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Non-verbal communication enables children's coordination in a "Stag Hunt" game

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This study assessed the role of non-verbal communication in 4-year-old children's decisions to coordinate with others. During a "Stag Hunt" game, the child and an adult individually and continually collected low-value prizes (hares). Occasionally, an alternative option of collecting a high-value prize (stag) cooperatively with the adult arose, but entailed a risk: a lone attempt on this prize by either player would leave that player empty handed. Children coordinated with the adult to obtain the high-value prize more often when that adult made mutual eye contact and smiled at them than when she attended to the prizes only. This suggests that neither verbal nor gestural communication are necessary for coordination: Minimal, non-verbal communication enables children's coordination with others towards joint goals.

Keywords: Cooperation; Coordination; Communication; Joint attention.

Cooperation in the broad sense of "doing things together with others" may include activities as complex as building an airplane, to those as simple as carrying a table together (see Sebanz, Bekkering, & Knoblich, 2006; Tomasello, Carpenter, Call, Behne, & Moll, 2005). Central to all types of

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cooperation, however, are two different types of coordination: Individuals must first coordinate their decisions of whether or not to cooperate. Then they must coordinate their particular actions. For instance, when faced with some obstacle, we must first agree on whether or not we want to move it together. Once this decision has been made, I may grasp it from one end and you from the other, in order to effect our goal.

Most developmental research has focused on how children coordinate once the decision to do so has already been made (e.g., by an adult), or in the absence of any obvious alternative forms of action (i.e., alternative activities). Conducted mainly with young children, this research suggests a developmental trajectory in which children start to coordinate towards cooperative goals in their second year of life (Carpenter, 2009): Eighteen-month-olds coordinate simple actions effectively with an adult (Warneken, Chen, & Tomasello, 2006), and repair coordination breakdowns (Gräfenhain, Behne, Carpenter, & Tomasello, 2009; Ross & Lollis, 1987; Warneken et al., 2006). Peers in their second year also actively initiate cooperative play with one another, through imitation (Eckerman, Davis, & Didow, 1989), and by offering out objects in games like ''give and take'' (Carpenter, Tomasello, & Striano, 2005; Ross, 1982). By 24 months, they systematically monitor and anticipate the actions of their partners (Brownell, Ramani, & Zerwas, 2006). And a year later, they even understand the commitments involved in cooperation, and that they ought to share the rewards after having cooperated (Gräfenhain, Behne, Carpenter, & Tomasello, 2009; Hamann, Warneken, Greenberg, & Tomasello, 2011; Warneken, Lohse, Melis, & Tomasello, 2011). Lastly, by 42-months, children actively direct and instruct their peers during cooperation (Ashley & Tomasello, 1996).

However, little is known about how children coordinate their decisions to cooperate with others in the first place. Open questions remain as to how children make cooperative decisions when there are obvious alternatives to cooperation, when the other person's intentions are unknown, and when their decisions to do so are mutually interdependent. Mutually interdependent decisions are those in which an individual target actor's preferred action depends critically on what others do, which in turn depends on what the target actor does, which in turn depends on what the others do, and so on, in a potentially infinite recursion. These are often investigated using game theoretic models (see, for example, Lewis, 1969), that represent a broad range of cooperative challenges: In ''conflict games'' such as the well-known ''Prisoner's Dilemma'' (see Axelrod, 1984) cooperative decisions run counter to each individual's personal interest: Participants choose an option representing either ''cooperation'' or ''defection'' (e.g., a card with a circle or a triangle). If both players ''cooperate'', they each receive a payoff. If one ''defects'' against a cooperator, he or she wins a higher payoff. But if both defect against each other, they each receive the lowest payoff possible.

Given the complexity of this decision-making context, research on children's decisions of whether or not to cooperate in such games has focused on older age groups. This has shown, for example, that when faced with such decisions, children aged between 6 and 10 years old are understandably reluctant to cooperate (Sally & Hill, 2006). Knowing that the game will be played repeatedly appears to promote cooperation in older children in this range (Fan, 2000), and interpersonal processes affect the solutions they converge upon: Friends (in this study aged between 4 and 5) cooperate more with one another, and the emotional reactions of players affect the likelihood that equitable solutions occur later (Matsumoto, Haan, Yabrove, Theodorou, & Carney, 1986).

