The Official Journal of the International Society on Infant Studies
Infancy

Infancy, ***18***(1), 10–39, 2013

ISSN: 1525-0008 print / 1532-7078 online
DOI: 10.1111/j.1532-7078.2012.00126.x

WILEY-BLACKWELL

Active Experience Shapes 10-Month-Old Infants' Understanding of Collaborative Goals

Annette M. E. Henderson
Department of Psychology
University of Auckland

Ying Wang
Department of Psychology
University of Auckland

Lauren E. Matz
Department of Psychology
University of Maryland

Amanda L. Woodward
Department of Psychology
University of Chicago

Collaborative activities in which individuals coordinate their actions to attain a common goal play a fundamental role in our everyday lives. Evidence suggests that infants engage in collaborative activities before their first birthday; however, little is known about infants' understanding of collaborative action. Using a visual habituation paradigm, this research consists of two

Correspondence should be sent to Dr. Annette M. E. Henderson, 10 Symonds St, HSB Building, Department of Psychology, The University of Auckland, 1142, Private Bag 92019, Auckland, New Zealand. E-mail: a.henderson@auckland.ac.nz

experiments designed to investigate whether 10-month-olds understand that the actions of collaborative partners are critical to the attainment of a common goal. The results of Experiment 1 suggest that 10-month-olds represent the actions of collaborating partners in terms of a common collaborative goal only after receiving active experience with a collaborative activity. Experiment 2 demonstrated that infants who received active experience with a collaborative activity viewed active engagement in a collaboration as being critical for an individual's actions to be interpreted as being directed towards a collaborative goal. Together, these findings demonstrate that 10-month-olds exhibit an understanding of the shared nature of collaborative goals after a highly salient experience with the activity. Identifying the effects of experience on infants' understanding of collaborative goals in a laboratory context provides insights into the role that experiences in their everyday lives might play in their understanding of collaboration.

INTRODUCTION

Much of the everyday functioning of human societies relies on collaboration to achieve goals and attain resources. In collaboration, the actions of collaborating partners may be the same, or different, but both are critical for attaining a common goal (Bratman, 1992; Deutsch, 1949; Johnson & Johnson, 1983; Tomasello, Carpenter, Call, Behne, & Moll, 2005), such as when we work with others to prepare a meal or move a heavy object. Because actions involving collaborative goals pervade our daily lives (e.g., Barkow, Cosmides, & Tooby, 1992; Richerson & Boyd, 2005; Tomasello, 1999; Tomasello, Kruger, & Ratner, 1993), it is critical that children understand them early in development. Without an understanding of these activities, children would be unable to interpret many of the actions in their social world and their everyday interactions would be extremely limited. The present research investigates whether 10-month-old infants understand the common-goal structure underlying collaborative action and the role that experience plays in the emergence of this understanding.

Three decades of research have demonstrated that children engage in activities involving common goals early in their lives (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Bakeman & Adamson, 1984, 1986; Brenner & Mueller, 1982; Brownell & Carriger, 1990, 1991; Bruner, 1983; Duncan & Farley, 1990; Eckerman, Davis, & Didow, 1989; Eckerman & Didow, 1989; Ross & Lollis, 1987; see also Brownell, 2011 for a review). Before their first birthday, infants can coordinate their own actions with those of a social partner in familiar routines and cooperative social games, such as passing a ball to and fro, in which infants' actions are the same as their

social partner (Duncan & Farley, 1990; Hubley & Trevarthen, 1979; Ross & Lollis, 1987). In the second and third years of their postnatal lives, children become skilled collaborative partners in novel and more complex collaborative exchanges in which infants' actions are complementary to those of their social partner, such as working together to retrieve a toy from a puzzle box (Ashley & Tomasello, 1998; Brenner & Mueller, 1982; Brownell & Carriger, 1990; Brownell, Ramani, & Zerwas, 2006; Warneken, Chen, & Tomasello, 2006; Warneken & Tomasello, 2007). Importantly, engagement in collaborative activities plays a critical role in children's development by supporting their event memory (Sommerville & Hammond, 2007), planning and problem-solving skills (Azmitia, 1988; Radziszewska & Rogoff, 1988), and learning of culturally specified behaviours (Rogoff, 1990; Tomasello, 2009).

Although previous research provides strong evidence that infants engage in activities involving common goals, the findings are inconclusive about whether infants truly understand the common-goal structure that underlies these activities. To illustrate, researchers have claimed that infants understand that collaborative partners share a common goal by their second birthday (Ross & Lollis, 1987; Warneken & Tomasello, 2007; Warneken et al., 2006). In these prior studies, infants engage in a collaborative activity with an experimenter who stops completing her role at some point during the activity. Infants' responses to the disruption, such as showing frustration or attempting to draw their partner's attention back to the activity, have been interpreted as evidence that they understand the common-goal structure of the collaboration (i.e., that their partner's actions are complementary and critical for the attainment of the common goal). There is an equally viable explanation, however, which makes this conclusion premature. Infants might protest the interruption simply because the attainment of their own goal was thwarted and the adult was merely a "social tool" to help them attain their goal (see also Gräfenhain, Behne, Carpenter, & Tomasello, 2009; Warneken, Gräfenhain, & Tomasello, 2012). Because infants' engagement in the collaboration cannot be separated from their understanding of the activity, these studies do not rule out the "social tool hypothesis".

Recently, researchers have begun to design studies to rule out the social tool explanation in toddlers (Warneken et al., 2012) and preschoolers (Gräfenhain et al., 2009). Using a modified version of the interruption paradigm (e.g., Ross & Lollis, 1987; Warneken & Tomasello, 2007; Warneken et al., 2006), Warneken et al. (2012) demonstrated that 21- and 27-month-old toddlers responded to a non-compliant collaborative partner by producing behaviours that attempted to re-engage the individual, regardless of whether the actions of the partner were critical for the child to attain their goal (i.e., the collaborative task involved complementary roles) or not (i.e., the

collaborative task involved parallel roles). These findings suggest that children as young as 21 months represent the actions of their collaborative partner as jointly engaged in the activity and thus provide evidence that toddlers appreciate the shared nature of collaborative action. These findings raise the important question of whether younger infants might also appreciate the shared nature of collaborative action.

To address the limitations of the previous work studying younger infants' understanding of collaborative goals, Henderson and Woodward (2011) developed a visual habituation paradigm in which infants' visual attention is used as a measure of their understanding of the common-goal structure underlying a collaborative action sequence involving complementary roles. In this paradigm, infants were repeatedly shown a collaborative activity until their looking time decreased to a pre-determined criterion. Specifically, 14-month-old infants were habituated to an event in which one actor (i.e., the box-opener) opened a box containing a toy and a second actor (i.e., the toy-getter) removed the toy from inside the box. After habituating to the above collaboration sequence, infants were shown a series of test events in which the box-opener grasped either the box or the toy. The findings revealed that infants looked longer towards the test events in which the box-opener grasped the box than they did towards the test trials in which she grasped the toy. This pattern of looking suggested that infants reliably represented the collaboration in terms of a collaborative goal; infants interpreted the box-opener's actions during habituation as directed towards attaining the toy, despite the fact that she did not physically touch the toy. A series of control conditions further demonstrated that 14-month-olds assume that the actors were acting towards the attainment of a common goal only when the actions of both individuals were actively directed towards goal attainment. Because infants' understanding of collaboration is assessed using their observations of, and not involvement in, collaborative action, Henderson and Woodward argue that this paradigm addresses key limitations of previous studies by ruling out the social tool hypothesis and thus provides evidence suggesting that 14-month-olds understand the shared-goal nature underlying collaborative action.

