Coordinative Processes Underlying the Emergence of Infant Agency

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INTRODUCTION

Understanding that our actions can affect the world (sense of agency) is key for human success. However, we know little about how intentional, goal-directed action first develops.

Mobile conjugate reinforcement (MCR) experiments show that infants greatly increase their kicking rate when one of their feet is tethered to a mobile hanging overhead. Infants do not kick more simply because the mobile moves. Rather, increase in kicking rate depends on the contingency between infant and mobile motion (Rovee & Rovee, 1969) and may reflect the infants' realization that they can control the mobile's movement (Kelso, 2016). What mechanisms underlie the formation of agency?

Kelso and Fuchs (2016) proposed an autocatalytic process as a key mechanism involved in emergence of the agentive self. Once connected to the mobile, the infant's initially spontaneous movement causes the mobile to move, stimulating more infant kicking. The more the infant kicks, the more the mobile moves in response. Positive feedback gradually amplifies the coordination between infant kicking and mobile response. At some critical level of coupling, the infant suddenly discovers its own agency (*"Aha! I'm making this happen!"*) and transitions from spontaneous to intentional movement. Kelso and Fuchs (2016) hypothesized that the moment of realization will be marked by an abrupt increase in kicking rate as well as an increase in coordination between mobile and infant. As the infant becomes more aware of functional relevance of coordination with the mobile, we might expect toe~mobile coordination to strengthen and coordination within the body to weaken.

Purpose

Despite the MCR paradigm's long history, neither mobile motion nor the coordination between mobile and baby movement have ever been measured. Here we seek to identify a moment of infant realization and to demonstrate that emergence of intentional action depends both upon dynamics of infant~mobile coordination as well as dynamics of coordination within the infant's body.

METHOD

Participants

- 15 full-term infants, 2-4 month-old infants.
- Results for two infant presented here

Materials

- Mobile- two colorful blocks on a wooden arm which rotated when two strings were pulled. The strings could be snapped to a sock.
- 3D position of mobile and infant's feet were measured (100 Hz) using Vicon mocap system.

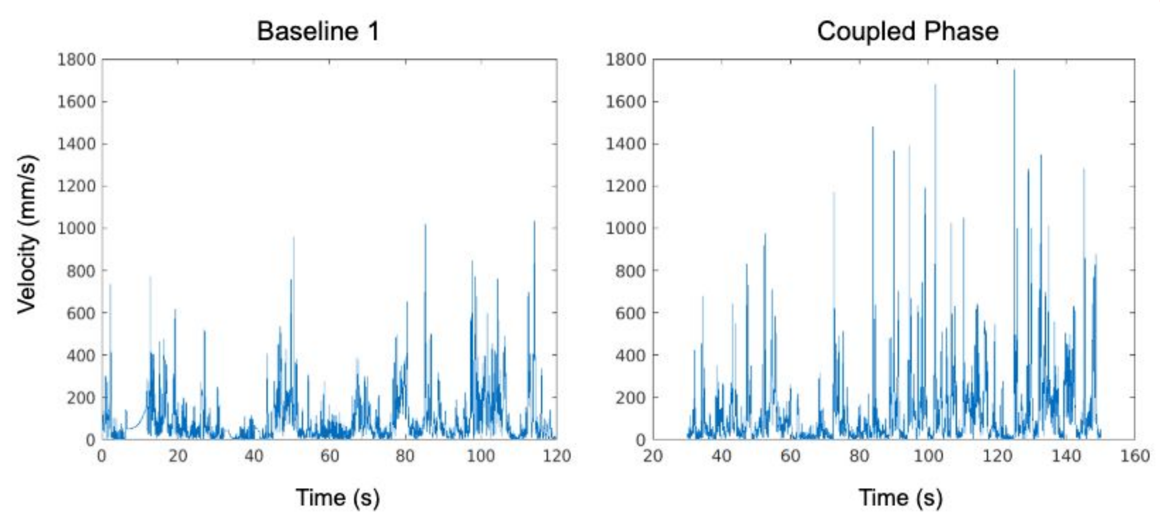
Procedure

MCR paradigm with four experimental phases:

baseline 1 (mobile stationary -2 min.) (B1)
baseline 2 (experimenter moves mobile - 2 min.) (B2)
coupled (infant connected to mobile - 6 min.)
decoupled (mobile disconnected, stationary- 2 min)