Although much attention has been given to conflict games such as the Prisoner's Dilemma, they may not represent the ideal setting in which to investigate children's cooperation: Players benefit substantially from non-cooperation, and so the focus is on cooperative motivations when they conflict directly with players' personal interests. In other situations, however, cooperation may be *mutualistic*, offering the highest reward for all players. These are modelled and known formally as "coordination games", and here the focus shifts away from cooperative motivations, asking instead how individuals coordinate their decisions to converge together on the highest payoff. The idea behind the "Stag Hunt" game (see Skyrms, 2004), for example, is that two individuals continually but individually retrieve a low value payoff (their "hares"). Occasionally a high value payoff becomes available that requires cooperation to retrieve (the "stag"). A joint decision to hunt cooperatively would mean huge gains for both, but a lone attempt to capture it results in loss of all prizes by that player. Thus, players must coordinate on a decision to embark on cooperation, and so the crucial question becomes how to gauge whether the other person will also cooperate.

For two individuals to cooperate in a "Stag Hunt" situation there needs to be mutual understanding or "mutual knowledge" of several things (see Gilbert, 1989; Lewis, 1969; Schiffer, 1972): Both must know together that each prefers the high- to the low-value option; that cooperation is required for its retrieval; and that a lone attempt to retrieve it ensures loss of all prizes. Beyond this, when the particular opportunity arises, they both must know together that this high-value prize is indeed available. For instance, I may see the stag and also see you seeing it. But if you don't know I saw you seeing it, you might decide not to hunt. Moreover, even if you *do* know that I saw you seeing it, I may be uncertain of this, and so still decide to forage alone. This problem iterates potentially indefinitely, and so the question arises: how is mutual knowledge of what the other sees, knows or intends to do ever achieved?

Research with adults suggests that this mutual knowledge problem is effectively solved by communication. When playing the Stag Hunt game, in the absence of communication, many adults fail to reach the high-value payoff together (Brosnan, Parrish, Beran, Flemming, Heimbauer, et al., 2011). But when they verbally communicate about the game itself during play, they reach the superior solution easily, and maximize their individual payoffs over multiple rounds (Brosnan, Wilson, & Beran, 2012). Lastly, adults use gestural communication such as pointing and directional waving to communicate their strategic intentions in such games (e.g., pointing out a high yield foraging patch to meet at), thus maximizing both individual and group payoffs (King, Narraway, Hodgson, Weatherill, Sommer, et al., 2011). But how explicit must communication be to establish enough mutual understanding for coordination? One possibility is that such communication would need to entail clear information about what a player intends to do (e.g., a statement "I will go for stag", or a gestural point towards the "stag" itself). Another is that, given the mutualistic benefit of coordinating on the stag option, quite minimal forms of non-verbal communication might be enough to establish mutual knowledge. That is, on the appearance of the "stag" payoff, little more than a "knowing look" by way of mutual eye contact and a smile might suffice to establish coordinated decision making. And, in theory, this ought be observable even in young children.

In the current study, therefore, we investigated whether this type of minimal non-verbal communication affected children's decisions to cooperate in a "Stag Hunt" game. Both the child and an adult continually and individually retrieved low-value prizes. Occasionally, however, in addition to these, a high-value prize that could be shared became available. On seeing both types of prize available together, children had to make a critical choice; they could either retrieve the low-value prize alone (as they had been doing previously), or instead try to retrieve the high-value prize cooperatively with the adult. Importantly, if their attempt to cooperate was not matched by this adult, they would receive nothing at all. Children's decisions to cooperate or act individually were investigated under two conditions. In the control condition, when the stag appeared, the child could see the prizes and could see the adult monitor the prizes (and was potentially aware that the adult could see the same as them). However, the adult did not look at the child at all. In the experimental condition, when the stag appeared, the adult not only looked at the prizes but also made eye contact with the child and smiled—thus potentially establishing mutual knowledge of the presence of the high-value prizes.