One important question raised by the previous experiments conducted by Henderson and Woodward (2011) is whether 14-month-olds in the studies discern the collaborative goal simply by observing the collaborative activity because of the likely possibility that they had participated in these types of collaborative activities in the past. That is, an infant's own actions might provide a model for understanding others' actions and thus Henderson and Woodward's findings might only be a reflection of infants' ability to engage in collaborative action. Support for this possibility comes from previous work, which has shown that 14-month-old infants engage in collaborative

tasks similar in structure to that depicted in Henderson and Woodward's habituation event (e.g., Warneken & Tomasello, 2007). However, it is possible that infants' engagement in less complex collaborative activities involving parallel roles might support the emergence of an understanding of the common-goal structure underlying collaborative action. If this were the case, infants might possess an understanding of collaboration before engaging in collaborative activities that require complementary roles. It remains unclear whether younger infants who have been shown to engage in ritualized collaborative activities involving parallel roles (e.g., Duncan & Farley, 1990; Ross & Lollis, 1987) understand the common-goal structure underlying collaborative action.

The present research uses the visual habituation paradigm used by Henderson and Woodward (2011) to investigate whether 10-month-old infants can identify collaborative goals in a context in which two individuals are working together by completing complementary actions towards the attainment of a common goal. Ten-month-old infants have been shown to engage in more ritualized collaborative activities involving parallel roles (e.g., Duncan & Farley, 1990; Ross & Lollis, 1987), yet little is known about their understanding of the common-goal structure underlying these activities. Isolating the age at which infants come to understand this fundamental fact about collaboration will provide novel insights into the developmental window in which an understanding of collaboration emerges. With this information, future work can be designed to identify the factors that contribute to the development of an understanding of collaboration and examine how infants' engagement in collaborative activities changes as a function of their understanding of collaboration. Together, this work will clarify the processes and mechanisms underlying the development of collaboration.

In Experiment 1A, infants were repeatedly shown a box-toy collaborative action sequence (similar to the event utilized in Henderson & Woodward, 2011). After infants' attention to the collaboration decreased to a certain criterion, infants were shown a series of test events in which the box-opener grasped either the toy or the box. If infants understood the collaboration (the toy as the collaborative goal), they should look longer when the box-opener grasps the box. These results would offer evidence suggesting that 10-month-olds understand the collaborative-goal structure of an observed collaborative exchange involving complementary roles well before the age at which previous work has shown that they engage in such activities. If, however, 10-month-olds do not interpret the box-opener's goal during habituation as the toy, this would suggest that specific experiences with collaborative exchanges involving complementary roles might play an important role in infants' understanding of these kinds of activities. Experiments 1B, 2A, and 2B investigate whether active or observational experience

with a collaborative activity influences 10-month-olds' ability to identify the common-goal structure underlying collaborative exchanges involving complementary roles. Identifying the effects of experience on infants' understanding of collaborative goals in a laboratory context provides preliminary insights into the role that everyday experience might play in fostering the emergence of an understanding of collaboration. Together, these findings provide novel insights into when and how infants might come to understand the collaborative-goal structure underlying collaboration – a core component of human behaviour.

EXPERIMENT 1A

Method

Participants

Eighteen full-term infants (nine males, *mean age* = 9 months, 26 days, range = 9 months, 12 days to 10 months, 10 days) participated in this experiment. Participants were recruited from a database of families managed by a large university in the Eastern United States. Families had responded to advertisements stating that they were interested in volunteering for infant development studies. Fourteen infants were Non-Hispanic and of the following races: White (n = 10), Black (n = 2), and more than one race (n = 2). Four infants were Hispanic and of the following races: White (n = 2), more than one race (n = 1), and unreported (n = 1). Six additional infants began the experiment, but were excluded because they had extremely low attention from the start and thus did not reach the habituation criterion (n = 1), did not watch all of the test trials (n = 3), there was a break longer than 120 seconds between test pairs (n = 1), or because of procedural error (n = 1). Infants received a small toy and a certificate for participating.

Materials and procedure

Infants were familiarized to the actors who would be presenting the habituation and test events during a warm-up phase in which infants played with each actor individually for approximately 2 minutes and then both actors together for 2 minutes. After the warm-up, parents and infants were escorted into the testing room in which infants sat on their parent's lap approximately 27 inches away from the stage on which the habituation and test events were presented. A transparent blue-tinted box ($7' \times 6' \times 5'$) with a white rubber duck ($4' \times 2.5' \times 3'$) inside was centred approximately

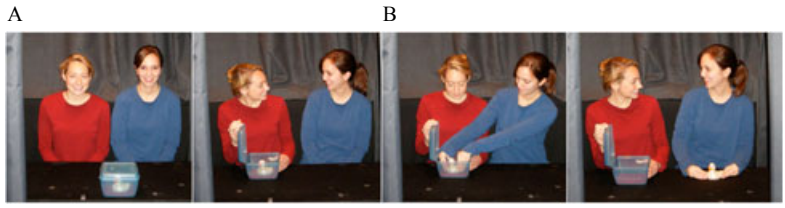

Figure 1 Collaboration habituation event used in Experiments 1A and 1B.

2 inches from the front of the stage. The two actors were seated approximately 25 inches from the objects on a bench side-by-side splitting the centre of the stage (see Figure 1). The side on which the actors sat was counterbalanced across sex and condition.

On each habituation trial, infants viewed the following action sequence: (1) two female actors (i.e., the box-opener and the toy-getter) looked at the infant and then smiled at each other, (2) the box-opener used both hands to retrieve the box, (3) the box-opener examined the box and opened the lid, (4) both actors smiled at each other, (5) the toy-getter used both hands to retrieve the toy duck, (6) the toy-getter interacted with the toy, (7) both actors smiled at each other, and (8) the actors ended looking at the objects upon which they acted (see Figure 1). Each habituation trial began with this action sequence and ended with the actors maintaining their final positions until the trial ended. The trial ended when the infant looked away for more than 2-seconds or more than 120 seconds had elapsed. When each trial ended, a screen was raised to hide the stage from infants' view while the actors set-up for the next trial.

Infants were shown the habituation event until infants' attention towards three successive trials was less than half of their total attention towards the first three trials or until 14 trials had elapsed. After the habituation criterion was reached, infants watched one more trial of the habituation event (i.e., baseline). The objects were then removed from the stage out of infants' view, and infants watched the toy-getter leave the stage area. The toy and box were then placed 8 inches apart on the stage out of infants' view. Next, infants watched a trial to familiarize them to the set-up for the test trials in which the box-opener looked at the infants and said, "Hi. Where is it? Where did it go?". Infants then watched two types of test events in which the box-opener grasped either the box or the toy in alternation for a total of six test trials (see Figure 2).

Infants' attention towards each trial was timed from when the actors stopped moving until the end of the trial, which occurred when the infant looked away for 2-seconds or when 120 seconds had elapsed. Infants' looking was coded online by a trained observer who was unaware of the testing order

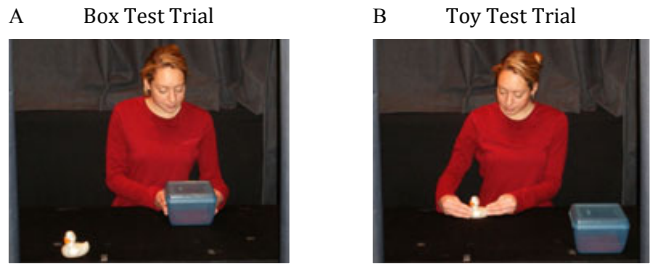

Figure 2 Test events used in Experiments 1A and 1B.

and could not see any of the events, and the software, jHab (Casstevens, 2007), was used to calculate the looking times. To assess reliability, a second coder completed offline coding for all of the infants using the digitized recordings. Coders were reliable if they judged the trial ended on the same look away (agreement = 97% of the test trials). We also assessed whether the directions of the disagreements reflected bias with respect to the hypothesized findings. Each disagreement was classified based on the direction of the disagreement and the test trial type on which it occurred. The distribution of disagreements was unsystematic across the two types of test trials (Fisher's Exact Test, $p = 1$, two-tailed).

