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UNDERSTANDING RATIONAL ACTION IN INFANCY

We present evidence that infants as young as 9 months of age can interpret movements of computer-animated abstract figures as rational goal-directed actions and that this interpretation does not require a prior categorization of the observed characters as animate agents. The study demonstrates that explaining behaviour in terms of reasons, which is thought to be a cardinal requirement for understanding other minds, does not share its developmental origin with understanding animacy or agency. It is argued that this early ability for teleological interpretation may provide the basis not only for the infant's emerging theory of mind, but for understanding instrumental action and tool use as well.

People tend to interpret each other's behavior as purposeful and rational actions (Dennett, 1987; Fodor, 1987). In addition, it is not only human behavior that we prefer to explain this way; we are also inclined to see sensibly acting agents when looking at cartoons or computer animations even if the external appearance of the animated figures does not resemble human beings or animals (Heider & Simmel, 1944). This phenomenon is usually thought to be the result of our tendency to anthropomorphize inanimate moving objects and treat them as humans by overextending the mentalistic interpretational strategies that we have developed to explain other people's and our own actions (Piaget, 1929). In fact, some researchers (Dasser, Ulbaek, & Premack, 1989) have shown that preschool children interpret certain behaviors of inanimate objects by attributing intentions to them, and hypothesized (Premack, 1990) that even young infants can do it as well. It is often proposed (Premack, 1990; Mandler, 1992; Baron-Cohen, 1994; Leslie, 1994) that such an interpretation of behavior is based on and triggered by the perception of self-propulsion, i.e., the observation that an object starts to move or changes its path of movement without external assistance. Thus, these approaches consider the detection of animacy or agency, i.e., the ability to induce one's own behavior to be a precondition for the interpretation of behavior in terms of reasons.

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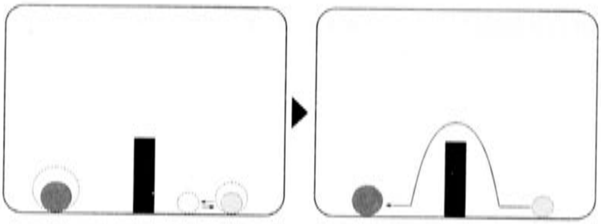

Fig. 1. An illustration of the habituation events for the experimental group (Gergely et al., 1995). First, the large circle expands then contracts regaining its original size. This is immediately followed by a similar expansion-contraction sequence performed by the small circle. This sequence of events is then repeated again and then the small circle starts to move towards the large circle. It stops in front of the rectangular figure then retreats to its original position and starts out again towards the large circle. This time it jumps over the obstacle and, landing in front of the large circle, it continues to approach it until they make contact. When they touch, the large circle exhibits the contraction-expansion routine again, which is immediately reciprocated by an identical response performed by the small circle, and this interchange is repeated a second time.

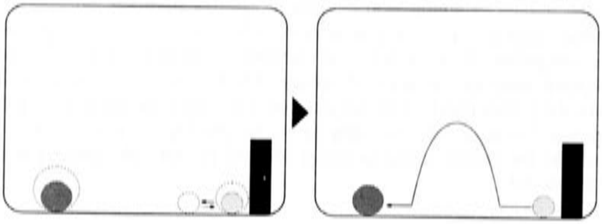

Fig. 2. Habituation events for the control group (Gergely et al., 1995). The sequence of the actions is identical to that of the experimental group, but the rectangular figure is placed behind the small circle, rather than in between the two.