METHODS

Participants and design

Forty-eight 4-year-olds (24 girls, 24 boys, mean age = 57 months, age range: 54–59 months) were included in the final sample. To our knowledge, this is the youngest age group that has been tested on cooperative decision making, on tasks of similar complexity (e.g., the Prisoner's Dilemma; see Matsumoto et al., 1986). Eight were excluded either because of experimental error ($N = 1$), because they explicitly indicated which prizes they would pursue at test, or they failed to make eye contact on both test trials (see procedure; $N = 1$, $N = 1$, respectively), or because they failed pre-tests ($N = 5$). Those who failed pre-tests were excluded because, having failed to demonstrate sufficient understanding of the game, the effects of non-verbal communication—or its absence—on their decisions to cooperate could not be assessed.

All children were recruited in urban day-care centres, from parents who had volunteered their children to participate in studies of child development, and came from mixed socioeconomic backgrounds. Each was randomly assigned to either the experimental or the control condition (between-subjects).

Materials

Apparatus. Three tubes were mounted approximately 30 cm apart on a low table about half a meter high. The middle tube was twice the width of the two outer tubes, and all three tubes descended along a small gradient towards the players. The child (C) and the first experimenter (C's "Partner") sat on the floor at the lower end of the tubes such that the middle tube was between them, and each had a narrower tube to the outer side of their person. Importantly, the tubes were open on the upper side so that when prizes were inserted in the top ends by a second experimenter (the apparatus "Operator"), they could easily be seen rolling down towards the two players. Also, each tube had a substantial-sized hole near the end where the players sat. When these holes were left unblocked, prizes inserted into the tubes would roll down and fall through into a wooden box underneath. (For a schematic representation see Figure 1).

Prizes. There were two types of prize: Low-value prizes (LVPs) consisted of a plain sticker for each of the players. High-value prizes (HVPs) comprised both an attractive sticker plus a coloured ball for each of the players.[1] Each player's LVP was placed inside a transparent plastic ball

[1]Children were given a preference test in which they were asked whether they preferred the HVPs or the LVP, asked in counterbalanced order. There was a clear preference for the HVPs (Binomial test, $p < .01$, this and all results presented henceforth are 1-tailed), and there was no effect of the order in which prizes were presented on children's preferences (Fisher's exact test, $p = .35$).