TABLE 1
Average looking times during the habituation, baseline, familiarization, and test trials for each condition in both experiments

	Habituation trials				*Test trials*	
Condition	*First 3*	*Last 3*	*Baseline*	*Familiarization*	*Toy*	*Box*
Experiment 1						
No training – collaboration	36.75 (5.2)	13.20 (1.7)	3.40 (0.8)	13.19 (1.96)	5.03 (0.5)	5.36 (0.9)
Action task – collaboration	52.83 (8.8)	15.05 (3.0)	5.79 (1.6)	10.17 (1.72)	6.28 (0.7)	9.31* (1.6)
Experiment 2						
Active – collaboration	28.80 (5.64)	9.00 (1.95)	4.16 (1.30)	12.63 (2.87)	3.78 (0.46)	6.18* (1.23)
Active – onlooker	27.25 (5.64)	10.66 (1.95)	5.10 (1.26)	8.99 (1.23)	4.55 (0.46)	4.24 (0.55)
Observation – collaboration	26.87 (3.74)	9.20 (1.67)	3.56 (1.14)	4.77 (1.05)	3.31 (0.71)	2.31 (0.38)

Note. Mean standard errors in parentheses.
*Different from the other test event, $p < .05$.

Results and discussion

Infants' average looking times are summarized in Table 1. Infants habituated in an average of 7.5 trials (SE = 0.4). The focal analyses were conducted on infants' average looking to the two types of test trials (i.e., box, toy). Of interest was whether infants viewed the box-opener as having a collaborative goal (i.e., the toy) during habituation. To investigate this, we examined infants' average looking times to the box and toy test trials. Preliminary analyses revealed no significant effects of gender or the side that the test actor was on during habituation. Therefore, the focal analyses were collapsed across these dimensions. A 2 (test trial type: box, toy) × 2 (first test trial: box, toy) mixed-design analysis of variance (ANOVA) with test trial type as the within-subject factor showed a significant test trial type by first test trial interaction, $F(1, 14) = 5.45$, $p = .04$, $\eta^2_{\text{partial}} = .28$. No other effects were significant.

To further explore the significant test trial type by first test trial interaction, we conducted a paired t-test on infants' looking to the box and toy test trials for infants who received each type of first test trial. The t-test for infants who watched the box-opener retrieve the toy on the first test trial looked reliably longer on the toy test trials (M = 4.82, SE = 0.71) than they did on the box test trials (M = 3.70, SE = 0.77), $t(8) = 2.45$, $p = .04$, $d = 0.51$, $r = 0.25$. The t-test for infants who watched the box-opener retrieve the box on the first test trial did not look significantly longer on the box test trials (M = 7.02, SE = 1.49) than they did on the toy test trials (M = 5.22, SE = 0.85), $p > .13$. These analyses suggest that infants did not reliably interpret the goal as either the box or the toy. Instead, infants' performance on the test trials seemed to be most influenced by which type of test trial they were shown first.

The above results were further confirmed by an individual level analysis. Eight of the 18 infants in this experiment looked longer on the box test trials than the toy test trials, $Z = -0.02$, $p = .98$ (signed-ranks). These findings provide additional evidence suggesting that the 10-month-old infants in this experiment did not form any reliable expectations regarding the box-opener's goal during habituation.

Experiment 1A was conducted to gain preliminary insights into the age at which infants first identify collaborative goals while watching a collaborative problem-solving task. The results provided no evidence that 10-month-old infants interpret the actions of two individuals working together to get a toy out of a box as being directed towards a common collaborative goal. Together with the findings of previous research using this paradigm (Henderson & Woodward, 2011), these findings suggest that the ability to identify collaborative goals in the present context emerges or

becomes more robust between 10- and 14-months of age. These findings raise questions concerning the factors that might contribute to the emergence of an understanding of the common-goal structure underlying collaborative action.

It is possible that 10-month-old infants have yet to develop the ability to identify collaborative goals because of the cognitive sophistication required to do so. Support for this possibility comes from previous work from Sommerville and Woodward (2005) who demonstrated that 10–12 months of age was a transitional period in infants' ability to identify the hierarchical goal structure of means-ends sequences similar to the box-toy action sequence depicted in the current study. However, Sommerville and Woodward also found that 10-month-olds' ability to structure means-ends sequences in terms of a higher-order goal was related to their own ability to perform means-ends action sequences on their own. In fact, a growing number of studies on infants' understanding of the actions of single individuals suggest that *active* experience is particularly important to the emergence of an understanding of goal-directed action (e.g., Brooks & Meltzoff, 2002; Gerson & Woodward, 2012; Sommerville, Hildebrand, & Crane, 2008; Sommerville, Woodward, & Needham, 2005). These prior findings raise the possibility that 10-month-olds might evidence an understanding of collaborative goals after receiving active experience in a collaborative interaction.

Experiment 1B was conducted to investigate whether 10-month-old infants who were provided with first-person experience in a box-toy collaborative action sequence would identify the collaborative-goal structure of our box-toy collaboration habituation event. To investigate this question, 10-month-olds received four rounds of training in which the infants and an experimenter engaged in a box-toy collaborative activity before participating in the same habituation paradigm as in Experiment 1A.

EXPERIMENT 1B

Method

Participants

Eighteen full-term infants (nine males, *mean age* = 9 months, 29 days, range = 9 months, 16 days to 10 months, 12 days) participated in this experiment. Participants were recruited in the same manner as in Experiment 1A. All infants were Non-Hispanic and of the following races: White (n = 7), Black (n = 7), Asian (n = 3), and more than one race (n = 1). Seven additional infants began the experiment, but were excluded because

of the following: they had extremely low attention from the start and did not reach the habituation criterion ($n = 1$), they did not watch all of the test trials ($n = 1$), there was a break longer than 120 seconds between test pairs ($n = 1$), or procedural error ($n = 4$).

Materials and procedure

The materials and procedure were identical to those of the collaboration condition in Experiment 1A with the key difference being the addition of an action task before infants participated in the habituation phase.

Action task. After completing the consent procedures, parents and their infants were escorted into our behavioural testing room. Parents were asked to sit at one side of a small table. The experimenter sat in a chair beside the parent and child. The experimenter then completed four rounds of a collaborative task with infants. The task involved the following sequence, which was modelled after the actions completed by the box-opener in the collaboration habituation event: (1) the experimenter placed a transparent box (similar to the box in the collaboration habituation event) that had a toy ball inside on the table in front of her and the child, (2) the experimenter looked down at her hands while infants were given an opportunity to become familiarized to the box with the toy inside (when infants stopped looking at the box, the experimenter tapped on it to direct their attention back to the box), (3) after 10 seconds the experimenter said, "Shall we get it? Let's get it", (4) the experimenter then used both hands to retrieve the box, (5) the experimenter examined the box and opened the lid, (6) the experimenter looked towards the infant and said, "Can you get it?", (7) the experimenter tilted the box towards the infant so that the infant could retrieve the ball from inside the box, (8) if the infant did not retrieve the ball after 10 seconds, the experimenter repeated her request for the infant to retrieve the ball. If the infant did not get the ball after the third attempt, the experimenter removed the ball and gave it to the infant. After 10 seconds, the experimenter retrieved the ball from the child, placed the box and the ball out of sight, and placed another box (with a different ball inside) that would be used for the next trial of the action task. After the fourth trial, infants and their parents were escorted into the habituation room and the habituation phase immediately began.

