EMERGENCE OF AGENCY IN INFANTS

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Abstract

Sense of agency is the feeling of control over one's actions and that those actions affect the environment. While agency has been studied in adults, the process of agency formation is unknown. We conducted a mobile conjugate reinforcement (MCR) experiment to explore agency formation in 16 healthy, 2-3 month old infants. In MCR, an infant is placed supine in a crib and their foot is tethered to a string. The mobile spins when the string is pulled. The larger/faster the infant movement, the faster the mobile spins. We first assess whether our novel motorized mobile replicates previous MCR results (Rovee & Rovee, 1969). Similar to past results, there was a significant increase in kicking rate when the infant was tethered to the mobile. This increase in kicking is a hypothesized signature of agency formation (Kelso & Fuchs, 2016). Our results validate the mobile and allow further analysis of agency formation.

Keywords: mobile conjugate reinforcement, infant learning, coordination, reinforcement

Introduction

A sense of agency refers to the feeling of control over one's own actions and that those actions affect the environment. Chambon, Sidarus, and Haggard (2014) suggested that humans feel this sense of agency when the predicted consequences of a goal-directed action match the actual consequences of that action. Additionally, a sense of agency may arise when a change in the environment can be traced back to one's own voluntary action and no other plausible causative force. While there is extensive research discussing what sense of agency is and how it relates to adult behavior and neuroimaging, there is a lack of scientific research discussing how a sense of agency emerges in the first place (Kelso, 2016). The understanding that our actions can affect change in the world is a basic and critical capacity for human survival and success. Exploring how sense of agency forms is valuable for understanding how the brain organizes itself, how basic cognitive capacities emerge and may lead to insights into mental disorders where there is a disruption in sense of agency.

In a departure from traditional explanations of adult agency (Chambon, et. al, 2014; Wegner, 2002) which rely on goal-directedness, mental planning, and comparison of goals with outcomes, Kelso (2016) proposed that agency emerges from initially spontaneous infant movement. A young infant may begin moving with no particular goal or plan in mind, but when these spontaneous movements result in some perceptible change in the infant's environment and when infant movement and environmental response are sufficiently coordinated, the infant will suddenly realize that its own movements are making things happen in the world (Kelso, 2016).

Kelso (2016) identified Rovee and Rovee's (1969) mobile conjugate reinforcement (MCR) paradigm as a possible window into the process of agency formation in infancy. MCR involves three phases of experimentation (Rovee & Rovee, 1969). During each phase, the frequency of infant kicking was measured. Phase 1 of MCR was a baseline period in which the infant was placed supine in a crib and observed a stationary mobile overhead. In Phase 2, the infant's ankle was tethered to the mobile by a silk cord that was connected to the mobile. The mobile, composed of colorful wooden figures, moved when the string was pulled. The faster or larger kicks produced by the infant, the more the mobile moved. Although the motion of the mobile has never been measured, conjugate reinforcement refers to the feedback the infant receives because any amount of movement from the mobile is assumed to be directly proportional to the size and frequency of the kicking produced by the infant (Angulo-kinzler, 2001; Kelso & Fuchs, 2016). The string was disconnected in Phase 3, and the infant observed a stationary mobile. Infants kicked at a rate of about 10 kicks per minute during Phase 1, then multiplied their kicking rate by a factor of 3-4 during Phase 2. During Phase 3 the kicking rate gradually returns back to the kicking rate of Phase 1 (Rovee & Rovee, 1969). In order to control for the possibility that an increased kicking rate could be attributed to a generalized state of arousal in response to the movement of the mobile, a control group of infants were also tested. In the control group, Phase 1 and Phase 3 were identical to the experimental group, however during Phase 2 an experimenter moved the wooden figures instead of the infant. Half of the infants in the control group received visual stimulation from the moving mobile and the other half received combined visual stimulation from the moving mobile and somesthetic stimulation from the silk cord that was looped around their ankle; though leg movements did not affect the mobile's movements. The results showed that neither infants in the visual stimulation group nor combined visual and somesthetic stimulation group increased their kicking rate during Phase 2 from the baseline rate. This confirms that the increased kicking rate during Phase 2 for infants in the experimental group was a result of learned contingency between the infant's leg movements and the mobile, not just a generalized state of arousal in response to the moving figures. Infants only increased their kicking rates when the mobile moved as a result of the infant's movement (not the experimenter's). Therefore, the tripling in infant kicking rate during Phase 2 hints at the emergence of agency in these infants as they realize that they are in control of the mobile's movements (Kelso & Fuchs, 2016).