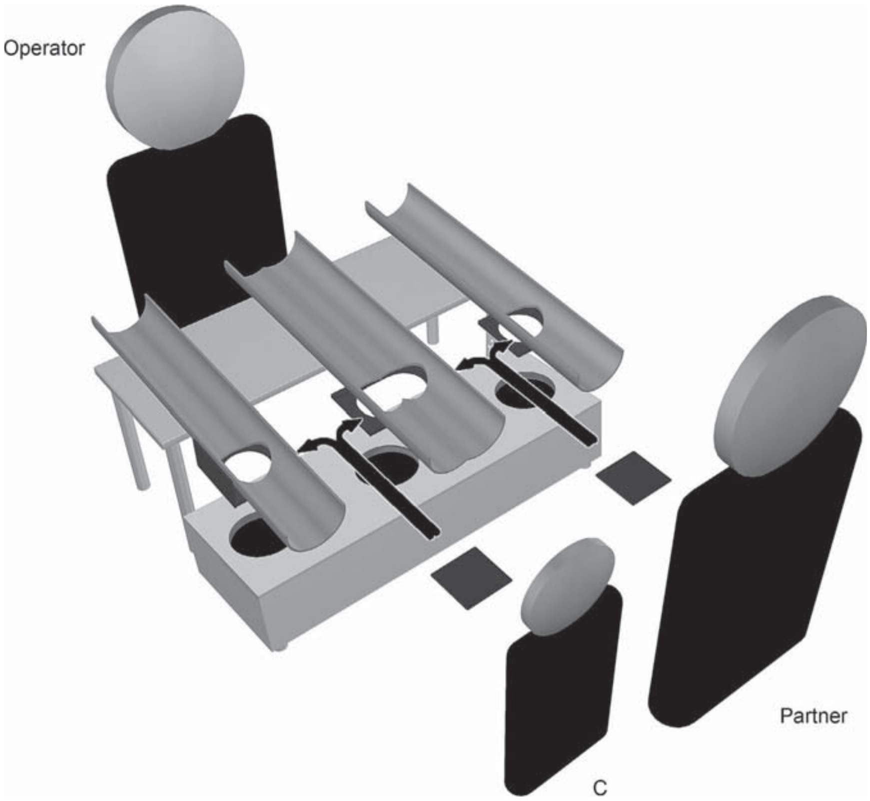

Figure 1. Schematic representation of the apparatus, the blocks, and child's and experimenters' positions during introduction and training. Arrows indicate the two potential locations (middle tube or outer tube) at which each player's block could potentially be inserted.

and these were always inserted individually into each of the *outer tubes* to roll downwards towards the players. The HVPs for both players were placed together in a larger transparent plastic container, and this was always inserted into the wider *middle tube* to roll downwards towards the players.

Blocks. Each player was given a block (a small wooden disc). This could be inserted to block the hole in their own outer tube to prevent the LVP from dropping through the hole, and allow it to be retrieved. Alternatively, it could be inserted into the hole in the middle tube in an attempt to retrieve the HVPs (see arrows on Figure 1). Crucially, however, since the hole in the middle tube was twice the size of the holes in the outer tubes, *both* players' blocks had to be inserted for it to be properly blocked and to prevent the HVPs from falling through (allowing retrieval).

Procedure

The Partner and the Operator collected C and brought him or her to the room with the apparatus. On arrival, a third experimenter (C's later to be "New Partner") greeted them, before sitting to the side to read. Then the procedure began. The basic structure of the game was that players continually received *non-critical rounds* in which LVPs only were inserted into the tubes (so players could only retrieve a LVP each). However, these were interspersed with *critical rounds* in which both HVPs and LVPs were inserted, and on these rounds C was forced to make a decision: they could either retrieve their LVP alone, or else try to retrieve the HVPs together with their Partner.

Introduction and training. C and their Partner received a short introduction to the prizes, the apparatus and the round structure of the game: On each round the Operator held the prizes up for C and Partner to see (either a LVP for each of the players, or a LVP for each plus HVPs for both). She then counted "1, 2, 3, go!" to signal that they should choose where to insert their blocks, and do so. Once the blocks were in place, she inserted the prizes into the tubes to roll down for the players to retrieve. C then received some brief training with feedback to highlight the principles of the game: namely, that they could not retrieve both their HVP and their LVP on any one round, that the LVPs could be retrieved alone, but the HVPs could not.

Pre-tests. C received a series of pre-tests to ensure the following: first, that they grasped the game principles; second, that they had not been making decisions on critical rounds during the Introduction and Training according to a set pattern of responses (for example, always inserting their block into their outer tube, or systematically switching between their outer tube and inner tube between rounds). If a child failed any of the final pre-tests, they were excluded ($N = 5$, see section on participants and design).

Test section. In preparation for the test rounds, a barrier was assembled (see Figure 2). This barrier still allowed players to see each other's shoulders and head, as well as minimal movement indicating that the other player was inserting their block. However, it critically ensured that players would have no visual information at all about *which tube* the other's block was placed into (visual access was blocked from above and below). Once the barrier was assembled, all then moved away from the toy for a short break.

