



# Critical Dynamics in the Emergence of Agency



Carter Sale, Aliza Sloan, J.A.S Kelso

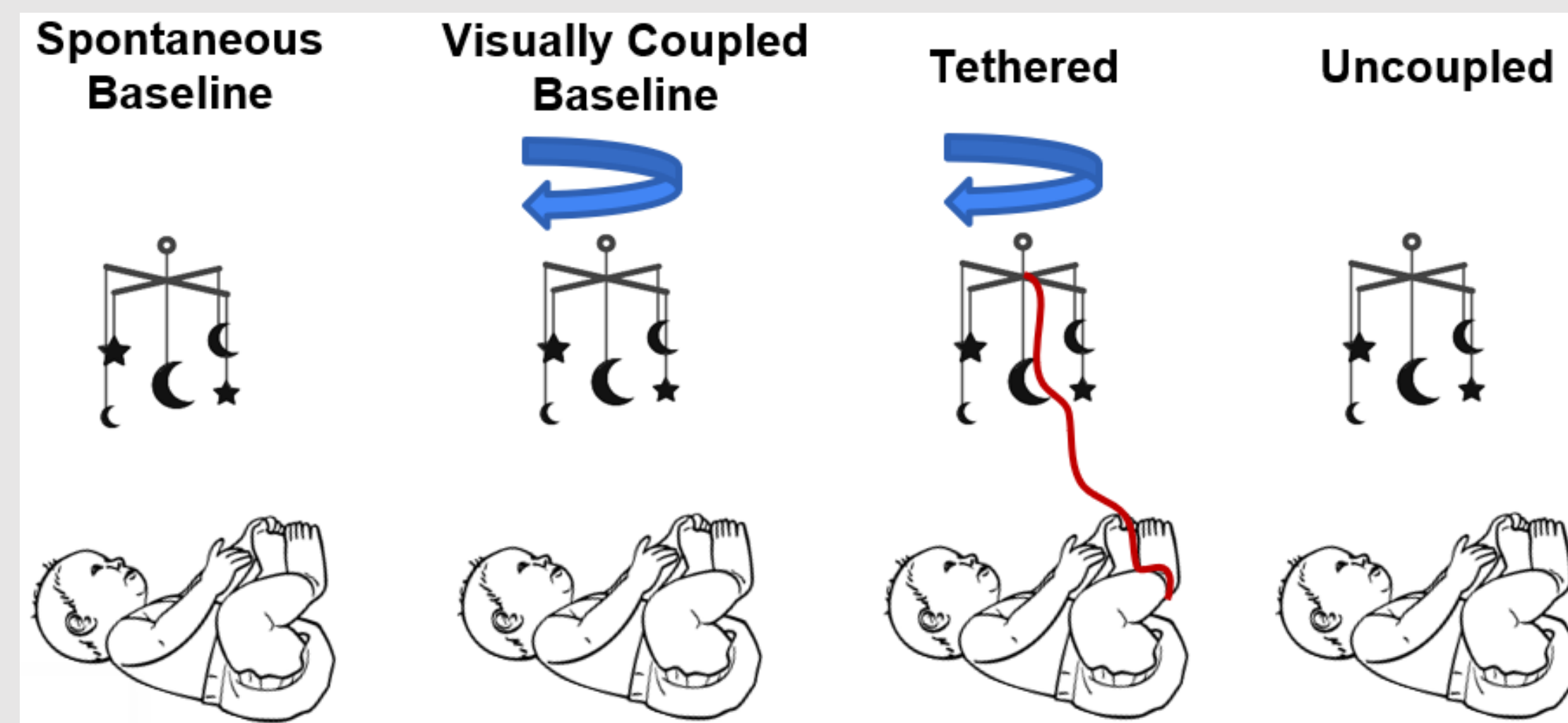
Center for Complex Systems and Brain Sciences, Florida Atlantic University

## INTRODUCTION

How do we come to understand that our actions can affect the world?

Human infants are a model organism for exploring how conscious **agency**, action towards an end, emerges in early life.

The **mobile-conjugate reinforcement (MCR)** paradigm offers an experimental window into this process (1, 2).



**Figure 1. MCR Schematic-** An infant is placed into a crib with a mobile hanging overhead. During the **spontaneous baseline**, the mobile is stationary. After a few minutes, the experimenter pulls a tether connected to the mobile causing the mobile to move. During the **visually coupled baseline**, the infant moves in response to externally-driven mobile motion. After a few more minutes, the **tether** is connected between the infant's foot and the mobile. Now, when the infant moves its foot the mobile moves in response. After several minutes of interaction, the mobile and infant are **uncoupled**, and the mobile is once again stationary.

Infants begin the experiment as detached observers, but when one of their feet is attached to an overhead mobile, infants can discover their ability to make the mobile move.

We propose that the moment an infant **realizes** it can move the mobile it will **suddenly increase its movement rate** (1-2), and that this abrupt behavioral shift reflects a phase-transition (*i.e.*, state change) as spontaneous movement transforms to purposeful action.