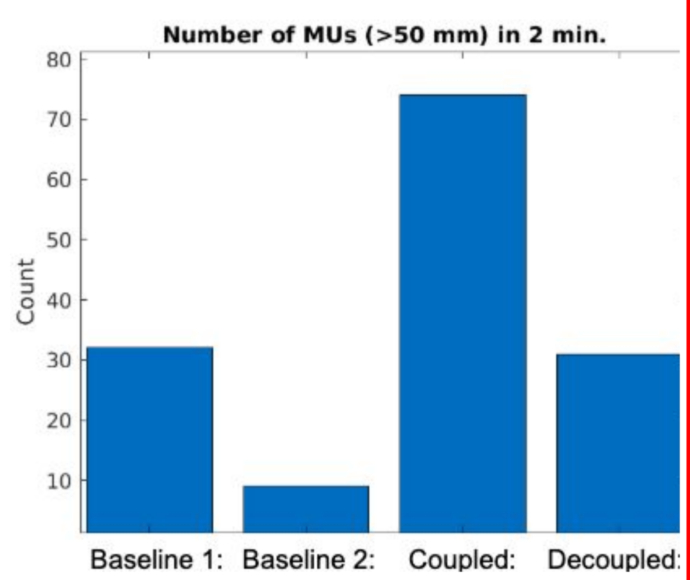
RESULTS

2 min samples of trigger toe velocity across phase:

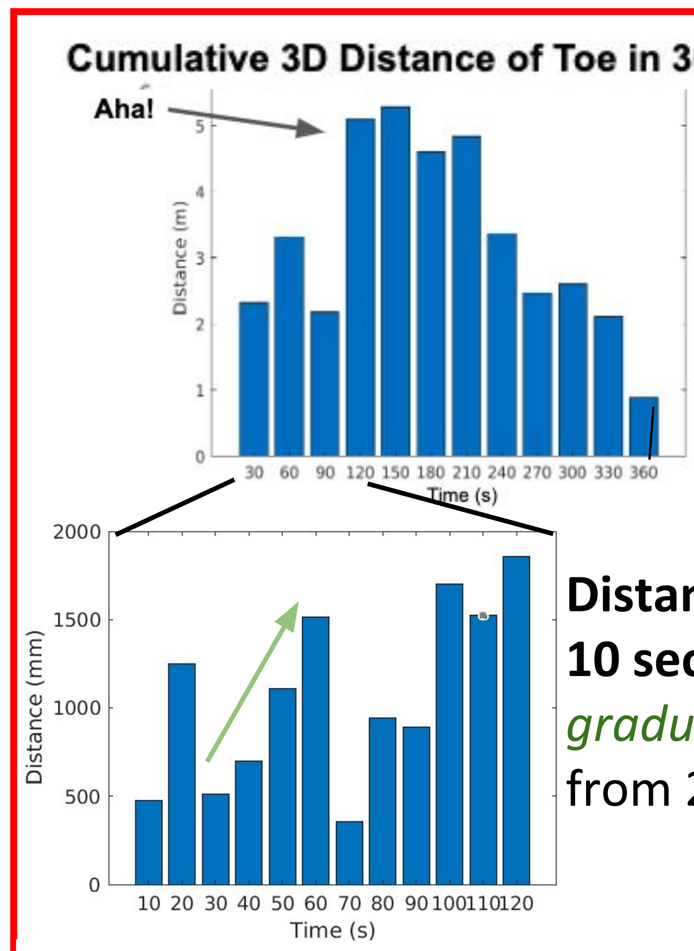


Movement frequency was quantified by identifying movement units (**MU**) - continuous movement in a single direction.

Trigger toe MU rate more than doubles during Coupling compared to B1. Infant is *less* active during B2 when experimenter causes the mobile to move.



To inspect **dynamics of change in infant activity during the Coupled phase,** 3D distance traveled by the trigger toe was summed across 30 sec. windows. A sudden burst in trigger toe activity after 90 sec of Coupling.

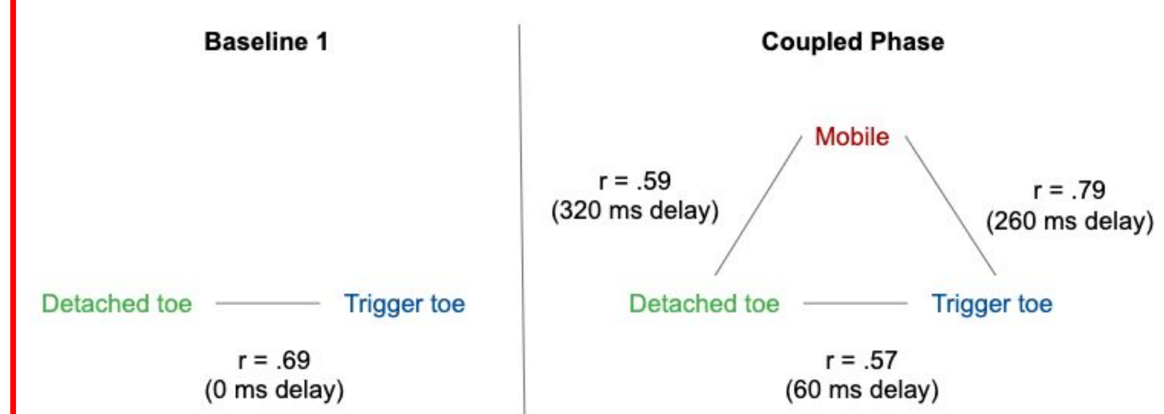


Moment of realization marked by sudden increase in infant activity after 90 sec!