For the test section, the Partner left the room (since C's training was complete). Operator then invited C and New Partner who had been reading quietly until now, to take up play positions at the toy (see Figure 2), and

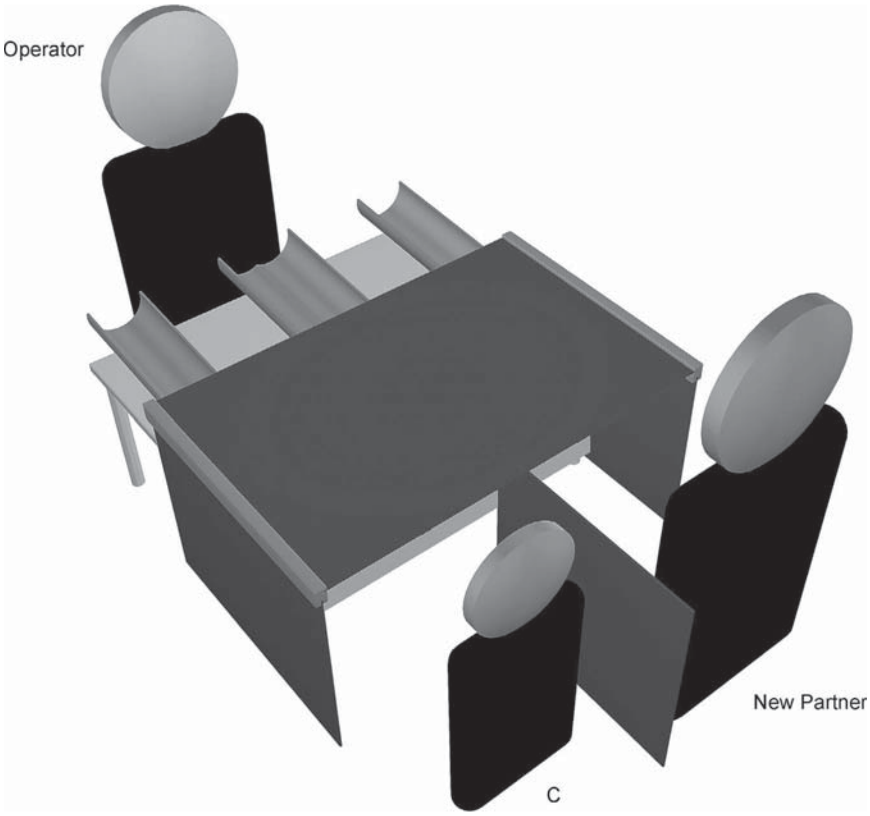

Figure 2. Schematic representation of the apparatus with visual barrier (and child's and experimenters' positions during test rounds).

pretended that a teddy bear had gone to sleep so they should try not to talk. Then in both conditions, players received a series of non-critical rounds interspersed with two critical test rounds. Again, on these rounds, C had to decide whether to retrieve the LVP by inserting the block into their outer tube, or to try to retrieve the HVP by inserting the block into the middle tube. But now, in order to assess the effects of non-verbal communication specifically on C's decisions, they played alongside New Partner with whom they had no previous play history, they could not see where New Partner placed her block, and verbal communication was discouraged on account of the "sleeping teddy".

The difference between conditions was that, on critical rounds in the control condition, when the Operator held the prizes up for the players to see, New Partner visually monitored these only. On critical rounds in the experimental condition, when Operator held the prizes up, New Partner looked at the prizes and, with raised eye-brows and slight smile made mutual eye contact with C, thus potentially establishing mutual knowledge with C of the high-value prizes.[2]

Observation and coding procedure

The central question of interest was whether non-verbal communication affected children's decisions to cooperate. Therefore, sessions were videotaped, and for each critical test round a coder recorded where C's block was when the prizes were either collected or lost through the holes in the tubes. Children were coded as having either *cooperated* if their block was in the middle tube, or as having played *individually* if their block was in their outer tube at this time. Twenty percent of trials were coded by second, independent coder, and inter-rater agreement was 100%.

Successful mutual eye contact between New Partner and C in the experimental condition was coded online (by New Partner). Since the non-verbal communication manipulation in this condition relied on children's spontaneously reciprocating mutual gaze with New Partner, for the small minority of children who failed to do so spontaneously ($N = 4$), New Partner made a quick tapping or a ''pssst'' sound in order to establish eye contact. In a conservative control analysis these children were excluded altogether, but since performance on children's first test round (the critical analysis) remained different between conditions even on this analysis (Fisher's exact test, $p < .05$) these children are included in all further analyses.

