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Research Article

Observed Human Actions, and Not Mechanical Actions, Induce Searching Errors in Infants

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Recent neurophysiological studies have shown that several human brain regions involved in executing actions are activated by merely observing such actions via a human, and not by a mechanical hand. At a behavioral level, observing a human's movements, but not those of a robot, significantly interferes with ongoing executed movements. However, it is unclear whether the biological tuning in the observation/execution matching system are functional during infancy. The present study examines whether a human's actions, and not a mechanical action, influence infants' execution of the same actions due to the observation/execution matching system. Twelve-month-old infants were given a searching task. In the tasks, infants observed an object hidden at location A, after which either a human hand (human condition) or a mechanical one (mechanical condition) searched the object correctly. Next, the object was hidden at location B and infants were allowed to search the object. We examined whether infants searched the object at location B correctly. The results revealed that infants in the human condition were more likely to search location A than those in the mechanical condition. Moreover, the results suggested that infants' searching behaviors were affected by their observations of the same actions by a human, but not a mechanical hand. Thus, it may be concluded that the observation/execution matching system may be biologically tuned during infancy.

1. Introduction

It has been proposed that actions are intrinsically linked to perception, and that imagining, observing, or in any way representing an action, excites the motor programs used to execute such actions. This proposal is originally derived from James' ideomotor theory [1] and recently developed by Prinz's common coding framework [2]. According to this framework, the representation of a perceived action involves simulative production of that action on the part of the observer. This covert motor activation results in the observation of an action facilitating its execution. Neurophysiological studies have supported the common coding framework by showing that several brain regions (e.g., the primary motor cortex) involved in executing actions are activated by the mere observation of such actions, through what is known as the mirror neuron in animals [3, 4] and the mirror neuron system in human [5, 6]. Importantly, the mirror neuron system can respond only to biological actions [7]. On the behavioral level, the biological tuning leads to the fact that observing a human's arm movements, but not those of a robot, significantly interferes with ongoing executed movements [8, 9].

Given this evidence, it has been proposed that we should understand another person's actions through matching between observed actions and internal motor repertories. Biological tuning has been interpreted as suggesting that non-biological actions are not part of behavioral repertories and therefore we do not understand those actions through matching processes [7, 10]. In other words, biological tuning may be one important property in the observation/execution matching system.

Developmental literature has reported that the observation/execution matching system can be functional during the initial years of life. For example, Shimada and Hiraki [11] showed that the neuroimaging data of the primary motor cortex among six-month-old infants was activated when observing another person's actions. Falck-Ytter et al. [12] reported that 12-month-old infants produced a proactive goal-directed movement during the observation of another person's actions and suggested that this reflected that the infants were able to map observed actions onto their internal motor representations. Taken together, the developmental research suggests that during the initial years of life infants, can understand another person's actions through the observation/execution matching system.

However, whether the observation/execution system in infants is biologically tuned is still unclear. This is in spite of the fact that biological tuning is a key aspect of the observation/matching system. There is some evidence that young children's observation/execution matching systems may be biologically tuned, in which observing a human's actions, but not a mechanical action, affected the children's execution of the same actions [13, 14]. Moreover, in an infant study, Kanakogi and Itakura [15] reported that infants' motor skills (grasping skills) were correlated with their ability to predict another person's goal of the same actions. Importantly, the infants were able to predict the goal-directed actions by a human hand, but not by a mechanical hand. The results suggest that the observation/execution matching system may be biologically tuned during the initial years of life. Nevertheless, the correlational data was not sufficient to draw a conclusion that the system might be biologically tuned. Rather, as in behavioral studies among adults [9], the functional dependency between the observation and execution of the same actions should be addressed for infants. If the infants' matching systems are biologically tuned, it may follow that observing a human's actions, but not mechanical actions, may interfere with the infants' execution actions.

Recently, the possibility that the infants' observation/execution matching system might be biologically tuned was reported from an A-not-B task [16, 17]. This task was first developed by Piaget [18], and the phenomenon was replicated and discussed by many researchers [19–21]. In the searching task, infants correctly searched an object they see hidden in one location (location A) and retrieved the object, after which they were allowed to search for the object hidden in the other location (location B). In the A-not-B task situation, infants aged 8 to 12 months continued to search in location A and were unable to retrieve the object in location B correctly. There were several explanations regarding why infants committed errors in the task, but many researchers suggest that reaching experiences in location A would cause the A-not-B errors [22–24].