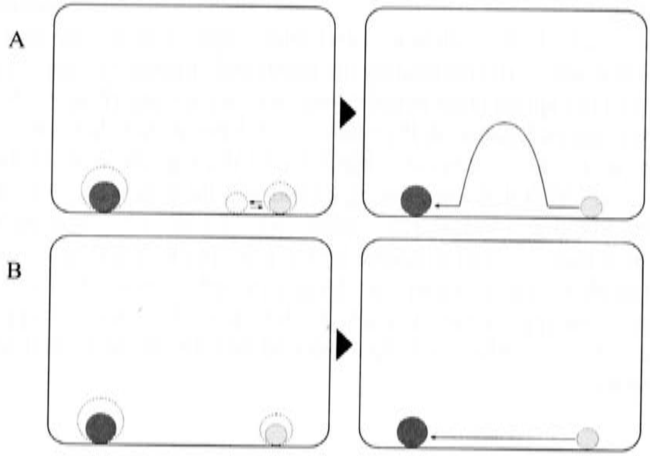

Fig. 3. Test events in the dishabituation phase (Gergely et al., 1995). (A) The small circle exhibits the same behavior as in the habituation phase in the absence of the rectangular figure (Old Action). (B) The small circle approaches the large one through the shortest straight pathway (New Action).

We have recently demonstrated (Gergely et al., 1994, 1997) that 12- and 9-month-old infants, but not 6-month-olds, who were observing the equifinal behavior of a computer-animated abstract figure which exhibited self-propulsion, did indeed interpret it as a case of rational goal-directed action. Let us summarize these experiments briefly. In the experimental condition the infants were habituated to a sequence of events (Fig. 1) in which a small circle repeatedly approached a large circle through equifinal pathways by jumping over a rectangular figure separating them. The behaviors of the circles provided animacy or agency cues such as self-propulsion (the small circle started to move on its own), irregular path of movement (jumping), and nonrigid transformations of their surface (before the approach the circles expanded then contracted in a contingent manner), all indicating an internal and renewable source of energy. The behavior of the small circle in this event could be interpreted as a rational means action towards a goal-state (the spatial location next to the large circle) within the constraint of the given reality context (the presence of the "obstacle").

In the control condition (Fig. 2) the habituation event was identical to that presented in the experimental condition with one exception. The circles exhibited the same behavior but the rectangular figure was placed behind the small circle, i.e. it did not serve as an obstacle between the two circles. Thus, the jumping action of the small circle could not be interpreted as a rational action toward its goal-state in this context as there was a more rational alternative action (the straight-line approach) available but not taken.

In both conditions the infants saw two test events (Fig. 3) depicting two different actions. The rectangular figure in both test events was removed. In the "New action" test event (see Fig. 3B) the small circle displayed a novel action: it approached the large circle in a straight line that was the most rational means action available in the changed (no obstacle) situation. In the "Old action" test event (see Fig. 3A) the small circle exhibited the same jumping behavior as in the habituation phase. This time, however, the jumping was unmotivated and violated the rationality assumption since there was a more rational alternative action available but not taken.

We hypothesized that if the infants interpreted the habituation event in the experimental condition as a case of goal-directed rational action, then they would be able to predict the small circle's new rational action (straight-line approach) in the changed situation (no obstacle present). The results supported our hypothesis: in the experimental condition the 12- and 9-month-old infants dishabituated significantly less to the rational but novel action ("New action" event) than to the non-rational old jumping action ("Old action" event). In the control condition, where the jumping approach of the habituation event could not be interpreted as a rational means action (as there was no obstacle), infants showed no difference in dishabituation times between the two test events, indicating that no specific expectation was developed. Since the test events were identical in the experimental and the control conditions, the pattern of results found in the control condition excluded the possibility that the significant difference in dishabituation times between the two test events in the experimental condition could have been due to a general preference for the more complex movement pattern of the "Old Action" event.

Note, however, that, based on the results in the control condition, one can draw a further conclusion. Recall that the behavior of the small circle was characterized by the perceptual cues of agency in both conditions. However, these cues in the control condition did not prove to be sufficient for interpreting the behavior of the small circle in terms of

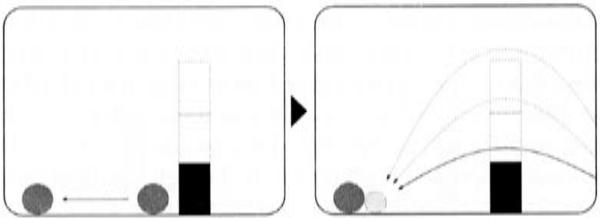

Fig. 4. Animated event sequences used in the experiment (habituation event). The background was green, the rectangular block was black, the large (1.5 cm diameter) circle was red, and the small (1 cm diameter) circle was yellow. The horizontal velocity of both circles' motion was 12 cm/sec. The action of the large circle (left) was immediately followed by the action of the small circle (right). In the habituation event for the experimental group the three different heights of the black column were randomly varied and the trajectory of the small circle was adjusted to match that height. The figures are not drawn to scale.