RESULTS

The number of children who *cooperated* and who played *individually* across both test rounds by condition is presented in Table 1. The first test round was the key focus of analysis, since the outcome of this round may have potentially affected children's decisions on the second test round. On their first test rounds, more children cooperated after the New Partner communicated non-verbally with them (Experimental condition: 19 cooperated; 4 played individually) than when she monitored the prizes only (Control condition: 11 cooperated; 12 played individually, Fisher's exact test, $p < .05$). Children's choices to cooperate or play individually were highly

[2]On critical test rounds in the experimental condition, new partner always inserted her block into the middle tube, but in the control condition she inserted it into the outer tube. Thus (although children could not see this in either case), by the second test round they may have deduced how new partner had played previously. For this reason, the first test round was of key theoretical interest.

TABLE 1
Number of children who cooperated and played individually on each test round across conditions

	Trial 1		*Trial 2*	
Response	*Exp*	*Ctrl*	*Exp*	*Ctrl*
Cooperate	19	11	15	13
Individual	4	12	4	10

Notes: Exp = experimental condition; Ctrl = control condition. Some children in the experimental condition had one trial excluded because they failed to make eye contact with New Partner ($N = 6$), and some in the control condition because they clearly communicated which prize they intended to retrieve ($N = 1$), or they removed their block as the prizes were rolling down the tubes ($N = 1$).

TABLE 2
Number of children that choose consistently versus switched strategy between Trial 1 and Trial 2

		Trial 1			
		Exp		*Ctrl*	
		Coop	*Indiv*	*Coop*	*Indiv*
Trial 2	*Coop*	13	1	10	2
	Indiv	1	3	1	9

Notes: Exp = experimental condition; Ctrl = control condition; Coop = played cooperatively; Indiv = played individually.

consistent over their two trials, as can be seen in Table 2 (Experimental condition: McNemar's test, $p = 1.00$; Phi correlation, $z = 0.68$, $p < .01$; Control condition: McNemar's test, $p = 1.00$; Phi correlation, $z = 0.73$, $p < .01$). Children also cooperated more across both of their rounds after non-verbal communication occurred in the experimental condition, than in its absence in the control condition (Mann–Whitney *U*-test, $p < .05$).

DISCUSSION

The current study established that minimal, non-verbal communication enables coordination in 4-year-old children, When, on seeing the high-value prizes, the potential cooperative partner monitored the prizes only, around half the children failed to coordinate with her (control condition). By contrast, when she monitored the prizes, but additionally made mutual eye contact and smiled to the child, the majority of children formed a mutualistic goal to cooperate with her, and did so (experimental condition).

These findings are in line with others that show communication enables coordination in adults (Brosnan et al., 2012; King et al., 2011), and extend these findings by showing that the same applies to young children. More importantly, however, they suggest that the type of communication required to establish enough mutual knowledge for coordination may be very minimal: just mutual eye contact and a slight smile is enough to motivate coordinated decision making (see below for further discussion). Our findings are also broadly in line with those demonstrating cooperative tendencies in children in social conflict situations such as the Prisoner's Dilemma (as in Fan, 2000; Matsumoto et al., 1986). However, in our study children's cooperative tendencies were assessed in the absence of competing temptations to defect for higher gain. Thus, our question was less about children's cooperative motivations and more about their skills in achieving a "meeting of minds" with others. Lastly, by requiring that children act instrumentally to retrieve prizes (rather than choose cards or abstract shapes representing cooperation), it was possible to assess not only the decision-making aspect of children's cooperative engagement, but the way in which it manifests itself in actual joint action.

