



Published in final edited form as:

Psychol Sci. 2005 August ; 16(8): 601–608. doi:10.1111/j.1467-9280.2005.01582.x.

Can a Self-Propelled Box Have a Goal?:

Psychological Reasoning in 5-Month-Old Infants

Yuyan Luo and Renée Baillargeon

University of Illinois

Abstract

Some researchers have suggested that infants' ability to reason about goals develops as a result of their experiences with human agents and is then gradually extended to other agents. Other researchers have proposed that goal attribution is rooted in a specialized system of reasoning that is activated whenever infants encounter entities with appropriate features (e.g., self-propulsion). The first view predicts that young infants should attribute goals to human but not other agents; the second view predicts that young infants should attribute goals to both human and nonhuman agents. The present research revealed that 5-month-old infants (the youngest found thus far to attribute goals to human agents) also attribute goals to nonhuman agents. In two experiments, infants interpreted the actions of a self-propelled box as goal-directed. These results provide support for the view that from an early age, infants attribute goals to any entity they identify as an agent.

Researchers have known for some time that infants engage in physical reasoning: They attempt to predict and interpret the outcomes of physical events (e.g., Baillargeon, Spelke, & Wasserman, 1985; Leslie, 1984). Recent research indicates that infants also engage in psychological reasoning: They attempt to predict and interpret the actions of others (e.g., Gergely, Nádasdy, Csibra, & Bíró, 1995; Woodward, 1998). In the case of physical reasoning, the ontological entities that concern infants are clearly physical objects, surfaces, and substances. But what of psychological reasoning? What are those "others" whose actions infants seek to understand?

As adults, we readily attribute goals to both human and non-human agents. For example, when seeing an ant drag a dead insect across a sidewalk, we assume that the ant is bringing the insect back to its nest to feed other ants. Do infants, like adults, attribute goals to nonhuman as well as to human agents?

There is considerable evidence that by 12 months of age, infants construe at least some actions by human and nonhuman agents as directed toward goals (e.g., Csibra, Bíró, Koós, & Gergely, 2003; Gergely et al., 1995; Johnson, Slaughter, & Carey, 1998; Kuhlmeier, Wynn, & Bloom, 2003; Phillips, Wellman, & Spelke, 2002; Premack & Premack, 1997; Thoermer & Sodian, 2001; Woodward & Guajardo, 2002). Of central concern to conceptualizations of early psychological reasoning is whether young infants do so as well. Is infants' psychological reasoning initially restricted to human agents? Two opposing views on this question have been proposed.

According to some researchers (e.g., Meltzoff, 1995, 2002; Tomasello, 1999; Woodward, Sommerville, & Guajardo, 2001), infants' ability to reason about goals develops as a result of their experiences with human agents. Proponents of this view disagree about the age at which infants first attribute goals to human agents, and about the mechanism that makes this achievement possible; nevertheless, all agree that infants' psychological reasoning is at first restricted to humans and is then gradually extended to other agents. This view thus predicts that young infants attribute goals to human but not to other agents. We refer to this view as the *humans-first* view.

Other researchers (e.g., Baron-Cohen, 1995; Gergely et al., 1995; Johnson, 2000; Leslie, 1995; Premack, 1990) have proposed that goal attribution is rooted in a specialized system of reasoning that is activated whenever infants encounter individuals they identify as agents. Proponents of this view disagree on the nature of infants' system of reasoning, and on the features infants use to identify agents; nevertheless, all predict that from an early age, infants attribute goals to both human and nonhuman agents. We refer to this view as the *all-agents* view.

The youngest infants found thus far to attribute goals to human agents are 5-month-olds (Woodward, 1998). In the present research, we examined whether infants this age would also attribute goals to nonhuman agents. We reasoned that positive evidence would support the all-agents view, and therefore would suggest that the ontological entities that concern young infants when engaging in psychological reasoning are agents, whether human or not.