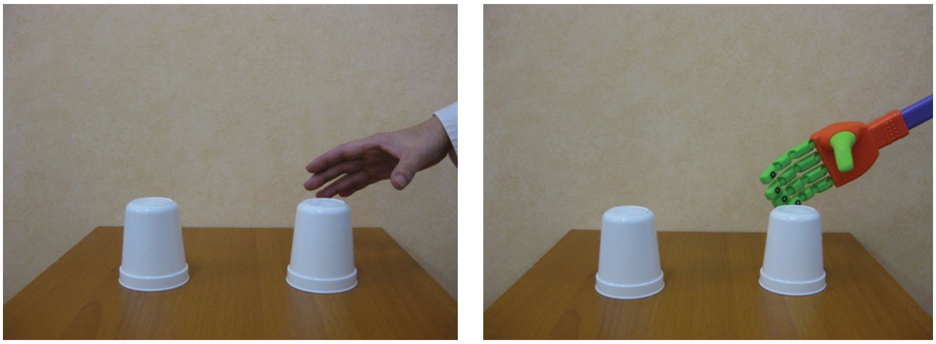
Importantly, the "real" reaching behaviors were not necessarily for the occurrence of the A-not-B errors. Longo and Bertenthal [17] reported that the mere observation of an experimenter's reaching out toward location A caused A-not-B like errors in infants. The researchers indicated that infants simulated the experimenter's searching behaviors at location A while observing, which caused the infants' reaching out toward location A in the B trials. Moreover, Boyer et al. [16] showed that infants were unlikely to commit the A-not-B errors after the observation of the actions performed by a mechanical devise, and that the familiarity with the devise may increase the likelihood for perseverative errors. Boyer et al. suggested that infants were less likely to commit the A-not-B errors when observing the actions by a mechanical devise than by human agents. However, the researchers have not directly compared the mechanical condition with the human condition. That is, there were no human conditions used in the previous study. To argue for biological tuning, a direct comparison between the human condition and the mechanical condition is needed. In addition, there were no control conditions in the previous study. Without a control condition, it was unclear whether infants' searching errors were due to the infants simply failing to search for objects or that the observation in the A trials affected the infants' performances in the B trials. The present study directly examined whether observations of a human's actions, and not a mechanical action, induced infants' searching errors.

In the present study, infants aged approximately 12 months observed either a human (human condition) or a mechanical hand (mechanical condition) searching an object at location A, after which they were allowed to search the object at location B. Infants were given four consecutive A trials, followed by four consecutive B trials. In addition to the two experimental conditions, a control condition was added. The control condition was the same as the human condition except for the A trials. In the A trials of the control condition, there was one cup instead of two cups used in the human condition. For each condition, there were two experimenters. The first experimenter hid the object and the second experimenter retrieved the object using her hand or a mechanical hand (Figure 1).

2. Materials and Method

2.1. Ethics Statement. Participants were recruited from nursery schools in Tokyo and Kyoto. Written informed consent was obtained from the parents and teachers of children prior to their involvement in the study. The study was conducted in accordance with the principles of the Declaration of Helsinki and the study design was approved by the ethics review board at the University of Tokyo.

2.2. Participants. Forty-two twelve-month-old infants (mean = 12.1, SD = 0.4; twenty-four boys and eighteen girls) participated in the study. Of these, seven infants were not included in the final data because of a failure to observe the demonstration (four), fussiness (one), and reaching out toward both locations simultaneously (two). The remainder of the infants were randomly assigned to three conditions: a human condition ($N = 12$, five girls), a mechanical condition ($N = 11$, six girls), and a control condition ($N = 12$, four girls). There were no significant differences in age (in weeks) between conditions. Parents provided written informed consent and were informed verbally of the purpose of the study.



(a) (b)

Figure 1: Infants observed either (a) a human or (b) a mechanical hand searching a toy.

2.3. Stimuli and Procedure. The experimental apparatus consisted of a tray with two cups placed on it. The cups were placed 10.0 cm apart.

Infants were seated on their mother's lap in front of a table and allowed to play with a toy (a cartoon character) for several seconds. Three warm-up trials were administered by an experimenter using procedures by Smith et al. [23] and Longo and Bertenthal [17]. On the first warm-up trial, the toy was placed on top of a single cup, after which infants were allowed to take the toy. During the second trial, the toy was placed in the cup but left uncovered and infants were required to get the toy. For the final trial, the toy was completely inside the cup, and infants were allowed to search for the toy.