Distance toe traveled in 10 sec: the infant *gradually* increase activity from 21-60 sec

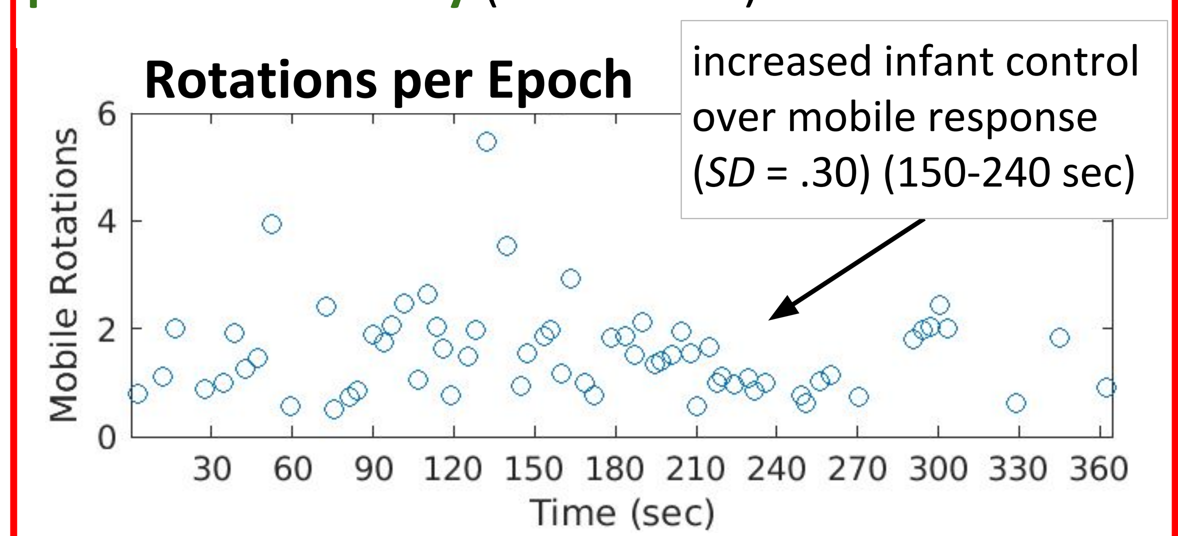
Infant agency is proposed to depend on the contingency between infant and mobile activity during Coupling. Result confirm distance traveled by trigger toe and number of mobile rotations in 30 sec windows across Coupled phase were highly correlated (r = .97, p < .001). **The more the trigger toe moved, the more the mobile rotated.**

Changes in coordination within & between

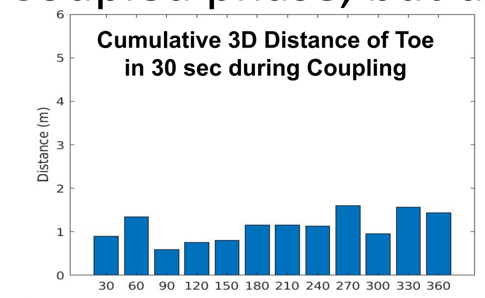


Correlation of inter-limb velocity **weakens** during Coupling. Coordination between infant and mobile (r = .79) was **much stronger** than inter-limb coordination (r = .57) during Coupling.

Efficiency of infant movement for mobile response was assessed by number of **mobile rotations per epoch** of infant movement during Coupling. **Instability** (SD = 1.16) is seen **at time of peak infant activity** (90-150 sec).



A second infant, who was *much less active* overall, also increased activity during the Coupled phase, but did so **gradually**.



There was no obvious 'Aha!' moment - no abrupt change in infant activity during Coupling. The disconnected toe was much more active than the toe controlling the mobile during Coupling. The two toes became *more* coordinated during Coupling (r = .65) compared to B1 (r = .57). Infant~mobile coordination (r = .72) was only slightly stronger than inter-limb coordination during Coupling. Finally, there were no changes in infant efficiency during Coupling.

DISCUSSION

Using traditional analytical methods and standards (Chen, et al., 2002), we would have concluded that both infants learned from environmental feedback given increased activity during Coupling. Here we expose qualitative differences by exploring dynamics of change in infant activity and in coordination. Only one infant displayed an abrupt activity spike. Furthermore, the gradual increase in activity preceding this spike together with the tight coupling between infant and mobile movement is evidence of positive feedback. Only the infant who abruptly increased trigger toe activity showed weakening of coordination within the body during Coupling. It appears the functional linkage with the mobile does not overcome the strong internal couplings of the second infant. Finally, changes in stability of mobile response for the infant with the abrupt shift depict the initial excitement of discovering control, followed by optimization of control.

This new approach allow us to lift the hood and, for the first time, pinpoint a moment of self discovery as well as confirm the mechanisms underlying an infant's switch from spontaneous to intentional action!

References

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