PRIOR FINDINGS

Previous experiments have been taken to suggest that 5- and 6-month-olds attribute goals to human but not to other agents, thus supporting the humans-first view (Woodward, 1998). In some experiments, infants saw a human actor's left arm and hand reach for and grasp toy A, on the left, as opposed to toy B, on the right. Following habituation, the toys' positions were reversed. During test, the actor grasped either toy A (old-goal event) or toy B (new-goal event). The infants looked reliably longer at the new-than at the old-goal event, suggesting that they (a) interpreted the actor's actions during habituation as directed toward the goal of obtaining toy A, (b) expected the actor to pursue the same goal during test, and hence (c) were surprised in the new-goal event when the actor grasped toy B. In additional experiments, the actor was replaced with a flat occluder shaped like an arm and hand, a rod tipped with a sponge, or a mechanical claw. The infants did not look reliably longer at the new-goal event, and Woodward concluded that 5- to 6-month-olds attribute goals to human but not to nonhuman agents.

However, there is another possible interpretation for the negative findings of the occluder, rod, and claw experiments: Because each object extended from a window in the right side of the apparatus, its right end was hidden from view, making it unclear whether its actions were externally or internally caused. (Although the actor's arm in the initial experiment also extended from the right side of the apparatus, the infants no doubt recognized that it belonged to a person, and so viewed its actions as internally caused.) Recent evidence suggests that infants view a novel object as inert unless given unambiguous information to the contrary (e.g., the object initiates its motion in plain view or reverses direction spontaneously; Kotovsky & Baillargeon, 2000; Luo, Kaufman, & Baillargeon, 2005). Perhaps the infants tested by Woodward (1998) did not attribute goals to the occluder, rod, and claw simply because the available information did not clearly mark them as agents. This interpretation suggests that 5-month-olds may attribute a goal to a nonhuman agent if given unambiguous evidence that they are indeed faced with an agent. The present research examined this possibility.

EXPERIMENT 1

The infants in Experiment 1 first received *orientation* trials in which a box moved back and forth across an apparatus floor (see Fig. 1). Like the rod, occluder, and claw used by Woodward (1998), the box possessed few agentlike features: It moved rigidly, lacked a face, and did not engage in contingent interaction (e.g., Johnson, 2003). Unlike the rod, occluder, and claw, however, the box was clearly capable of self-propulsion: It initiated its motion in plain view and reversed direction repeatedly. Many researchers have suggested that in infancy, self-propulsion is an important cue for agency (e.g., Baron-Cohen, 1995; Premack, 1990; we make no claim here that self-propulsion is the only agency cue available to young infants, or that this cue is interpreted in the same manner throughout infancy).

Following orientation, a cylinder and cone were placed on the left and right sides of the apparatus, respectively, and the infants received *familiarization* trials in which the box moved toward and rested against the cone. Next, the infants received a *display* trial in which the positions of the cone and cylinder were reversed. Finally, the infants received *test* trials in which the box approached and rested against the cone (old-goal event) or the cylinder (new-goal event).

We reasoned that if the infants categorized the box as an agent and attributed to the box the goal of contacting the cone, then they would look reliably longer at the new-than at the old-goal event.

One potential difficulty with our experiment was that the infants might look reliably longer at the new-goal event simply because they had formed an association between the box and cone during familiarization, and the event deviated from this association. To address this difficulty, we tested infants in a control condition identical to the experimental condition except that only the cone was present during familiarization (see Fig. 1). If the infants in the experimental and control conditions merely formed an association when the box contacted the cone, then the infants in both conditions would look reliably longer at the new-goal event. However, if the infants in the experimental and control conditions attempted to interpret the box's actions in terms of possible goals, then the infants in the control condition might look equally at the two test events. Because only the cone was present during familiarization, no prediction could be made about the box's actions during test: The box might again approach the cone, or it might approach the novel cylinder.

Method

Participants—Participants were 24 healthy term infants, 12 male and 12 female (5 months 0 days to 5 months 19 days, $M = 5$ months 8 days); 12 infants were randomly assigned to the experimental condition and 12 to the control condition. Another 10 infants were eliminated, because of fussiness, activeness, or inattentiveness (6); observer difficulties (2); or differences in test looking times that were more than 2.5 standard deviations from the mean (2).

Apparatus—The apparatus consisted of a wooden display booth (126 cm high \times 101 cm wide \times 48 cm deep). The infant sat on a parent's lap and faced an opening (47.5 \times 95 cm) in the front of the apparatus; between trials, a muslin-covered frame (60 \times 101 cm) was lowered in front of this opening. A muslin-covered window (51 \times 33 cm) in the right wall was used to introduce or remove the box, cone, and cylinder between trials.