Visual habituation phase. Infants were repeatedly shown the same collaboration habituation event as were infants in Experiment 1A. The experimenter who completed the action task with the infant was the box-opener during the habituation event and thus was also the actor who completed the

test trials. Infants' looking times during the visual habituation phase were coded in the same manner as the previous experiments. The original coder and the reliability coder agreed on 95% of the test trials. The distribution of disagreements was unsystematic across the types of test trials (Fisher's Exact Test, $p = 1$, two-tailed).

Results and discussion

Infants' average looking times are summarized in Table 1. Infants habituated in an average of 8.2 trials ($SE = 0.6$). As in Experiment 1A, our primary question of interest was whether infants identified the box-opener's goal as the toy (i.e., the collaborative goal). To investigate this question, the focal analyses were conducted on infants' average looking to the two types of test trials (i.e., box, toy). Preliminary analyses revealed no significant effects of sex, the side on which the box-opener was on during habituation, or type of first test trial. Therefore, the subsequent analyses were collapsed across these dimensions. A paired-samples *t*-test revealed that infants looked significantly longer during the test trials in which the box-opener retrieved the box than they did during the test trials in which she retrieved the toy, $t(17) = 2.85$, $p = .019$, $d = 0.57$, $r = 0.28$. Thus, these findings suggest that infants who were trained on a collaborative task reliably interpreted the goal of the box-opener's actions during habituation as the collaborative goal (i.e., the toy). These results were moderately supported by an individual level analysis. Eleven of the 18 infants looked longer towards the box test trials than the toy test trials, $Z = -1.89$, $p = 0.058$ (signed-ranks). Excluding the infants who had difference scores (looking to box-looking to duck) of < 1 reveals that nine of 16 infants looked longer towards the box test trials, $Z = -2.07$, $p = 0.039$ (Wilcoxon signed-ranks test). Together, our analyses indicate that 10-month-old infants who had previously been actively engaged in a collaborative exchange interpreted the box-opener's actions during the collaboration habituation event as being directed towards the attainment of a common collaborative goal.

In our final set of analyses, we compared the average looking times to the different types test trials of the infants in the present study with the average looking times of the infants in Experiment 1A by conducting a 2 (trial type: box, toy) × 2 (first test trial: box, toy) × 2 (condition: no training, training) mixed-design ANOVA with test trial type as the within-subject factor. The ANOVA revealed significant main effects of test trial type, $F(1, 32) = 7.25$, $p = .01$, $\eta^2_{\text{partial}} = .19$, first test trial, $F(1, 32) = 7.51$, $p = .01$, $\eta^2_{\text{partial}} = .19$, and condition, $F(1, 32) = 4.92$, $p = .03$, $\eta^2_{\text{partial}} = .13$. The significant main effects of first test trial and test trial type were qualified by a significant first test trial by test trial type interaction, $F(1, 32) = 7.56$,

$p = .01$, $\eta^2_{\text{partial}} = .19$. Exploration of this interaction revealed that infants who saw the first test trial in which the box-opener retrieved the box looked significantly longer on the box test trials ($M = 9.81$, $SE = 1.65$) than they did on the toy test trials ($M = 6.40$, $SE = 0.78$), $t(17) = 20.88$, $p = .01$, $d = 0.69$, $r = 0.33$. Infants who saw the first test trial in which the box-opener retrieved the toy looked equally towards both types of test trials.

Most importantly, the ANOVA revealed a significant condition by test trial type interaction, $F(1, 32) = 4.63$, $p = .04$, $\eta^2_{\text{partial}} = .13$. Thus, the average duration of time that the infants spent looking towards each of the test trials differed depending on whether they had engaged in the collaborative action task before participating in the habituation paradigm. Recall that 10-month-old infants who did not participate in a collaborative interaction before taking part in the visual habituation phase did not look reliably longer towards either test event. Conversely, 10-month-old infants who participated in a collaborative interaction before taking part in the visual habituation looked significantly longer at the test trials in which the box-opener retrieved the box than they did on the test trials in which she retrieved the toy. Thus, these findings suggest that 10-month-old infants structure the actions of two actors working together to retrieve a toy from inside a box in terms of a collaborative goal, but only after they had been an active participant in a similar collaborative interaction.

The findings of Experiment 1 provide initial insights into the role that experience might play in the development of an understanding of collaborative goals (as measured by performance in our visual habituation task). Our findings suggest that the ability to identify the collaborative-goal structure underlying collaborative tasks involving complementary roles such as the box-toy event recruited in the present research develops between 10- and 14-months of age and that infants' active participation in a similar collaborative exchange might play a fundamental role in the development of an understanding of collaborative goals. These findings are consistent with previous research and theoretical perspectives that emphasize the important role that active experience plays in infants' understanding of goal-directed action (e.g., Brooks & Meltzoff, 2002; Gallese, Rochat, Cossu, & Sinigaglia, 2009; Gerson & Woodward, 2012; Sommerville et al., 2005, 2008; Woodward, 2009; Woodward, Sommerville, Gerson, Henderson, & Buresh, 2009), as well as children's perceptual and cognitive development in general (e.g., Bushnell & Boudreau, 1993; Gibson, 1988; Libertus & Needham, 2011).

One particularly important question raised by the present findings concerns the nature of the goal-representation that infants formed during the action task. It is possible that providing 10-month-olds with active experience led them to successfully identify the box-opener's goal during habituation as a collaborative goal. However, it is also possible that experi-

ence might have promoted infants' understanding of the goal structure underlying the means-ends sequence more generally. If this were the case, infants could have generalized their own goal (i.e., the toy) that had been shaped during the action task to any individual present during a meaningful means-ends sequence. If this were the case, infants' longer looking towards the box test trials during Experiment 1B could have been a reflection of the general representations they held of the goal of the means-ends sequence, which was their own individual goal (as opposed to a collaborative goal). We explored this possibility in Experiment 2A by examining whether infants who received active experience in a collaborative activity would generalize their own goal to others in a context in which there was no evidence to suggest that the individuals had been engaged in a collaborative exchange.

To investigate this question, we examined whether 10-month-olds assume that two individuals have a collaborative goal even when one of the individuals was not actively engaged in attaining the goal. Ten-month-old infants participated in an action task similar to that in Experiment 1B and then participated in one of the two habituation paradigms. Infants in the active collaboration condition watched the collaboration habituation and test events as described in 1A and 1B. Infants in the active onlooker condition watched a habituation event in which one individual (actor) retrieved the box and took the toy out by herself while a second individual (onlooker) observed the action sequence (see also Henderson & Woodward, 2011). During test, infants watched the onlooker grasp either the box or the toy. If training in the collaborative task guides infants to generalize goals across individuals, even when they were not directly involved in goal attainment, infants in both the collaboration and onlooker conditions should look longer on the box test trials. In contrast, if training in the collaborative task promotes infants' ability to identify collaborative goals, only the infants in the collaboration condition should look longer towards the box test trials (as did infants in 1B), whereas infants in the onlooker condition should not look reliably longer towards either type of test trial. This experiment replicates and extends the results of Experiment 1B.