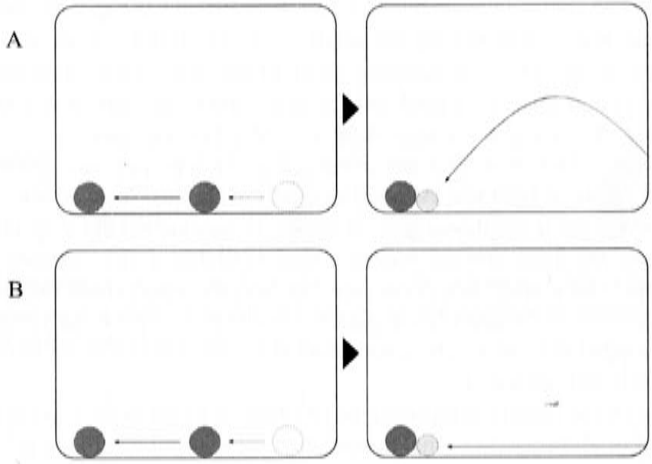

Fig. 5. (A) In the 'Old Action' test event the small circle followed the same trajectory as it did in the case of the medium height column or bar in the habituation event. (B) In the 'New Action' test event the small circle moved along a straight horizontal line. In the test events the large circle started out from the same location as in the habituation phase (experimental or control).

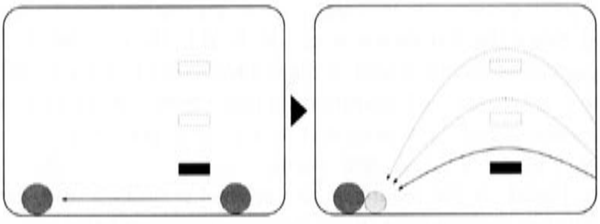

Fig. 6. In the control condition small bars replaced the columns of the experimental condition and the large circle passed under the bar at the beginning of every event.

reasons: for this to occur the goal-approach observed in the situation had to appear rational as well (as in the experimental condition). It seems clear, therefore, that agency cues (such as self-propulsion) are not sufficient to trigger goal attribution. However, whether agency cues are a necessary precondition for analysing behavior in terms of reasons cannot be decided from this study, as both the experimental and the control conditions contained such cues. Therefore, the aim of the present study is to clarify whether the perception of self-initiated movement (or of other cues of animacy or agency) is at all necessary for interpreting behavior as goal-directed and rational, or whether young infants are able to apprehend the 'pure reason' manifested in the pattern of behavior of an inertly moving object.

Method

Subjects and Procedure

The experiment applied the infant control procedure of the habituation of looking method (Bornstein, 1985). Seventy-two infants participated as subjects forming two age groups, 36 9-month-olds (25 males and 11 females, mean age = 279.3 days, SD = 14.2) and 36 12-month-olds (20 males and 16 females, mean age = 370.5 days, SD = 10.4). An additional 22 infants were rejected because of a) becoming fussy and not completing the experiment (6), b) failing to accomplish the criterion of habituation within 16 habituation trials (4), or c) too short looking times in the test phase (12). (Subjects who watched either of the test events for less than 4.0 sec were excluded from the analysis as they did not have an opportunity to see a long enough segment of the event to be able to interpret it.) The events were presented in a darkened room on an 18 x 24 cm computer monitor to the infant who was watching it from 1 m distance sitting in his/her mother's lap. Each event lasted 4.5 sec and was followed by an 1 sec pause. The same event was presented repeatedly as long as the subject was looking at the display. A trial was terminated when the subject looked away from the display for at least 2 consecutive seconds. The criterion for habituation was set as the half of the average looking time of the first three habituation trials. The habituation phase was terminated when the average looking time of three consecutive trials was below this criterion value. There was a 30 seconds break between the habituation and test phases of the experiment and the mothers were told in advance to close their eyes during the test phase. The order of the two types of test trials was counterbalanced between subjects and the experimenter was not aware of the actual order.