The box (5.5 \times 18 \times 15.5 cm) was covered with green paper. Attached to its back lower edge was a rod that extended through a fringe-filled opening (1.3 \times 101 cm) at the bottom of the back wall. An experimenter used a handle at the end of the rod to move the box; the handle

fit into a linear groove with adjustable stops that ensured the box traveled the right path in each trial. Because the rod was not visible to the infants, the box appeared to move by itself.

The cone consisted of a cylinder (16.5×11.5 cm) with a conical top 9 cm in slant height; it was covered with white paper decorated with pastel dots. The cylinder (13.5×11.5 cm) was painted yellow and decorated with blue stripes.

Procedure—Two observers monitored each infant's looking behavior through peepholes in cloth-covered frames on either side of the apparatus. Interobserver agreement in Experiments 1 and 2 averaged 93% per trial per infant.

All infants first received two orientation trials in which the box moved back and forth across the center of the apparatus, starting from the left in the first trial and from the right in the second. At the start of each trial, the box rested on the apparatus floor, 5 cm from the back wall and 31 cm from the left (or right) wall. After a 1-s pause, the box moved to the right (or left) at a speed of about 10.5 cm/s (2 s), until it was 31 cm from the right (or left) wall. After a 1-s pause, the box moved back to its starting position (2 s). Each event cycle thus lasted about 6 s; cycles were repeated until the trial ended. Each orientation trial ended when the infant (a) looked away for 2 consecutive seconds after having looked for at least 3 cumulative seconds or (b) looked for 60 cumulative seconds. The infants in the experimental ($M = 37.4$ s, $SD = 16.3$) and control ($M = 40.2$ s, $SD = 21.8$) conditions looked about equally, $F(1, 22) = 0.13$.

Next, the infants received four familiarization trials. In the experimental condition, the cone and cylinder stood on the right and left sides of the apparatus floor, respectively, 5.5 cm from the back wall and 9 cm from the side wall. In the control condition, the cylinder was absent. Each familiarization trial involved a 3-s pretrial and a main trial; looking times during the pretrial and main trial were computed separately. At the start of the pretrial, the box rested on the apparatus floor 41.5 cm from either side wall. After a 1-s pause, the box moved at a speed of about 10.5 cm/s until it stopped against the cone (2 s). During the main trial, the box remained in this position until the trial ended. Each familiarization main trial ended when the infant (a) looked away for 2 consecutive seconds after having looked for at least 2 cumulative seconds or (b) looked for 60 cumulative seconds. The infants in the experimental ($M = 15.1$ s, $SD = 9.3$) and control ($M = 14.0$ s, $SD = 6.5$) conditions tended to look equally, $F(1, 22) = 0.12$.

All infants next received a static display trial with the cylinder and cone in reversed positions; the box was absent during this trial. The display trial ended when the infant (a) looked away for 2 consecutive seconds after having looked for at least 5 cumulative seconds or (b) looked for 30 cumulative seconds. The infants in the experimental ($M = 14.9$ s, $SD = 7.9$) and control ($M = 12.9$ s, $SD = 7.7$) conditions looked about equally, $F(1, 22) = 0.38$.

Finally, all infants received two test trials in which the box approached and stopped against the cylinder in the new-goal event or the cone in the old-goal event (pretrial); the box then remained in this position until the trial ended (main trial). Half the infants saw the new-goal event first, and half saw the old-goal event first. Each test main trial ended when the infant (a) looked away for 2 consecutive seconds after having looked for at least 5 cumulative seconds or (b) looked for 40 cumulative seconds.

Preliminary analyses of the test data revealed no significant interaction among condition, event, and sex or order; the data were therefore collapsed across sex and order in subsequent analyses.