It is worth noting that even in the control condition, nearly half the children did attempt to cooperate. One explanation for this is that the uncertainty of the situation in this condition led children in this group to choose at chance rates of around 50%. Another is that some children deliberately played individually (being unsure of what the New Partner would do), while others assumed she would cooperate and so also did so: Since the adult sat stationary and beside the child they may have simply assumed mutual knowledge of the high-value prizes with them, even in the absence of any communication. Or because she had greeted them, and was clearly associated with the other experimenters, they may have assumed she too would have cooperative motivations. Indeed, in future studies it may be interesting to manipulate how familiar children are with this New Partner, to see whether this affects the rate at which they tend to coordinate. Nevertheless, although it is not possible to discern whether children were choosing at chance, or systematically in opposite directions (though the consistency of their decisions between trials is suggestive of the latter), it is clear that the absence of any communication at all left children with uncertainties about whether their partner would collaborate. This points all the more strongly to the way in which even extremely minimal communication can establish a common foundation upon which children are willing to launch joint action.

Unlike in previous studies with adults, the communication that children received in the experimental condition of this study contained no verbal discussion of the game (as in Brosnan et al., 2012), nor any gestural indication of the partner's strategic intentions (as in King et al., 2011).

So, how exactly might mutual eye contact and positive emotion have led to cooperation in these children? One possibility is that children perceived the manipulation as a full communicative act, that is, as an expression by the adult along the lines of "I will go for the HVPs" or "let's cooperate together". Another possibility (entailed by the first) is that the addition of mutual eye contact critically served to establish a basic form of mutual knowledge between the players in the form of "joint attention" (Campbell, 2005; Peacocke, 2005; Tollefson, 2005). Joint attention refers to instances in which multiple individuals not only look to the same object or scene, but also to each other in acts of mutual eye contact ("subject–subject attention", see Brink, 2001; or "attention contact", see Gomez, 2005). Thus, rather than observing something in parallel, individuals grasp that they are looking at it *together* (Bruner, 1998; Tomasello, 1995, 1999). And this "looking together" structurally resembles the "knowing together" of mutual knowledge in the sense that both may potentially iterate indefinitely: Just as I may "know that you know that I know, etc.", I may also "see that you see that I see, etc."

However, the perceptual nature of joint attention may allow individuals to bypass these complex inferences: each person can look and *see* if the other person attends to a target and to themselves in a way that they cannot see each other's knowledge states (Peacocke, 2005). Under certain conditions, therefore, people may use joint attention as a heuristic for assessing whether mutual understanding of a situation exists (see Clark & Marshall, 1981, on "co-presence heuristics"). And this may be particularly relevant to how coordination problems are solved: individuals may attempt to coordinate according to the reasoning, "if I see our target, you see it, and we are both attending to each other, perhaps we can assume that enough critical information is shared between the both of us to embark" (Campbell, 2005).

We cannot yet distinguish whether more children in the experimental condition coordinated because they perceived themselves to be in joint attention with the adult to the prizes, or whether they additionally interpreted the look from the experimenter as an act of full communication (e.g., "let's get the HVPs" or "let's cooperate"). However, communication entails joint attention foundationally: from the child's perspective, any communication or positive affect has to have been about a referent to which both parties were jointly attending. Otherwise, their significance and relevance to the interaction would have been incomprehensible, as would their increased rates of cooperation. Future studies might, then, profitably tease these alternatives apart to reveal whether mutual eye contact alone enables children's coordination in the absence of any other communicative cues.

The way in which children coordinate towards a cooperative goal has been assessed here via the use of an abstract game theoretic model and a mechanical toy. However, the underlying decisions involved have real-world equivalents: Any activity in which individuals must decide whether or not to act cooperatively, and in which the success of the endeavour rests on mutual involvement of others poses the same dilemma. Participating in a public protest, hunting for prey, or deciding to go to a party—when one does not want to do any of these things alone—are all ‘‘Stag Hunt’’ situations in some sense (see, for example, Alvard & Nolin, 2002). What has been shown here is that minimal forms of non-verbal communication may function as a coordination device in such contexts. Indeed, just mutual eye contact and a smile appear to be effective in inducing children's cooperation.

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