The experimental trials used a two-cup apparatus and comprised four A trials and four B trials. Infants were first given four consecutive A trials, followed by four consecutive B trials. There were two experimenters in the experimental trials. In the A trials of the human condition, the first experimenter showed the toy to the infants and the second experimenter hid it in one of the cups and waited for five seconds. Thereafter, the tray and cups were presented to the second experimenter. The second experimenter successfully searched for the toy. Infants observed the second experimenter's searching behavior (Figure 1(a)). The A-location of the toy (right or left) was counterbalanced across infants. In order to exclude the possibility that infants failed to observe the second experimenter's behaviors, in both trials, the toy was waved in the air and the infants' name was called to attract their attention. In the B trials, infants were presented with the tray with cups by the first experimenter in a similar manner as done in the A trials and they were allowed to search for the toy.

The mechanical condition was presented exactly in the same manner as the human condition, except for in the A trials. In these trials, infants observed a mechanical hand that searched for the toy (Figure 1(b)). The mechanical hand was operated by the second experimenter behind a screen, and infants were unaware of the experimenter's presence.

The control condition was the same as the human condition, except in the A trials. In the A trials of the control condition, there was one cup instead of two in the human condition. The first experimenter showed the toy to the infants and the second experimenter hid it inside the cup and presented both the tray and cup. Infants observed the second experimenter's searching behavior.

Infants received a score of 1 when they successfully searched for the toy in each of the B trials (0–4). If infants did not show any searching behaviors fifteen seconds after the tray was presented, the trials were excluded from the data. In total, four trials from the human condition, seven trials from the mechanical condition, and six trials from the control condition were excluded from further analyses.

3. Results

Infants were given a score of 1 if they successfully searched the toy in each of the B trials (0–4). The mean error rates out of the trials where children produced searching behaviors were calculated in each condition. If infants produced searching behaviors on 4 trials and failed to search the toy on 2 trials, the error rate of the infants was 0.5. The results are presented in Figure 2. We assume that the control condition would evaluate "pure" infants' searching abilities. Infants in the control condition observed the searching behaviors by the second experimenter in the A trials; however, the experimenter's behaviors did not provide any biases with infants' behaviors in the B trials because there was only one cup in the A trials of the control condition. In the control condition, infants were able to search the toy rather easily (mean error rate = 15.5%). On the other hand, infants' behaviors in the human control condition were strongly affected by observing the second experimenter's behaviors. They performed only 50.0% of the B trials correctly, which was consistent with previous results that observing another person's behaviors could induce A-not-B like errors. Finally, interestingly, infants' performances in the mechanical condition were similar to those in the control condition. Infants in the mechanical condition had an error rate of 20.5% in the B trials.

The mean error rates was analyzed using a one-way ANOVA, and we observed a significant main effect of condition, $F(2, 32) = 4.126$, $P < .02$. The post hoc analyses using

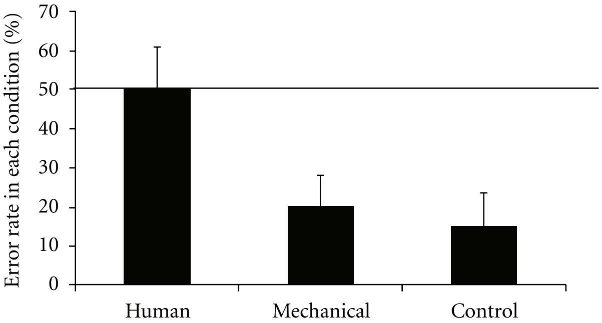


FIGURE 2: The mean error rates in the B trials in each condition. The bar indicates the standard error.

Tukey's HSD revealed that infants in the human condition performed the B trials significantly worse than those in the control conditions ($P < .05$). There were marginal differences between the human condition and the mechanical condition ($P < .09$), but no significant differences between the mechanical condition and the control condition.

Further, we also examined whether the error rates of infants in each condition were significantly different from what would have been expected to occur by chance. The chance level for each trial was 50%; therefore, the score expected by chance was 2 in the B trials. A one-sample t-test revealed that infants in the human condition performed at chance level in the B trials, $t(12) = 0.000$, $P > .99$, whereas the infants in the mechanical and control conditions correctly searched the toy in the B trials below chance level, $t(11) = 3.633$, $P < .001$ and $t(12) = 4.080$, $P < .001$, respectively.