Stimuli

The subjects were randomly assigned to two different (experimental and control) conditions. In the habituation event of the experimental condition (Fig. 4), first a stationary rectangular column appeared right from the centre of the screen with a large circle positioned on its left side. The height of the column was randomly varied over trials, being either small, medium, or tall. The event started when a large circle moved to the left side of the screen and stopped there. Then a small circle entered the screen from the right side, 'flying' just over the column, then landing and stopping at the position adjacent to the large circle. The pathway of the small circle formed a parabolic trajectory and its movement appeared inert as if succumbing to gravitation. The parabolic trajectory was created as a composite of a constant horizontal velocity and a constant vertical acceleration. The three trajectories differed only in their initial upward velocity, but there was no visible cue available as to the source of this difference. As a result, the perceiver could not establish whether the small circle was moving by itself or was set in motion by another object. In other words, the small circle displayed no cues of animacy or agency that would indicate an internal source of energy. Nevertheless, the height of its parabolic pathway was always adjusted to the variable height of the rectangular column that formed an 'obstacle' between the large circle and the small circle entering from the right side. In this respect the equifinal behavior of the small object exhibited a kind of rationality in relation to the presence and actual height of the 'obstacle' and the final 'goal' position of its pathway.

Having accomplished the habituation criterion, the infants were shown two test events (Fig. 5) in which the 'obstacle' was no longer present. In both cases, first the large circle moved from the middle to the left side of the screen as before. Then, in the 'Old Action' condition (see Fig. 5A) the small circle repeated its previous behavior, i.e., entering from the right side it 'flew' to its habitual 'goal' position along a parabolic trajectory that corresponded to the average (medium) height of the (now missing) obstacle. In the other test event ('New Action', see Fig. 5B), however, the small circle approached the same end-point through a novel pathway taking the shortest straight path parallel to the ground level. If infants interpret the habituation event as a case of rational goal-directed action, one would expect more surprise and hence more dishabituation upon seeing the Old Action test event where the parabolic pathway is no longer justified by the presence of an 'obstacle'. In contrast, the straight-line approach of the New Action test event, though novel, would continue to appear rational (as it is the shortest route now available that leads to the 'goal' position), and so less surprise is predicted. If, however, the infants do not apply this kind of teleological interpretation, they should display more surprise and longer looking time when seeing the novel straight-line approach as it would be an unanticipated change in the behavior of the circle.

Table 1
Mean looking times during the experiment (in seconds). The average number of habituation trials of all subjects pooled from both age groups was 6.81. The t-values in the Table refer to the results of within-subject t-tests for looking times of the two test trials and the P-values in the last column assume two-tailed statistics.

	Habituation phase						Test phase			
	First trials			Last trials			New Action	Old Action	t(17)	P
	1	2	3	-3	-2	-1				
Experimental group										
9-month-olds	62.2	32.2	14.3	7.7	9.9	8.0	15.8	28.9	2.29	<0.05
12-month-olds	76.8	26.4	20.5	11.7	9.6	10.2	12.2	17.1	2.11	<0.05
Control group										
9-months-olds	57.7	37.9	16.5	13.2	10.8	9.8	12.0	14.3	1.08	>0.20
12-month-olds	53.0	31.7	31.1	12.3	14.7	9.1	21.7	17.4	-0.81	>0.20

Results

The results (Table 1) supported the former prediction. Twelve of the 18 nine-month-olds (66.7 %) and 14 of the 18 twelve-month-olds (77.8 %) looked longer at the Old Action than at the New Action test event. A three-way ANOVA (age group X order of test events X type of test events) yielded only one significant main effect of event type [$F(1,32)=8.03$, $p<0.01$] and there was no interaction with age. Separate *t*-tests for the two age groups (see Table 1) also indicate that both the 9-month-olds and the 12-month-olds dishabituated more to the Old Action than to the New Action test event, indicating that they found the former type of action more unexpected when no 'obstacle' was present.