One hypothesis about MCR is that the infant learns the relationship between its kicks and the movement of the mobile: every kick moves the mobile, which provides an attractive visual stimulus that reinforces the infant to continue kicking. If agency may be said to emerge when the infant realizes its movements can cause the environment to change (here the mobile), then the MCR model could be used to gain a closer understanding of how the sense of agency emerges by observing the infant in control of the mobile's movements. While emergence of infant agency seems to depend on the coordination of infant and mobile movement, no previous MCR study has measured mobile motion or coordination between infant and mobile.

The aim of this study is to replicate previous results produced by MCR using a novel motorized mobile. Replicating previous MCR results will validate the novel mobile apparatus used here and allow for further analysis of the coordinative basis of the emergence of agency.

Method

Participants

Participants were 16 infants who ranged in age from 78 to 160 days (M=104.93, SD=23.58) and ranged in weight from 10.06 to 17.40 pounds (M=13.49, SD=2.00). All infants were apparently healthy, full term infants (more than 39 weeks gestation) and were tested at a time of day where the mother reported the infant to be awake and active. Infants were recruited through postcards mailed to families informing them of the study. Participants were excluded from the study if they reached past the age range of 2-4 months or if parents were uncomfortable with any of the experimental procedures. All infants were tested in the Human Brain and Behavior Laboratory at Florida Atlantic University and parental consent was obtained before the start of the experiment. Three infants did not participate in Baseline 2 of the experiment because Baseline 2 was not part of the testing procedure for those infants. As a part of a larger study, detailed kinematic measures of the infant's movements and EEG were also obtained. Here, analysis is confined to the video recordings. After the completion of the experiment, parents were given a gift card and an infant toy for their participation. This study was approved by Florida Atlantic University's Institutional Review Board.

Procedure

In this experiment, the mobile was controlled by a motor and composed of two blocks decorated in colorful paper that hung above the crib. The mobile spun when a string was pulled, tilting a sensor. Before the start of the experiment the infant was strapped supine in a crib to prevent the infant from rolling over, and a sock with snaps was placed on either the infant's left or right foot. The MCR experiment consisted of four phases: Baseline 1 (2 min.), Baseline 2 (2 min.), Coupled (5 min.), and Decoupled (2 min.). During Baseline 1, the infant observed a stationary mobile overhead. In Baseline 2, the experimenter tugged on the string that caused the mobile to spin and the infant observed the spinning mobile. In the coupled phase, a string that was also connected to the mobile was connected to the sock using the snap. The faster the infant moved and the larger the infant movement, the faster the mobile spun. In the decoupled phase the string was disconnected, and the infant again observed a stationary mobile. The infants were videotaped throughout the entire experiment. Using the Behavioral Observation Research Interactive Software (Friard & Gamba, 2016) behavior coding software, one coder viewed the videos and recorded the frequency of kicks in each phase of the experiment for each infant. To test reliability, a second coder independently recorded the frequency of kicks for 13% of the sessions. Inter-rater reliability raised from 20.7% agreement to 61.4% after training. A kick was defined as a vertical or horizontal excursion of the right foot which at least partially retraced its original path in a smooth, continuous motion (Rovee & Fagen, 1976). Further work will use quantitative measures of infant movement.

