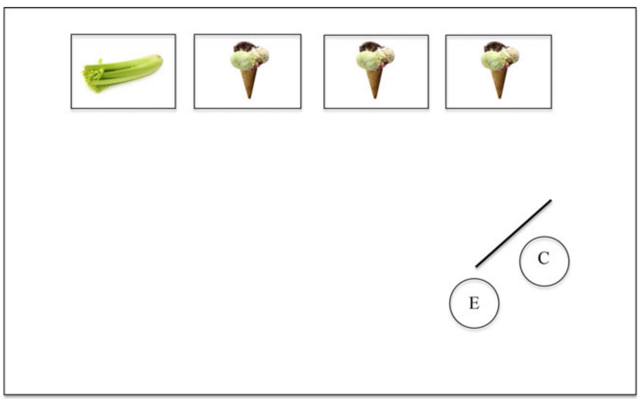

Figure 2 *Experimental setup. Children are presented with four boxes. A unique (and thus salient) picture is attached to one box, and identical pictures are attached to the other boxes. Only one child (C) is in the room with the experimenter (E) while the other child waits outside with a second experimenter.*

The procedure for dyads in the control condition was identical, except that the first instructions were changed to 'you will get both balls so this time you can get the gummy-bears alone'.

Sessions were videotaped and coded from video by the first author. A second coder, blind to the study's predictions, recoded 20% of children's choices. There was complete agreement between coders.

Results

An overview of children's choices is shown in Table 1. Since children made only a single test decision without receiving any information about their partner's choice, our dependent measure was whether or not individual children chose the salient box as a solution (rather than successful coordination by dyads). We first analyzed children's choices with a logistic model using the glm function in R (R core team, 2012) with the categorical predictors condition, age as well as their interaction in the model. We also controlled for sex by including it as a covariate.

The model was highly significant when comparing it to a null model only including sex (likelihood ratio test: $\chi^2(5) = 56.781$, $p < .001$; all further tests were also LRT's unless otherwise stated) indicating that the predictors and/or their interaction affected children's choices. Further analysis revealed that the interaction between age and condition was not significant (full model compared to a reduced model not including the interaction: $\chi^2(2) = 1.106$, $p = .575$), so we devised a new model without the interaction to test for effects of the two predictors. This revealed significant effects of both condition (new model compared to reduced model excluding condition: $\chi^2(1) = 26.116$, $p < .001$) and age (new model compared to reduced model excluding age $\chi^2(2) = 35.135$, $p < .001$). Hence, children in the experimental condition chose the salient box significantly more often than children in the control condition, and the probability of choosing the salient box increased with age.

Table 1 *Children's choice of box in the experimental and control conditions*

		Box 1 (salient)	Box 2	Box 3	Box 4
3-year-olds	Experimental	4	2	5	13
	Control	0	7	5	12
5-year-olds	Experimental	12	2	4	6
	Control	3	2	10	9
8-year-olds	Experimental	20	1	3	0
	Control	8	4	6	6

The lack of an interaction between condition and age seemed to suggest that children of all age groups were able to solve the task. Indeed, and as can be seen in Figure 3, children in all age groups chose the salient box more often when coordination was required (83.3%, 50.0%, and 16.7% for 8-, 5- and 3-year-olds, respectively) than when they could choose independently (33.3%, 12.5%, and 0% for 8-, 5- and 3-year-olds, respectively). It should be noted, however, that the numbers for the 3-year-olds are very low: Only four out of 24 children chose the salient box in the experimental condition. We therefore followed up our initial analysis by comparing children's performance in the experimental condition to chance levels. This revealed that only the 5- and the 8-year-olds but not the 3-year-olds chose the salient box significantly above chance (3-year-olds: binomial $p = .885$; 5-year-olds: binomial $p = .014$; and 8-year-olds: binomial $p < .001$, with p-values adjusted for multiple comparisons using Holm's procedure) suggesting that caution should be exercised with regard to the 3-year-olds' competence.