Results

The infants' looking times during the main-trial portions of the test trials (see Fig. 2) were analyzed by a 2×2 analysis of variance (ANOVA) with condition (experimental or control) as a between-subjects factor and event (new- or old-goal) as a within-subjects factor. The analysis yielded a significant main effect of event, $F(1, 22) = 6.36, p < .025$, and a significant Condition Event interaction, $F(1, 22) = 6.36, p < .025$. Planned comparisons revealed that the infants in the experimental condition looked reliably longer at the new-goal event ($M = 23.9$ s, $SD = 13.2$) than at the old-goal event ($M = 11.2$ s, $SD = 7.0$), $F(1, 22) = 12.72, p < .0025$, Cohen's $d = 1.2$, whereas those in the control condition looked equally at the new-goal ($M = 13.4$ s, $SD = 9.8$) and old-goal ($M = 13.4$ s, $SD = 9.0$) events, $F(1, 22) = 0.00, d = 0.0$. In the experimental condition, 10 out of the 12 infants looked longer at the new-than at the old-goal event, Wilcoxon signed-ranks $T = 73.5, p < .005$; in the control condition, only 6 of the 12 infants did so, $T = 39, p > .10$.

Discussion

The infants in the experimental condition looked reliably longer at the new-than at the old-goal event, suggesting that they (a) categorized the box as an agent, (b) interpreted the box's actions during familiarization as directed toward the goal of contacting the cone, (c) expected the box to pursue the same goal during test, and hence (d) were surprised when the box approached the cylinder. The demonstration that infants as young as 5 months attribute goals to nonhuman agents supports the all-agents view of early psychological reasoning.

In contrast to the infants in the experimental condition, those in the control condition looked equally at the two test events, suggesting that they (a) categorized the box as an agent, (b) interpreted the box's actions during familiarization as directed toward the goal of contacting the cone, and (c) recognized that the box might change its goal and hence its actions after the cylinder was introduced.

The results of the control condition rule out low-level interpretations of the experimental-condition data, because the only difference between the two conditions was whether the cylinder was present during familiarization. In addition, the control condition results call for a richer interpretation of the experimental-condition data in this and related experiments (e.g., Thøermer & Sodian, 2001; Woodward, 1998, 1999; Woodward & Sommerville, 2000). When the infants in the experimental condition watched the box repeatedly approach the cone during familiarization, they could construe the box's behavior in two ways: They could infer that it preferred the cone over the cylinder, or they could reason that the box, having contacted the cone once, sought to do so again in subsequent trials. The results of the control condition support the first possibility. Had the infants in the experimental and control conditions simply expected the box, after contacting the cone once, to continue doing so, they would have responded in the same manner during test. The fact that they did not suggests that (a) the infants in the experimental condition assumed that the box preferred the cone over the cylinder, and therefore expected it to continue approaching the cone during test, and that (b) the infants in the control condition realized at the start of the test trials that they had no information as to whether the box would prefer the cone or the novel cylinder, and so could make no prediction about its behavior. The present results thus suggest that when infants see an agent repeatedly approach one of two distinct objects, they infer that the agent not only seeks that object, but also prefers it over the other object.

EXPERIMENT 2

In Experiment 2, we sought to confirm the positive results of Experiment 1, and also to test the hypothesis that the infants in Woodward's (1998) experiments did not attribute goals to the rod, occluder, and claw because they did not perceive them as agents. These objects all

extended from the right side of the apparatus, so that it was unclear whether their actions were internally or externally caused.

Experiment 2 was identical to Experiment 1, except that a handle was attached to the box (see Fig. 3). For half of the infants, the handle was short and remained within the apparatus (short-handle condition); for the other infants, the handle was long and extended through the window in the right side of the apparatus (long-handle condition). We predicted that the infants in the short-handle condition would identify the box as an agent and would again look reliably longer at the new-than at the old-goal event; in contrast, the infants in the long-handle condition would not perceive the box as an agent and would look about equally at the two test events.

Method

Participants—Participants were 24 healthy term infants, 10 male and 14 female (4 months 26 days to 5 months 21 days, $M = 5$ months 11 days); 12 infants were randomly assigned to the short-handle condition and 12 to the long-handle condition. Another 10 infants were eliminated because of fussiness, activeness, or inattentiveness (8); observer difficulties (1); or a sneezing fit (1).