EXPERIMENT 2A

Methods

Participants

Thirty-six full-term infants participated in this study (*mean age* = 9 -months, 25 days; *range* = 9 months, 9 days to 10 months, 18 days). Participants were recruited from a database of families managed by an infant

development laboratory in a university in a large city in New Zealand. Families had responded to advertisements stating that they were interested in volunteering for infant development studies. Eighteen infants (10 males, eight females; *mean age* = 9 months, 26 days) participated in the *collaboration condition* and 18 participated in the *onlooker condition* (10 males, eight females; *mean age* = 9 months, 24 days). Infants belonged to the following ethnic groups: New Zealand European (n = 32), other European (n = 1), Maori (n = 1), Asian (n = 1) or more than one ethnic group (n = 1, New Zealand European and Pacific Islander). An additional 17 infants participated in the study, but were excluded from the final analyses for the following reasons: the session ended early because of infant distress (n = 1), procedural error (n = 3), the infant did not watch the entire test event and/or had looking times of zero for at least one of the test trials (n = 11), the test trial ended prematurely because of the infant moving out of the camera's view (n = 1), or the infant was not exposed to any English at home (n = 1). Parents received a $10 gift voucher to a local grocery store for participating, and infants received a small prize.

Materials and procedure

The materials and procedure utilized in Experiment 2A were similar to those used in Experiment 1B with the following differences. Firstly, infants participated in one of two habituation paradigms: the collaboration condition (as in Experiment 1) or the onlooker condition (described below). Secondly, this experiment was conducted in a different laboratory than were Experiments 1A and 1B, which resulted in the need to make the following two modifications to the procedure. Firstly, the objects that the actors acted upon during habituation were a box and a toy block (as opposed to a toy duck). Secondly, the habituation phase of the study was presented via video, as opposed to live presentation. As a result, the experimenter who conducted live training was not one of the actors involved in the videos of the habituation and test events. Presenting the habituation events via video also resulted in the habituation room having a slightly different set-up (see below).

Habituation apparatus. After participating in the action task, parents and their infant were escorted to the habituation room. Infants were seated on their parent's lap at a distance of approximately 150 cm from a 42-inch LCD TV screen, which was used to present the habituation, familiarization, and test events. The TV screen was placed on a black cloth that covered a TV stand where a Canon Legria HV40 camcorder was also situated. The cloth concealed the camcorder, allowing only for a small circular opening in

which the lens could be seen. Behind the TV stand and screen, a black cloth back drop was extended from one side of the room to the other to cloak the devices used to manage the presentation of the events and record the infant's visual attention. A Dell computer was running two programs: (1) Cutfour (AvTake 2010: Cut Four SD (Version 3.504) [Computer Software]), which was the software used to record the live visual and audio feed of the infant as captured by the video camcorder (with the video events in picture-in-picture mode), and (2) jHab (Casstevens, 2007), which was used to record infants' looking time. A MacBook Pro laptop was used to run the software Looking Time X (Hannigan, 2008), which controlled the presentation of the video events. The picture and sound of the video events were projected from the laptop to the TV and Dell computer through an HDMI splitter.

Visual habituation phase. Once the parent and infant were seated comfortably in the habituation room, infants were shown the habituation events. All infants saw a video in which two actors were seated side-by-side behind a table that was covered by a black tablecloth and in front of a black back drop. On the table, there rested a transparent plastic container (21 cm × 21 cm × 16 cm) with a lid that was attached to the container on one side with hinges and opened with a snap lock on the opposite side of the container. A yellow wooden block (10 cm × 10 cm × 9 cm) sat inside the closed container; this was always positioned in front of the actor who would be opening the container.

Infants in the collaboration condition saw the collaborative action sequence similar to the collaboration sequence used in Experiment 1 (see

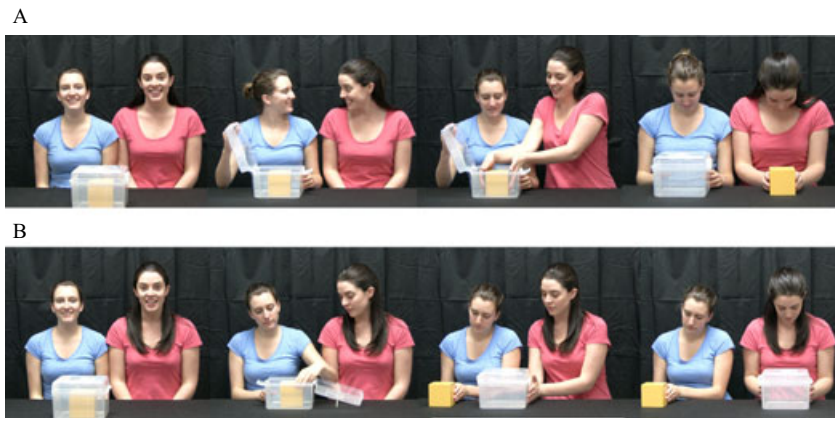

Figure 3 Habituation events used in the collaboration (A) and onlooker (B) conditions of Experiment 2.

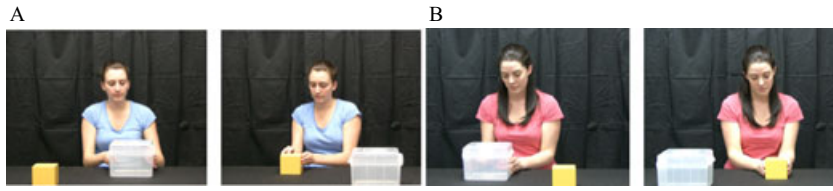

Figure 4 Test trial events used in the collaboration (A) and onlooker (B) conditions of Experiment 2.

Figure 3). Infants in the onlooker condition saw a sequence of events that was identical to that viewed by the infants in the collaboration condition with one key difference. One actor removed the toy from the box while a second actor (i.e., the onlooker) observed the action sequence (see Figure 3). After the toy was removed from the box, the onlooker grasped the box so that the last frame that infants in the onlooker condition saw was matched to that of the collaboration condition (i.e., each actor was grasping an object).

After reaching the habituation criterion, infants were shown a baseline trial, a familiarization trial, and six test trials in which the test actor grasped either the box or the toy (as in Experiment 1). Infants in the collaboration condition watched the box-opener complete the test trials and infants in the onlooker condition watched the onlooker complete the test trials (see Figure 4). As in Experiment 1, the actors in both conditions held their final position during all of the trials until the infant looked away for more than 2-seconds or 120 seconds had elapsed. A trained coder who watched the live feed of the infant judged infants' visual attention. The coder was blind to which condition the infant had been assigned and to which events were being run. A second coder reliability coded 30 of the infants' habituation phases (there were seven infants for which the videos were corrupt). The original coder and the reliability coder agreed on 96% of the test trials. The distribution of disagreements was unsystematic across the types of test trials (Fisher's Exact Test, $p = 1$, two-tailed).

Results and discussion

Infants' average looking times can be seen in Table 1. Preliminary analyses explored whether there were any reliable differences across conditions in infants' looking times during habituation and familiarization trials. A 2 (habituation trial: sum of first three trials, sum of last three trials) $\times$ 2 (condition: collaboration, onlooker) mixed-design ANOVA showed a significant

main effect of habituation trial. As expected, infants' attention declined across habituation trials, $F(1, 34) = 36.98$, $p < .001$, $\eta^2_{\text{partial}} = .52$. There were no other significant effects. An independent samples t-test revealed that the conditions did not differ in the average number of trials in which infants habituated, $t(34) < 1$, $d = -0.07$, $r = 0.04$. Infants in the collaboration condition habituated in an average of 7.7 trials ($SE = 0.54$) and infants in the onlooker condition habituated in an average of 7.9 trials ($SE = 0.56$). The conditions did not differ in infants' looking towards the baseline and familiarization trials, $t(34) < 1$, $d = -0.18$, $r = 0.09$ and $t(34) = 1.16$, $p = 0.25$, $d = 0.40$, $r = 0.20$, respectively.