Finally, we examined whether there were some learning effects in the B trials. We divided the four B trials into the first two and second two trials and compared the performances. The results revealed no significant differences between conditions ($P > .10$).

4. Discussion

The present study examined whether observing another person's actions, and not a mechanical action, interfered in infants' execution of the same actions using the A-not-B task. Previous studies showed that infants were likely to commit perseverative errors after the observation of a human's actions, but observation of the mechanical actions may not induce these errors [16, 17]. However, there were no direct comparisons between them. The results revealed that 12-month-old infants committed searching errors after observing a human's actions, but not mechanical actions. That is, after infants observed another person searching for an object at location A, infants tended to search it at location A, even though the object was at location B. On the other hand, infants successfully retrieved the object after observing a mechanical hand searching the object at location B. The results suggested that infants' observation/execution matching systems might be biologically tuned during the initial years of life.

One can argue that infants pay more attention to the human's actions, but not to the mechanical hand's actions in the A trials, which might explain the different results between the conditions. However, in this experiment, we carefully monitored an infant's gazing behavior during the A trials and excluded the trials where the infants did not observe the demonstration in both conditions from the final analyses. At least at the observable level, it is unlikely that infants paid more attention to the human's actions but not to those of the mechanical hand in the A trials.

The results in the present study are generally consistent with the evidence regarding the observation/execution matching system during infancy. On the behavioral level, Sommerville et al. [25] revealed that the action experience among three-month-old infants facilitated their perception of another person's actions. Falck-Ytter et al. [12] reported that 12-month-old infants produced a proactive goal-directed movement during the observation of another person's actions. At the neural level, the mirror neuron system might be functional during the initial years of life. Shimada and Hiraki [11] showed that six-month-old infants activated the primary motor cortex when observing another person's actions. Southgate et al. [26] recorded nine-month-old infants' electroencephalographs (EEGs) during their reaching and observation of the actions and found that the motor activities during observation was also similar during execution.

The critical property of the observation/execution matching system may be biological tuning. In this regard, there was little evidence during infancy. At the perceptual level, Woodward [27] showed that six-month-old infants attributed the goal to a human's actions, but not a mechanical hand's actions. Kanakogi and Itakura [15] reported that six-month-old infants were able to predict goal-directed actions by a human hand, but not by a mechanical hand. The infants' ability to predict another person's goal is correlated with their ability to perform the same actions. Moreover, Longo and Bertenthal [17] showed that infants' searching behaviors were strongly affected by their observation of the same actions by another person. Boyer et al. [16] reported that infants were unlikely to commit the errors after observation of mechanical actions. The present study directly compared the effects of human actions with those of mechanical ones and found that infants committed the errors after the observation of human actions, but not mechanical actions. Taken together, the results indicate that the observation/execution system may be biologically tuned during infancy.

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References

[1] W. James, *Principles of Psychology*, Holt, New York, NY, USA, 1890.

[2] W. Prinz, "A common coding approach to perception and action," in *Relationships Between Perception and Action*, O. Neumann and W. Prinz, Eds., pp. 167–201, Springer, Heidelberg, Germany, 1990.

[3] V. Gallese, L. Fadiga, L. Fogassi, and G. Rizzolatti, "Action recognition in the premotor cortex," *Brain*, vol. 119, no. 2, pp. 593–609, 1996.

[4] G. Rizzolatti, L. Fadiga, V. Gallese, and L. Fogassi, "Premotor cortex and the recognition of motor actions," *Cognitive Brain Research*, vol. 3, no. 2, pp. 131–141, 1996.

[5] G. Buccino, F. Binkofski, G. R. Fink et al., "Action observation activates premotor and parietal areas in a somatotopic manner: an fMRI study," *European Journal of Neuroscience*, vol. 13, no. 2, pp. 400–404, 2001.

[6] J. Decety, J. Grèzes, N. Costes et al., "Brain activity during observation of actions. Influence of action content and subject's strategy," *Brain*, vol. 120, no. 10, pp. 1763–1777, 1997.

[7] Y. F. Tai, C. Scherfler, D. J. Brooks, N. Sawamoto, and U. Castiello, "The human premotor cortex Is 'mirror' only for biological actions," *Current Biology*, vol. 14, no. 2, pp. 117–120, 2004.