Apparatus and Procedure—The apparatus and procedure in Experiment 2 were similar to those of Experiment 1, except that a short or a long handle was attached to the box, and a slit was created in the window's curtain to accommodate the long handle. The handle was covered with red paper and shaped like an L rotated 90° clockwise. The vertical portion of the handle was mounted on the box at the center of its top back edge; the horizontal portion extended to the right 4 cm above the box and was either 17.5 cm long (short handle) or 80.5 cm long (long handle). The long handle always extended out of the apparatus; the short handle never did.

No reliable differences were found between the looking times of the infants in the two conditions during the orientation trials (short handle: $M = 34.1$ s, $SD = 18.3$; long handle: $M = 46.2$ s, $SD = 13.3$), $F(1, 22) = 3.42$, $p > .05$; familiarization trials (short handle: $M = 17.3$ s, $SD = 9.5$; long handle: $M = 15.3$ s, $SD = 8.7$), $F(1, 22) = 0.30$; or display trial (short handle: $M = 13.0$ s, $SD = 5.6$; long handle: $M = 15.5$ s, $SD = 9.0$), $F(1, 22) = 0.67$. As in Experiment 1, preliminary analyses revealed no significant interaction among condition, event, and sex or order; the data were therefore collapsed across sex and order in subsequent analyses.

Results

The infants' looking times during the main-trial portions of the test trials (see Fig. 2) were analyzed by a 2×2 ANOVA with condition (short- or long-handle) as a between-subjects factor and event (new- or old-goal) as a within-subjects factor. The analysis yielded a significant main effect of event, $F(1, 22) = 8.20$, $p < .01$, and a significant Condition \times Event interaction, $F(1, 22) = 8.39$, $p < .01$. The infants in the short-handle condition looked reliably longer at the new-goal event ($M = 18.9$ s, $SD = 7.8$) than at the old-goal event ($M = 9.1$ s, $SD = 2.6$), $F(1, 22) = 16.59$, $p < .001$, $d = 1.7$, whereas those in the long-handle condition looked equally at the new-goal ($M = 11.1$ s, $SD = 5.8$) and old-goal ($M = 11.1$ s, $SD = 9.3$) events, $F(1, 22) = 0.00$, $d = 0.0$. In the short-handle condition, 10 of the 12 infants looked longer at the new-goal event, $T = 74$, $p < .005$; in the long-handle condition, only 7 of the 12 infants did so, $T = 44$, $p > .10$.

Discussion

As in the experimental condition of Experiment 1, the infants in the short-handle condition looked reliably longer at the new-than at the old-goal event, suggesting that they (a) categorized the box with its short handle as an agent; (b) attributed to the box the goal of contacting the cone, which it apparently preferred over the cylinder; (c) expected the box to approach the cone in its new position during test; and (d) were surprised when this expectation was violated. The results of the short-handle condition thus provide further evidence that young infants attribute goals to nonhuman agents—even a novel nonhuman agent such as a self-propelled box with a short handle. Although the infants were unlikely to have encountered such an agent prior to coming to the lab, they readily interpreted its actions as goal-directed, as predicted by the all-agents view of early psychological reasoning.

In contrast to the infants in the short-handle condition, those in the long-handle condition looked equally at the two test events. This result suggests that the infants did not categorize the box as an agent when its handle extended out of the apparatus, making it unclear whether it moved by itself or not. Because the infants did not perceive the box as an agent, they did not interpret its actions as goal-directed.

GENERAL DISCUSSION

The present experiments indicate that 5-month-old infants—the youngest found thus far to attribute goals to human agents (Woodward, 1998)—also attribute goals to nonhuman agents. These results support the all-agents view that the ability to reason about goals is rooted in a specialized system of reasoning that is activated when infants attempt to predict and interpret the actions of entities they identify as agents.

Several findings may appear inconsistent with those reported here. Some of these findings come from experiments that examined 5- to 9-month-olds' ability to reason about the goals of nonhuman agents, with negative results (e.g., Csibra et al., 2003; Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Kuhlmeier et al., 2003). These experiments differed from the present experiments in two respects: They involved computer-animated events, and they required infants to reason about the interactions of two or more nonhuman agents. Young infants might have difficulty interpreting such events because they lack the perceptual skills necessary to understand their spatial layout (e.g., Luo, Baillargeon, & Lécuyer, 2005), or because they cannot keep track of multiple agents' goals. In the present experiments, the infants saw live events involving a single agent, and they readily identified the agent's goal.