We also tested for potential alternative coordination strategies based on the dyad's shared experience during training. This revealed that children were neither more likely to choose the box they had chosen most often during training (3-year-olds: binomial $p = .332$; 5-year-olds: binomial $p = .481$; 8-year-olds: binomial $p = .235$), nor were they more likely than chance to choose the box they had chosen on the last training trial (3-year-olds: binomial $p = .393$; 5-year-olds: binomial $p = .753$; 8-year-olds: binomial $p = .753$).

Finally, we inspected children's training performance. We found that younger children were more likely to make at least one mistake during training[2] (52.8%, 18.8% and 4.2% for 3-, 5-, and 8-year-olds, respectively) and made more mistakes on their last training trial than older children (25%, 8.3%, and 0% for 3-, 5-, and 8-year-olds, respectively). However, when re-running the analysis after excluding all children who had made a mistake on their last training trial the results remained identical (the same holds when excluding all children who made any mistake throughout the whole training session). Furthermore, after inserting the first ball on their last training trial, 86% of the 3-year-olds correctly indicated which box their partner would have to choose, suggesting that they had understood the game rules. Again, excluding children who did not answer this question correctly does not alter the results.

[2] A mistake was coded as an attempt to go for a wrong box before being corrected by the experimenter and/or failure to remember the box their partner had previously indicated.

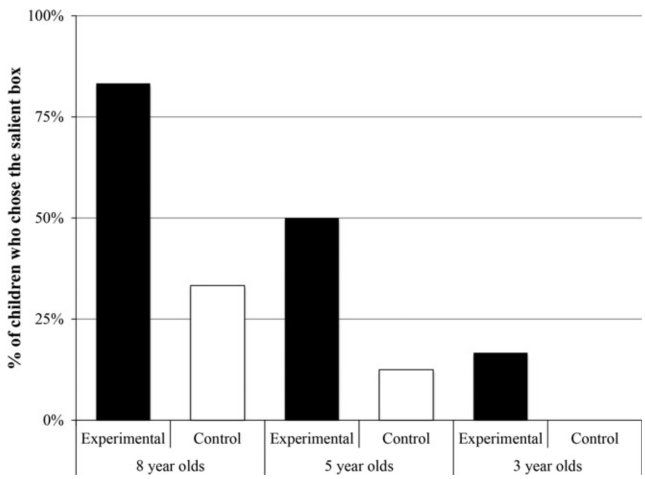

Figure 3 *Percentages of children who chose the salient box in the Experimental and the Control condition.*

Discussion

Our findings indicate that children from at least age 5 are able to use salience to solve tacit coordination problems. Children of all age groups chose the box marked with a salient picture more often when they tried to coordinate their decisions with a partner (experimental condition) than when they performed the same task, but could retrieve a reward independently (control condition). In contrast to the older children, however, the 3-year-olds only rarely chose the salient box. Also, unlike the 5- and the 8-year-olds, the 3-year-olds were not more likely than chance to choose the salient box in the experimental condition. The results therefore suggest that the ability to effectively identify salient focal points as strategic solutions to coordination problems is likely to emerge somewhat later in development.

Critically, the younger children's low performance is unlikely to be accounted for by their inability to understand the game rules as the results were close to identical when excluding children who failed to demonstrate a clear understanding of the task at training. A different explanation for the 3-year-olds' reluctance to choose the salient box is that they may have been unable to inhibit choosing the more attractive alternatives. Correspondingly, previous research has shown that children's capacities for inhibition increase during the preschool years (Carlson, Zelazo & Faja, 2013), raising the possibility that younger children might be more successful in tasks with lower inhibitory demands (indeed, the fact that all 3-year-olds who did choose the salient box were in the experimental condition might reflect the first signs of some rudimentary competence at this age). However, inhibition can also be viewed as intrinsic to solving coordination problems since individuals are generally required to disregard what stands out for them individually and consider instead what is jointly salient.