The question of interest was whether infants who received active experience in a collaborative activity interpret an individual's actions as being directed towards a collaborative goal only when his/her actions are causally related to the attainment of a common goal. Consistent with the findings of Experiment 1B, if experience fosters an understanding of the common-goal structure underlying collaboration, infants in the collaboration condition should look longer on the test trials in which the box-opener grasped the box. If experience helps infants come to understand that *active* engagement in a collaborative activity is critical to interpret an actor's actions in terms of a collaborative goal, infants in the onlooker condition should not view the onlooker as having a collaborative goal and thus should not look longer towards the box test trials. In contrast, if experience leads infants to generalize their own goal across individuals, regardless of an individual's active participation in the collaboration, infants in both conditions should look longer when the test actor grasps the box.

Preliminary analyses revealed no significant effects of sex, the side on which the box-opener was on during habituation, or the type of first test trial on infants' looking during the test trials. Therefore, the subsequent analyses were collapsed across these dimensions. To investigate our questions of interest, a 2 (test trial type: box, toy) × 2 (condition: collaboration, onlooker) mixed-design ANOVA with test trial type as the within-groups factor was conducted on infants' average looking times towards the test trials. The results of this ANOVA revealed a significant test trial type by condition interaction, $F(1, 34) = 5.20$, $p = 0.03$, $\eta^2_{\text{partial}} = .13$. No other effects reached significance. To further explore the significant interaction, a paired t-test on infants' average looking times towards the box and toy test trials was performed for each condition. These analyses revealed that infants in the collaboration condition looked significantly longer towards the box test trials than they did the toy test trials, $t(17) = 2.36$, $p = .03$, $d = 2.58$, $r = 0.79$. Infants in the onlooker condition did not differ in their average looking times towards the box and toy test trials, $t < 1$. The above results

were confirmed by an individual level analysis. Fifteen of the 18 infants in the collaboration condition looked longer towards the box test trials than the toy test trials, $Z = -3.16$, $p = .002$ (signed-ranks). Conversely, only eight of the 18 infants in the onlooker condition looked longer towards the box test trials than the toy test trials, $Z = -0.59$, $p = .557$ (signed-ranks). These findings provide further evidence suggesting that 10-month-olds who viewed a collaborative event after receiving training on a collaborative task successfully identified a common collaborative goal, whereas infants who received the same experience with a collaborative activity, but watched an event in which the test actor simply observed the action sequence, did not.

These results replicate and extend those of Experiment 1B. Consistent with the results of Experiment 1B, providing 10-month-olds with active experience engaging in a collaborative activity supported the emergence of infants' ability to represent the actions of individuals engaged in a collaborative activity in terms of a collaborative goal. Critically, our findings demonstrate that active engagement in a collaborative activity did not guide infants to over-attribute a common goal to an individual who was present during the same sequence of events, but was not actively involved in removing the toy from the box. Thus, our findings demonstrate that 10-month-old infants who were trained on a collaborative task were able to identify at least one context in which individuals do not share a common goal (as in the onlooker condition).

Although these findings suggest that active experience plays an important role in shaping infants' understanding of the common-goal structure underlying collaborative activities, one open question concerns whether active experience per se matters. That is, it remains unclear as to whether infants would have demonstrated the ability to identify collaborative goals had they only been provided with additional experience observing the collaboration prior to habituation. The large body of evidence demonstrating the important role that active experience plays in children's development (e.g., Bushnell & Boudreau, 1993; Gallese et al., 2009; Gibson, 1988; Libertus & Needham, 2011) and infants' action understanding in particular (e.g., Brooks & Meltzoff, 2002; Gerson & Woodward, 2012; Sommerville & Woodward, 2005; Sommerville et al., 2005, 2008) gives us reason to believe that *active* collaboration experience would be particularly important to the development of an understanding of collaborative goals. Experiment 2B was conducted to investigate whether additional experience observing a collaborative activity promotes an understanding of collaborative goals. To investigate this question, 10-month-old infants watched two experimenters engage in the box-toy collaboration before participating in the collaboration visual habituation paradigm. If additional experience in general fosters the development

of an understanding of collaborative goals, infants in this experiment should perform similarly to the infants in the active collaboration condition in Experiment 2A. That is, they will look longer towards the box test trials. However, if firsthand experience with the collaboration in particular promotes an understanding of collaborative goals, then infants should not look reliably longer towards either test event.

EXPERIMENT 2B

Method

Participants

Eighteen full-term infants participated in this study (nine males, *mean age* = 9 months, 28 days; *range* = 9 months, 15 days to 10 months, 10 days). Participants were recruited in the same manner as in Experiment 2A. Families had responded to advertisements stating that they were interested in volunteering for infant development studies. Infants belonged to the following ethnic groups: New Zealand European ($n = 15$), or more than one ethnic group ($n = 3$). An additional nine infants participated in the study, but were excluded from the final analyses for the following reasons: the session ended early because of infant distress ($n = 2$), procedural error ($n = 1$) and the infant had looking times of zero for at least one of the test trials ($n = 4$) or was an outlier (>2.5 SD above the mean) on total looking time across all test trials ($n = 2$).

Materials and procedure

The materials and procedure were identical to those of the collaboration condition in Experiment 2A with the key difference being the removal of the action task and the addition of an observation phase before infants participated in the habituation phase.

Observation phase. As in Experiment 2A, after completing the consent procedures, parents and their infants were escorted into our behavioural testing room. Parents were asked to sit with their infant on their lap at one side of a small table. The host experimenter sat in a chair on one side of the parent and infant. A second experimenter sat on the other side of the parent and infant, across from the host experimenter. The infant and parent watched the two experimenters complete four rounds of the box-toy collaborative task. The action sequence was identical to the sequence of actions carried out in the collaborative action task from Experiment 2A. The only difference was that the second experimenter was the one who removed the

ball from the container and thus the infant was not actively involved in the collaboration. After the fourth round of the collaboration, infants and their parents were escorted into the habituation room and the habituation phase immediately began.

Visual habituation phase. Infants were repeatedly shown the same collaboration habituation event as in the previous experiments. As in Experiment 2A, the experimenters in the habituation event were different from the experimenters who completed the collaboration during the observation phase. Infants' looking times during the visual habituation phase were coded in the same manner as in the previous experiments. The original coder and the reliability coder agreed on 99% of the test trials. The distribution of disagreements was unsystematic across the types of test trials (Fisher's Exact Test, $p = 1$, two-tailed).

Results and discussion

Infants' average looking times are summarized in Table 1. Infants habituated in an average of 8.83 trials ($SE = 0.73$). Our primary question of interest was whether providing infants with observational experience with a collaborative activity before habituation would guide infants to identify the box-opener's goal during habituation as the toy (i.e., the collaborative goal). To investigate this question, the focal analyses were conducted on infants' average looking to the two types of test trials (i.e., box, toy). Preliminary analyses revealed no significant effects of sex, the side on which the box-opener was on during habituation, or type of first test trial. Therefore, the subsequent analyses were collapsed across these dimensions. A paired-samples t-test revealed that infants did not look reliably longer towards either type of test trial, $t(17) = 1.50$, $p = .15$, $d = 0.41$, $r = 0.20$. Thus, these findings suggest that infants who observed a live collaborative activity did not reliably interpret the goal of the box-opener's actions during habituation as the collaborative goal. These results were supported by an individual level analysis. Eleven of the 18 infants looked longer towards the toy test trials than the box test trials, $Z = -1.07$, $p = 0.29$ (signed-ranks). Together, our analyses indicate that 10-month-old infants who had previously watched a live collaborative exchange did not interpret the box-opener's actions during habituation as being directed towards the attainment of a shared collaborative goal.