The control condition was designed to exclude the possibility that the above difference could be attributed to a general preference for the more complex movement pattern of the Old Action event. The infants in this condition were subjected to the same procedure as those in the experimental group. However, they were habituated to an event (Fig. 6) that differed from that of the experimental condition in two details: a) The rectangular column was replaced by a small rectangular bar 'hanging in the air', whose upper edge was at the same height as that of the corresponding column in the experimental group. Thus, in this condition the rectangle did not form an 'obstacle' between the two sides of the screen. b) At the beginning of every habituation event, the large circle started out from the right end of the screen and passed under the bar thereby demonstrating the availability of a short straight-line route leading from the right side to the left. These two changes served to make sure that the behavior of the small circle flying over the rectangular bar, would not be interpreted as a case of rational goal-approach since a more sensible alternative route was available. Therefore, when the bar in the test events was removed, the subjects had no basis on which to predict what novel action (if any) the small circle would perform. The test events for the control group were identical to those of the experimental group (Fig 5A-B).

In the test phase of the control condition, 10 of the 18 nine-month-olds (55.6 %) and 9 of the 18 twelve-month-olds (50.0 %) looked longer at the Old Action than at the New Action event. A three-way ANOVA (age group X order of test events X type of test events) yielded only a significant main effect of age group [$F(1,32) = 6.43$, $p<0.05$], indicating that the 12-month-olds looked longer at the test events than did the 9-month-olds, irrespective of event type (Table 1). This result indicates that when the goal-approach in the habituation event did not appear rational, the subjects did not develop specific expectations about the behavior of the small circle in the new situation. In addition, it demonstrates that the looking time difference in the experimental group was not a result of a mere preference for the Old Action display over the New Action event.

Discussion

In summary, we have demonstrated that 9- and 12-month-old infants can interpret the behavior of a computer-animated abstract figure as a case of rational goal-directed action

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[1] Recent neuroimaging studies also suggest that separate brain areas are involved in recognizing animate objects (Perani et al., 1995) and in engaging in reasoning about mental states (Fletcher, 1995), the former is associated with the inferior temporal and occipital regions while the latter activates specifically the left medial frontal gyrus.

even if they have not perceived it as self-propelled or animate. Therefore, although young infants have been shown to be sensitive to patterns of biomechanical movement (Bertenthal et al., 1985), the perception of rational goal-directedness seems to be independent of the detection of animacy or agency. Based on these results we suggest that around 8-9 months of age a rather general interpretational strategy (the 'teleological stance', see Gergely and Csibra, 1997; Csibra, Gergely, Bíró and Koós, 1997) emerges in human infants that leads them to attempt to interpret the behavior of human as well as non-human objects as being rationally related to future goal-states.

From this point of view, it seems that the well-known human tendency to explain the behavior of non-human objects (be it a cloud, a bee, a thermometer, or a computer) in terms of reasons, may not be due to an 'anthropomorphic' overextension of our mentalistic interpretational strategies developed originally to account for human action. Rather, such 'animistic' explanations (Piaget, 1929) might stem from a primary application of the general functionalist interpretational stance demonstrated in our study, which may also form the ontogenetic basis of the infant's developing understanding of human behavior in terms of intentional mental states[1].

Note in this respect that the 9-month-old infant's interpretational strategy need not be mentalistic: While it involves reference to future goal-states and the assumption of rationality, it does not imply the attribution of mental states such as desires and beliefs to the observed objects. It is noteworthy that this kind of 'teleological' interpretation appears simultaneously with the infant's emerging ability for instrumental action and interest in systematic exploration of object properties (Piaget, 1954), on the one hand, and with the appearance of qualitatively new types of social communicative behaviors, such as pointing and social referencing, on the other (see Moore and Corkum, 1994). Therefore, we suggest that the infant's new interpretational strategy emerging at the end of the first year may provide the basis for an early understanding of instrumental action and tool use, as well as laying the foundation for the later developing mentalistic understanding of the human mind, which may turn out to be a uniquely human capacity (Povinelli and Preuss, 1995).

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