Another relevant finding comes from an experiment by Shimizu and Johnson (2004). In that experiment, 12-month-olds saw an oval object move toward and contact toy A, on the left, as opposed to toy B, on the right. Following habituation, the toys' positions were reversed, and the object approached either toy A (old-goal event) or toy B (new-goal event). The infants looked about equally at the two events. One possible explanation for this negative result is that infants attribute a goal of contacting a particular object to an agent only when given clear evidence that the agent chooses to approach that object. At the start of each habituation trial in Shimizu and Johnson's experiment, the object was oriented toward toy A and moved in the direction it was "facing" until it contacted toy A. As a result, the infants might have been uncertain whether the object chose to approach toy A or happened to contact it while moving in that direction. In the present experiments, the box moved back and forth across the center of the apparatus during orientation and then moved toward the cone near the right wall during familiarization. Because the box changed its behavior when the cone was introduced, the infants had evidence that the box chose to approach the cone. This analysis predicts that if the orientation trials in the present experiments were modified

so that the box followed the same trajectory during orientation and familiarization— before and after the introduction of the cone—the infants would be less likely to attribute to the box the goal of contacting the cone. Preliminary results support this prediction.

The present research extends prior results by showing that 5-month-old infants attribute goals not only to human (Woodward, 1998) but also to nonhuman agents—even an unfamiliar agent such as a self-propelled box with a short handle. Future research can build on these findings to explore what features may lead young infants to categorize individuals as agents, what goals they may attribute to the agents, and whether these goals should be described as primitive mental states, implying a nascent theory of mind (e.g., Gergely & Csibra, 2003; Johnson, 2003; Leslie, 1995; Premack & Premack, 1995).

Acknowledgments

This research was supported by a grant from the National Institute of Child Health and Human Development (HD-21104) to the second author. We thank Paul Bloom, Gergely Csibra, Cindy Fisher, György Gergely, Nora Newcombe, Kris Onishi, and Amanda Woodward for helpful suggestions; the staff of the University of Illinois Infant Cognition Laboratory for their help with the data collection; and the parents and infants for participating in the research.

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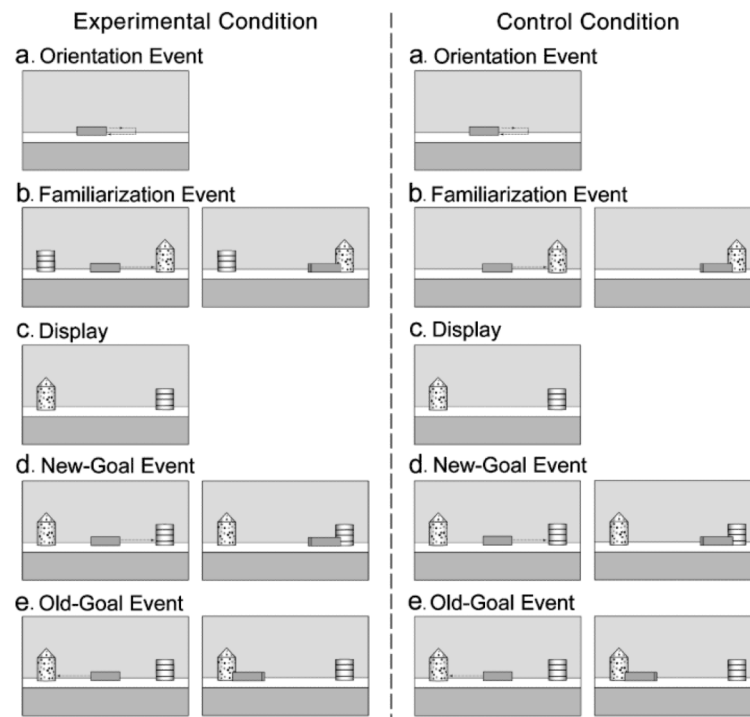


Fig. 1.