In our final set of analyses, we compared the average looking times to the different types test trials of the infants in the present study with the average looking times of the infants in the action task-collaboration condition of Experiment 2A. Because infants in the active condition looked

significantly longer on the familiarization trial, which preceded the test events, $t(34) = 2.57$, $p = .017$, $d = 1.11$, $r = 0.48$, we conducted a 2 (test trial type: box, toy) × 2 (condition: active, observation) mixed-design ANCOVA with test trial type as the within-subject factor and duration of the familiarization trial as the covariate. The ANCOVA revealed a significant condition by test trial type interaction, $F(1, 33) = 5.20$, $p = .03$, $\eta^2_{\text{partial}} = .14$. No other effects were statistically significant. Thus, the results of the ANCOVA confirm that the average duration of time that infants spent looking towards each of the test trials differed depending on whether they had been actively engaged in or observed the box-toy collaboration before participating in the habituation paradigm. Ten-month-olds who participated in a collaborative exchange before taking part in the visual habituation phase looked significantly longer at the test trials in which the box-opener grasped the box than they did on the test trials in which she grasped the toy. Conversely, 10-month-old infants who observed the collaboration event before taking part in the habituation phase did not look reliably longer towards either test event. Together, Experiment 2 provides the first evidence that active experience in a collaborative task promotes the development of 10-month-old infants' ability to identify the common-goal structure underlying collaborative action.

General discussion

Infants engage in collaborative activities within the first 2 years of their postnatal lives (see Brownell, 2011 for a review), yet little is known about infants' understanding of the shared nature of these activities. This research investigated whether 10-month-old infants understand that the complementary actions of two collaborating individuals are directed towards the attainment of a common collaborative goal. To investigate this question, 10-month-old infants participated in a visual habituation paradigm that has previously been used with 14-month-olds (Henderson & Woodward, 2011). Infants were habituated to a collaboration event in which one actor opened a box, and a second actor removed the toy from inside the box. After habituation, infants watched a series of test trials in which the box-opener grasped either the box or the toy. In Experiment 1A, infants' looking towards the test events did not provide evidence that they viewed the box-opener's actions during habituation as being directed towards the collaborative goal (i.e., the toy), suggesting that 10-month-old infants do not view the actions of collaborative partners in terms of a collaborative goal. Infants were then either provided with active (i.e., Experiments 1B and 2A) or observational (i.e., Experiment 2B) experience with a box-toy collaborative

exchange before participating in the collaboration habituation paradigm. The results suggest that *active* experience in a collaborative task led infants to view the box-opener's actions during habituation as being directed towards the toy (i.e., the collaborative goal). Further, infants in the onlooker condition of Experiment 2A did not form any expectations regarding the onlooker's habituation goal and most importantly did not generalize the active actor's goal to the onlooker. Thus, providing infants with active experience in a collaborative activity did not guide infants to assume individuals have a common goal in a non-collaborative means-ends context. These studies provide the first direct evidence that active experience shapes infants' understanding of the common-goal structure underlying collaborative action.

The findings of our first experiment extend the findings of the research conducted by Henderson and Woodward (2011). In a series of three experiments, Henderson and Woodward (2011) demonstrated that 14-month-olds viewed the actions of two individuals engaged in a box-toy collaborative action sequence as being directed towards the attainment of a collaborative goal. Together with these findings, our findings suggest that the ability to identify the collaborative-goal structure underlying the box-toy collaboration without receiving prior training on a similar task develops some time between the ages of 10- and 14-months. The fact that the 10-month-olds in our first experiment were unable to identify the collaborative-goal structure underlying the collaborative action sequence is consistent with the large body of work, demonstrating that children do not engage in collaborative activities involving complementary roles in their everyday lives until their second year after birth (e.g., Aureli & Presaghi, 2010; Bakeman & Adamson, 1984, 1986; Hay, 1979). Future work will be conducted to gain further insights into the developmental trajectory of an understanding of collaboration by investigating how changes in infants' engagement in collaborative activities in their everyday lives, as well as changes in their action understanding and socio-cognitive abilities, contribute to the development of an understanding of collaborative goals.

Previous studies have demonstrated that infants engage in ritualized collaborative activities involving parallel actions such as peek-a-boo before their first birthdays (e.g., Ross & Lollis, 1987). Our findings raise questions surrounding the extent to which 10-month-old infants represent collaborative goals in the context of these ritualized games in which two individuals are acting simultaneously and completing the same roles to attain a collaborative goal. Given infants' engagement in collaborative activities involving parallel roles, it is possible that the 10-month-olds in the present study might have demonstrated an understanding of collaborative goals if they were tested on a procedure in which individuals completed the same actions in the

service of attaining a collaborative goal. To this end, Ross and Lollis (1987) suggested infants' responses to a collaborative partner's interruption in play were indicative of an understanding of the shared nature of the activity. However, as mentioned in the introduction, infants' responses could have been because of frustration at the fact that their goal was thwarted, and not at the termination of the shared activity (see also Gräfenhain et al., 2009; Henderson & Woodward, 2011; Warneken et al., 2012). By measuring infants' interpretations of collaborative goals in an observed collaborative exchange, our study demonstrates that active experience with a collaborative task involving complementary roles is critical for infants' ability to identify collaborative goals in a similar collaborative exchange. An interesting question for future investigation would be to determine the nature of the relationship between infants' engagement in cooperative activities involving parallel actions and their understanding of collaborative goals across a variety of contexts.

There are still several open questions concerning the nature of 10-month-olds' understanding of collaborative goals. In the present research, 10-month-olds interpreted the box-opener's actions in the collaboration event as being directed towards a common collaborative goal only after being given the opportunity to engage in a similar collaborative activity. One open question concerns *how* active experience changed infants' understanding of collaborative goals. One possibility is that infants had very little (if any) pre-existing knowledge about collaborative goals before taking part in the experiment and that active engagement brought forth a completely new understanding of the collaborative-goal structure underlying collaborative action. However, evidence that infants collaborate with others in social games and routines within the first year of their lives (see Brownell, 2011 for a review) gives us reason to believe that 10-month-old infants would have at least some notions about the shared nature of collaborative goals.

A second possibility is that active experience removing the ball from the box may have simply primed infants' ability to identify the overarching goal of the box-toy means-ends action sequence. This possibility is inline with existing evidence specifically demonstrating that active experience with a means-ends action sequence promotes 9- to 12-month-olds' ability to identify the goals of means-ends sequences (Gerson & Woodward, 2012; Sommerville et al., 2005, 2008). Our findings cannot rule out the possibility that training fostered a general understanding of the means-ends structure of the box-toy action sequence, as opposed to supporting a specific understanding of collaborative goals. However, the results of our onlooker condition suggest that the understanding that infants developed during active training extended beyond that of an understanding of means-ends action sequences. If infants' performance on our task was simply a reflection of a

means-ends understanding, infants in the onlooker condition would have generalized the goal of the meaningful sequence to the onlooker. This was not the case – active training encouraged infants to pay particular attention to the relationship between actions of individuals who are (or are not) engaged in a collaborative exchange.