It should also be noted here that several of the boxes could have, in principle, been perceived as salient for different reasons: Thus, children who did not choose the box with the salient picture might have pursued different coordination strategies such as, for example, 'pick the closest box' or 'pick the middle of the three attractive boxes'. Indeed, these children mostly chose the boxes that were closest to them. However, this bias was equally present in the control condition. A more likely explanation is therefore that these children were either unable to identify the salient solution or unable to overcome their bias for choosing the closest boxes. Children also rarely chose the same non-salient box as their partner and they did so equally often in the control condition, suggesting that these coordination successes were due to chance. Children also did not appear to pursue alternative coordination strategies based on the shared training experience they received with their particular partner. They were neither more likely to choose the box they had chosen most often during training, nor did they increasingly choose the box they had chosen on the last training trial. The only coordination strategy we can unambiguously infer from our data is that children opted for the box that was most salient – i.e. the one with a different picture from all the others.

The performance of the older children in our task demonstrates capacities substantially beyond those of basic action coordination (e.g. Brownell *et al.*, 2006). In basic action coordination children have to understand and share intentions, align their attention, and generally possess a motivation to engage in joint activities (Tomasello, Carpenter, Call, Behne & Moll, 2005), all of which are surely prerequisites for solving the coordination problem presented in this study. The crucial challenge of our task, however, was to coordinate on one and the same of several equally functional solutions to reach a shared goal without communicating. To do this, they had to understand that their partner – like themselves – would perceive one option as salient relative to the alternatives, and use this as a basis for forming mutual expectations of each other's choices. Successful coordination thus required children to engage in sophisticated perspective taking and action prediction. In line with this notion, previous research with adults has shown that proficiency at solving coordination problems is associated with theory-of-mind functioning (Curry & Jones Chesters, 2012). This fits with our conjecture of a developmental change between 3 and 5 years of age, a period which has been widely noted as critical in the development of children's understanding of others' mental states (e.g. Wellman, Cross & Watson, 2001).

Interestingly, older children in our study not only increasingly chose the salient box when coordination was required but also when they could choose independently, which might be explained by a growing general preference for uniqueness. In Western societies people tend to prefer unique over common options – supposedly because uniqueness is valued culturally in individualistic societies (Kim & Markus, 1999) – and it is possible that this preference increases with age. Note, also, that choosing the salient box in the control condition does not constitute a failure (i.e. it was not incorrect in any way), and may even suggest that mutual preferences for uniqueness may be one way in which children and adults come to mutually identify solutions to coordination problems (in Western individuals at least). An interesting topic for future research would be to further investigate the development of coordination capacities throughout ontogeny, and how it interacts with other cognitive task demands such as developing preferences, and inhibition skills.

A valuable extension to this finding would be to examine by what other means children are able to solve coordination problems – possibly at even younger ages and using simpler strategies. Visual salience is only one way in which a solution can be prominent relative to its alternatives and children may be able to use a range of different types of salience. For instance, when trying to meet a friend in the schoolyard they may go to the most central location (thereby using spatial salience) or they may go to the trampoline rather than the swings if they have previously talked about how they both like jumping (thereby using salience derived from shared personal history). Moreover, when facing recurring coordination problems children might be able to use precedents as a simple but effective strategy (e.g. when two friends have previously met successfully at the swings they may go back to the swings next time they want to meet, i.e. they simply do what has worked before, see Lewis, 1969, on precedence). What is more, rather than relying on personal experience only, coordination may be greatly aided by access to social information. Humans may be particularly sensitive to the conventionality of certain solution strategies and we may often achieve coordination simply by copying what other people do. Studies that examine the various coordination strategies that children have at their disposal, and how they enable them to coordinate with others in the broad range of situations characteristic of human social life are thus part of our ongoing investigations (e.g. Grueneisen, Wyman & Tomasello, 2014).

Finally, the study of coordination problems has in recent years become an important framework for theories addressing the evolution of human cooperation (Skyrms, 2004, Tomasello, 2009). In this spirit, Tomasello *et al*. (2012) have argued that the emergence of some of our species-specific socio-cognitive capabilities is related to the pervasive need to collaborate for mutual advantage in situations of interdependence. Correspondingly, we found that fairly early in ontogeny children are capable of coordinating their decisions in the pursuit of joint goals, even without communication and in novel settings stripped of the rich social environment they are able to rely on in much of their everyday lives. This attests to an important achievement in becoming competent collaborators in situations requiring coordination with interdependent partners.

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