Illustration of the experimental (left) and control (right) conditions in Experiment 1. Both conditions began with two orientation trials (a), during which a box moved back and forth at the center of the apparatus floor. During the four familiarization trials (b), a cone stood near the right side of the apparatus, and a cylinder stood near the left side (in the control condition, only the cone was present). The box moved toward the cone, stopped against it, and remained in that position until the trial ended. Prior to the static display trial (c), the positions of the cone and cylinder were reversed (in the control condition, the cone was moved to the left side of the apparatus, and the cylinder was added on the right side); the box was absent during this trial. Two test trials followed. In the new-goal event (d), the box moved to the right and stopped against the cylinder; in the old-goal event (e), the box moved to the left and stopped against the cone.

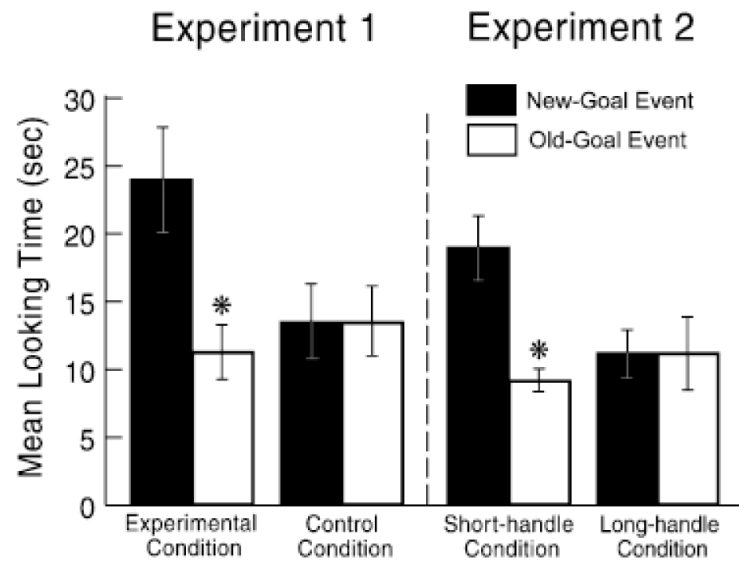


Fig. 2. Results of Experiments 1 and 2: mean looking times (with standard errors) at the new- and old-goal test events as a function of condition. An asterisk denotes a statistically reliable difference.

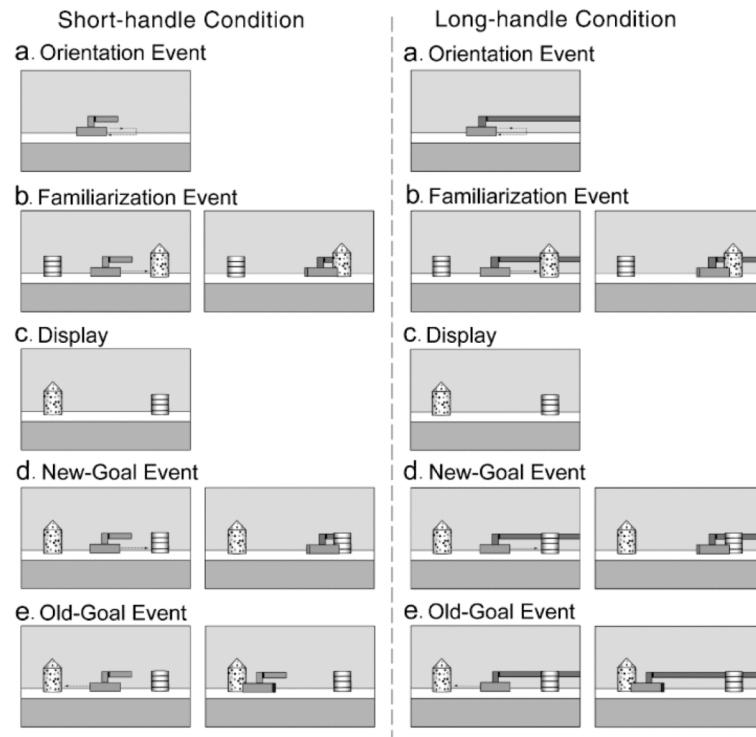


Fig. 3. Illustration of the short-handle (left) and long-handle (right) conditions in Experiment 2. The events were similar to those of the experimental condition in Experiment 1 (see Fig. 1) except that a handle (short or long) was attached to the box.