A third possibility is that providing infants with direct experience attaining the goal in our study solidified infants' developing understanding of the common-goal structure underlying collaboration. These findings, as well as the existing body of evidence surrounding collaboration (for a review see Brownell, 2011), lead us to speculate that it is likely that infants came into the study with some kernel of an understanding of collaborative goals (probably from their previous experience in collaborative activities involving parallel roles) and that active experience primed the emergence of infants' ability to identify collaborative goals in collaborative activities involving complementary roles, at least in the present context.

How might experience support the expression of this understanding? Some insight into possible mechanisms by which active experience may be working can be gleaned from theoretical approaches on the role of experience in infants' learning (for a review see Gerson & Woodward, 2010). One possible explanation of our findings is inline with the structural alignment perspective (Gerson & Woodward, 2010), which proposes that active experience functions by fostering infants' ability to represent and organize their own actions as being structured by goals. Infants then use the relational similarity between their own actions and others' actions to identify the goals underlying others' actions. With respect to our research, active experience provided infants with repeated exposure to exemplars of the goal-directed nature of the collaborative task (i.e., removing different balls from inside different boxes). This repeated exposure would have highlighted the hierarchical goal structure of the task. During habituation, when infants watched two actors performing a similar collaborative task, infants might have been able to identify the relational similarities of the actions that the actors were performing to the joint actions involved in the action task. This would encourage infants to map the same hierarchical goal structure onto the event. We argue that infants did not structure the actions of the onlooker in terms of a collaborative goal because the onlooker's actions were relationally quite different than were the actions in the collaboration event. The relevance of the structural mapping account to our findings raises the interesting question of how changing the similarity of the event in collaborative training and habituation may influence infants' ability to generalize representations of two differing collaborative events.

Our future work will systematically explore the aspects of active experience that are critical to the emergence of an understanding of collaborative

goals. For instance, future work could investigate whether infants show an understanding of collaborative goals after being trained on the box-opener's role. This would tell us whether experience *attaining* the goal in a collaborative activity involving complementary roles is critical to developing an understanding of collaborative goals. These studies will speak to how experience might (or might not) support the ontogeny of an understanding of collaboration, as well as shedding insights into the nature of the mechanisms that might contribute to the emergence of an understanding of collaboration.

Another important question concerns the extent to which infants' understanding that was gleaned by active training in a box-toy collaborative action sequence would generalize across a range of contexts. For instance, it remains unclear whether the understanding of collaborative goals gained from active experience with the box-toy collaboration would generalize to more complicated collaborative activities in which the actions of collaborative partners are related at a much higher level. Although our findings do not speak directly to this possibility, they do give us some reason to believe that infants' understanding of collaborative goals could generalize to other contexts involving simple means-ends sequences such as the one presented in the present work. For instance, in the present study, the goal of the action sequence (i.e., the toy) was always different during training than in the habituation phase (e.g., balls vs. duck in Experiment 1B and balls vs. block in Experiment 2A). Further, in Experiment 2, the experimenter(s) who completed the box-toy collaboration in training differed from the actors involved in the habituation and test events. Infants did not have any difficulties identifying collaborative goals with these changes in context. Future work will examine the extent to which 10-month-old infants can generalize collaborative goals in a range of collaborative contexts and partners.

It has been argued that adults play an important role in scaffolding infants' engagement in collaborative tasks in the first 2 years of their postnatal lives (see Brownell, 2011). In fact, Brownell (2011) contends that infants younger than 12 months of age rely on adults to successfully structure their actions in collaborative activities. Because infants do not typically engage in collaborative problem-solving tasks such as the box-toy action sequence used in the present experiment until after their first birthday, infants in the present experiment were provided with a fair amount of support and encouragement to remove the toy from the box during training. Considering this, an interesting question concerns the role that this social support played in shaping infants' collaborative goal understanding. Future work will identify the extent to which 10-month-olds rely on the experimenter's behavioural and verbal scaffolding in the collaborative task

and whether changes in scaffolding influences infants' ability to identify collaborative goals.

Our findings demonstrate that active experience fosters 10-month-olds' ability to identify the actions of collaborative partners as being directed towards attaining a common goal. However, a mature understanding of collaboration requires much more than an ability to identify the common-goal structure underlying collaboration (see also Brownell, 2011). For instance, a complete understanding of collaboration requires the understanding that collaborative partners are mutually aware of their role in the collaborative exchange (e.g., Bratman, 1992). Although infants in the present research were provided with cues (i.e., joint eye gaze) that the collaborative partners were aware of each other's role in the collaboration, our findings do not address the question of whether 10-month-olds understand the role of mutual awareness in collaboration (see also Henderson & Woodward, 2011). It remains unclear as to whether infants in the current studies identified the collaborative-goal structure underlying the collaboration without fully understanding the mutual commitment that would be required by the collaborating individuals. It is likely that a mature understanding of the core components of collaboration develops gradually over the first 3–4 years of a child's life. In fact, the development of an understanding of mutual awareness might be a key factor underlying the growth in collaborative skill that has been demonstrated between 18- and 36-months of age (for a review, see Brownell, 2011). Future work will identify the extent to which infants understand the critical role that mutual awareness plays in collaborative exchanges.

At a very broad level, these findings are relevant to the process by which culture is maintained and transmitted across generations of the human species. Some researchers have argued that one-on-one collaborative interactions with the mature members of a community play a fundamental role in children's acquisition of the cultural norms and behaviours that are relevant to the communities in which they live (e.g., Csibra & Gergely, 2009; Tomasello, 1999; Tomasello et al., 2005). Our findings suggest that 10-month-old infants require active experience in collaborative interactions to be able to appropriately identify collaborative goals. However, societies take very different approaches to socialize developing children into their community (for examples, see Ochs & Schieffelin, 1995). For instance, there are a significant number of societies in which one-on-one interactions with infants are rare at the best (e.g., the Kaluli people in Papua New Guinea). In these societies, children are expected to acquire the linguistic and behavioural systems of their culture primarily through observation. If active experience is, in fact, fundamental to identifying culturally relevant behaviours (as our findings suggest), our research raises interesting questions surrounding how infants growing up in societies in which one-on-one interactions are

rare might acquire culture. Future work should investigate whether there are cultural variations in infants' ability to identify collaborative goals.

In conclusion, our findings provide the first demonstration that 10-month-old infants can identify the contexts in which individuals are acting towards the attainment of a common collaborative goal, but only after they were actively engaged in a similar collaborative task involving complementary actions to attain a shared goal. These findings demonstrate that infants experience important gains in making sense of the range of actions that they witness in their everyday lives within the first 2 years of their postnatal lives. Finally, these findings contribute to theories of folk psychology by providing the first evidence that infants can appropriately identify the goal-directed nature of actions involving multiple individuals by their first birthday. Future work will address the kinds of experiences that support the ontogenetic processes underlying an understanding of collaboration, as well as the extent to which engagement in collaborative activities might be a primary force driving cultural maintenance and transmission.

ACKNOWLEDGMENTS

A special thank to the families who participated in these studies and S. DeWath, V. Garcia-Hoyos, L. Crisford, L. Silailai, K. Featherstone, M. Thompson, V. Schell, and R. Westcott for their assistance with data collection. We would like to thank the members of The University of Maryland Infant Studies Laboratory and The Early Learning Laboratory at the University of Auckland for their assistance with data collection, coding, and their helpful comments. Experiments 1A and 1B were supported by a Social Sciences and Humanities Research Council of Canada (SSHRC) Post Doctoral Fellowship awarded to the first author and a NICHD operating grant (R01-HD035707) awarded to the fourth author. Experiments 2A and 2B were supported by a University of Auckland Faculty Development Research Fund Grant awarded to the first author.

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