[8] C. Press, G. Bird, R. Flach, and C. Heyes, "Robotic movement elicits automatic imitation," *Cognitive Brain Research*, vol. 25, no. 3, pp. 632–640, 2005.

[9] J. M. Kilner, Y. Paulignan, and S. J. Blakemore, "An interference effect of observed biological movement on action," *Current Biology*, vol. 13, no. 6, pp. 522–525, 2003.

[10] G. Rizzolatti, L. Fogassi, and V. Gallese, "Neurophysiological mechanisms underlying the understanding and imitation of action," *Nature Reviews Neuroscience*, vol. 2, no. 9, pp. 661–670, 2001.

[11] S. Shimada and K. Hiraki, "Infant's brain responses to live and televised action," *NeuroImage*, vol. 32, no. 2, pp. 930–939, 2006.

[12] T. Falck-Ytter, G. Gredebäck, and C. von Hofsten, "Infants predict other people's action goals," *Nature Neuroscience*, vol. 9, no. 7, pp. 878–879, 2006.

[13] Y. Moriguchi, T. Kanda, H. Ishiguro, and S. Itakura, "Children perseverate to a human's actions but not to a robot's actions," *Developmental Science*, vol. 13, no. 1, pp. 62–68, 2010.

[14] A. N. Meltzoff, "Understanding the intentions of others: re-enactment of intended acts by 18-month-old children," *Developmental Psychology*, vol. 31, no. 5, pp. 838–850, 1995.

[15] Y. Kanakogi and S. Itakura, "Developmental correspondence between action prediction and motor ability in early infancy," *Nature Communications*, vol. 2, no. 1, article 341, 2011.

[16] T. W. Boyer, J. Samantha Pan, and B. I. Bertenthal, "Infants' understanding of actions performed by mechanical devices," *Cognition*, vol. 121, no. 1, pp. 1–11, 2011.

[17] M. R. Longo and B. I. Bertenthal, "Common coding of observation and execution of action in 9-month-old infants," *Infancy*, vol. 10, no. 1, pp. 43–59, 2006.

[18] J. Piaget, *The Construction of Reality in the Child*, Basic Books, New York, NY, USA, 1954.

[19] Y. Munakata, J. L. McClelland, M. H. Johnson, and R. S. Siegler, "Rethinking infant knowledge: toward an adaptive process account of successes and failures in object permanence tasks," *Psychological Review*, vol. 104, no. 4, pp. 686–713, 1997.

[20] H. M. Wellman, D. Cross, and K. Bartsch, "Infant search and object permanence: a meta-analysis of the A-not-B error," *Monographs of the Society for Research in Child Development*, vol. 51, no. 3, pp. 1–67, 1986.

[21] E. Thelen, G. Schöner, C. Scheier, and L. B. Smith, "The dynamics of embodiment: a field theory of infant perseverative reaching," *Behavioral and Brain Sciences*, vol. 24, no. 1, pp. 1–34, 2001.

[22] S. Marcovitch and P. D. Zelazo, "A hierarchical competing systems model of the emergence and early development of executive function," *Developmental Science*, vol. 12, no. 1, pp. 1–25, 2009.

[23] L. B. Smith, E. Thelen, R. Titzer, and D. McLin, "Knowing in the context of acting: the task dynamics of the A-not-B error," *Psychological Review*, vol. 106, no. 2, pp. 235–260, 1999.

[24] A. Diamond, "Neuropsychological insights into the meaning of object concept development," in *The Epigenesis of Mind: Essays on Biology and Cognition*, S. Carey and R. Gelman, Eds., pp. 67–110, Lawrence Erlbaum Associates, Hillsdale, NJ, USA, 1991.

[25] J. A. Sommerville, A. L. Woodward, and A. Needham, "Action experience alters 3-month-old infants' perception of others' actions," *Cognition*, vol. 96, no. 1, pp. B1–B11, 2005.

[26] V. Southgate, M. H. Johnson, T. Osborne, and G. Csibra, "Predictive motor activation during action observation in human infants," *Biology Letters*, vol. 5, no. 6, pp. 769–772, 2009.

[27] A. L. Woodward, "Infants selectively encode the goal object of an actor's reach," *Cognition*, vol. 69, no. 1, pp. 1–34, 1998.