Results

A repeated measures analysis of variance was conducted on the number of kicks per minute across 2 minutes of each phase: Baseline 1, Baseline 2, Coupled, and Decoupled. The test showed a significant main effect for the phases, $F(3, 36)=4.13$, $p<0.05$. The test also showed a significant cubic effect $F(1, 12)=17.65$ $p<0.05$. The number of kicks per minute decreased from Baseline 1 (M=6.81, SE=2.12) to Baseline 2 (M=5.50, SE=1.71), and then increased from Baseline 2 to the Coupled phase (M=12.35, SE=2.73), returning to baseline rates in the Decoupled phase (M=8.31, SE=1.76) (Table 1).

In addition, an independent samples t-test between the mean number of kicks per minute, summed across all the infants (and not for each infant), for the Baseline 2 (2 minutes) and Coupled phase (5 minutes) was used to evaluate if the kicks in the Coupled phase was higher than in the Baseline 2 phase. The test was significant in a two-tailed test, $t(5)= 3.26$, $p<0.05$. There were more kicks per minute for the Coupled phase (M=8.80, SD=0.85) compared to the Baseline 2 (M=5.50, SD=1.36) phase.

Table 1

Descriptive statistics for the mean number of kicks per minute in the Baseline 1, Baseline 2, Coupled, and Decoupled phase. N=13.

Phase	M	SD
Baseline 1		
Minute 1	8.46	10.10
Minute 2	5.15	5.91
Baseline 2		
Minute 3	6.46	8.39
Minute 4	4.53	6.02
Coupled		
Minute 8	11.31	8.37
Minute 10	13.38	12.69
Decoupled		
Minute 12	8.38	7.78
Minute 13	8.23	6.25

Note. Three infants did not participate in Baseline 2 and as a result they were not included in this sample

Discussion

This study was able to replicate past findings of the MCR paradigm and validated our use of a novel motorized mobile as a relevant stimulus to the babies. Similar to past results (Rovee & Rovee, 1969), the infants increased their kicking rate significantly from the Baseline to the Coupled phase and lowered their kicking rate back down to baseline rates during the Decoupled phase. The results also indicated that visual stimulation from the mobile alone, presented in Baseline 2, did not significantly increase the kicking rate in these infants from Baseline 1. In fact, the kicking rate decreased from Baseline 1 to Baseline 2. This decrease in kicking rate could be attributed to a surprise/interest reaction upon observing the mobile spin (Piaget, 1952; Sullivan & Lewis, 2003). As no increase was observed when the mobile moved in Baseline 2, the increased kicking rate in the Coupled phase could not just be due to a generalized state of arousal in response to the moving mobile. This indicates that the increased kicking rate during the Coupled phase was due to the infants learning the relationship between their movements and the spinning of the mobile.

The significant increase in kicking rate from the baseline to the Coupled phase hints at the emergence of agency in these infants as they realized they were in control of the mobile's movements. Further analysis of infant movement may elucidate this issue. Validating the current novel motorized mobile in this experiment allows for further research into how the formation of agency in these infants during the Coupled phase depends on coordination between infant and mobile. In this study, and in other studies using the MCR paradigm, the movements of the mobile have not been measured, nor their coupling to the infant's actions (for preliminary findings see Sloan, Jones & Kelso, 2020). Such analyses of movement between the infant and mobile should afford new insights into how agency forms as a result of organism~environment coupling (Kelso, 2016).

Overall, through the current novel motorized mobile the infants were able to learn that they were in control of the mobile's movements and a sense of agency is hypothesized to have emerged in these infants while interacting with the mobile. The present preliminary findings allow for further analysis into how and when the sense of agency emerges, thus providing a scientific basis for the emergence of agency, currently lacking in the literature. Moreover, if the present work was extended, e.g. to include detailed measures of brain activity, it might allow even deeper insights into the workings of the infant brain and its relation to goal-directed behavior.

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