Complex systems far from equilibrium often exhibit drastic changes in dynamics immediately surrounding state change (*i.e.* **criticality**). Fluctuations in infant movement, one measure of dynamics, are explored here surrounding the peak increase in movement rate.

**By probing the roots of agency using methods and tools of Coordination Dynamics, this research aims to uncover principles which govern how living systems organize behavior and stabilize interactions with the world.**

## METHODS

•Sloan (2022) collected 3D mobile and tethered foot movement at 100 Hz from 16 babies (age:  $M = 100.33$  days,  $SD = 15.57$ ) and calculated cumulative displacement of the tethered foot during infant~mobile interaction.

•Foot displacement was differentiated twice across 1-min. intervals with 1s shifts (using the MATLAB function *movingslope.m* (5)) to produce 1-min. movement rate (**velocity**) and 1-min. changes in movement rate (**acceleration**) (Fig. 2a).

•We applied linear regression to displacement 45 seconds preceding and following the infant's peak acceleration to explore movement dynamics related to agentic discovery (Fig. 2b).

## RESULTS

### Shrinkers

These infants stabilized fluctuations after the critical point. This point might reflect a moment of insight (Aha!).

'Shrinkers' fell between the 25<sup>th</sup> - 75<sup>th</sup> percentiles in overall tethered movement rate

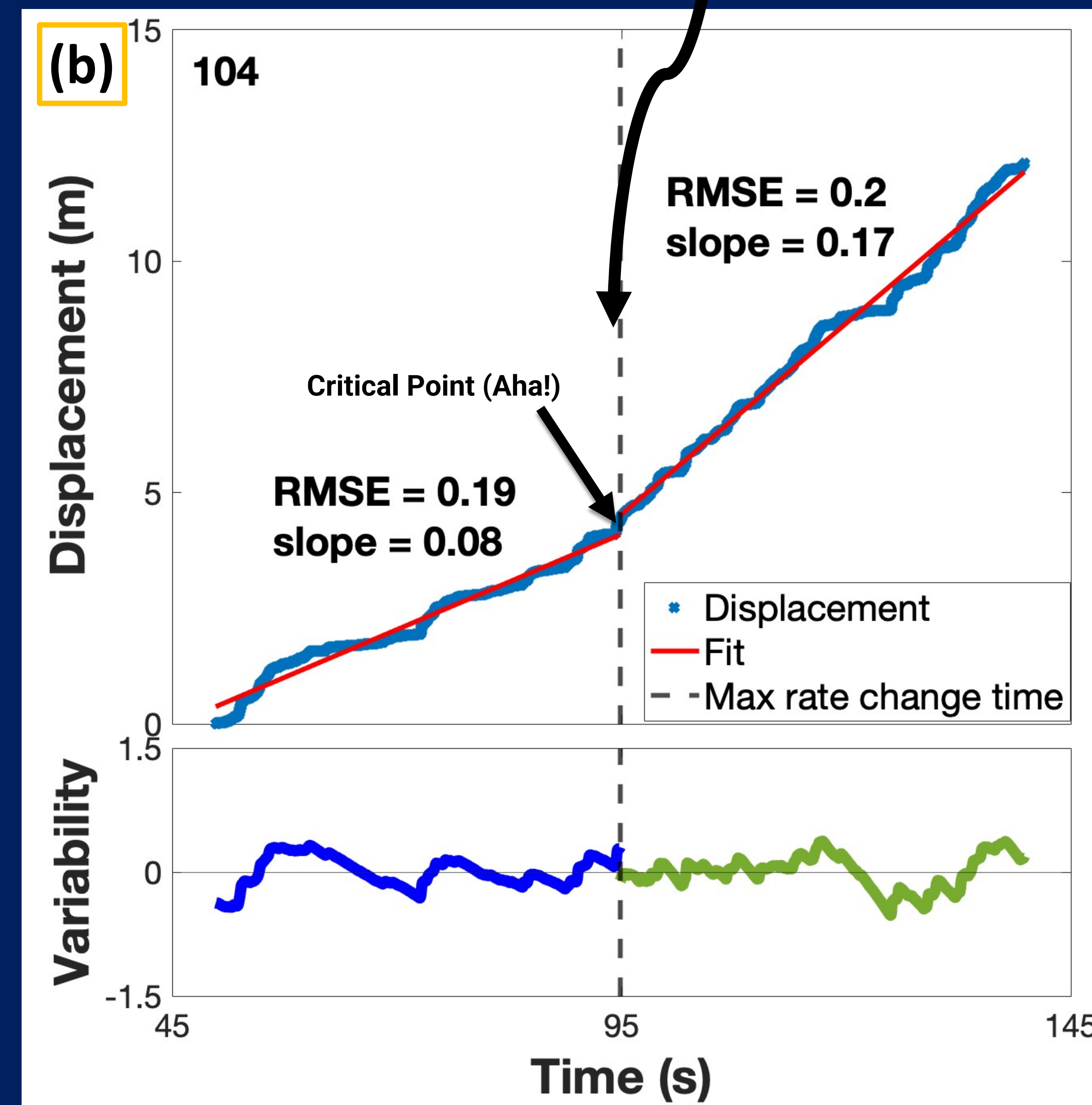
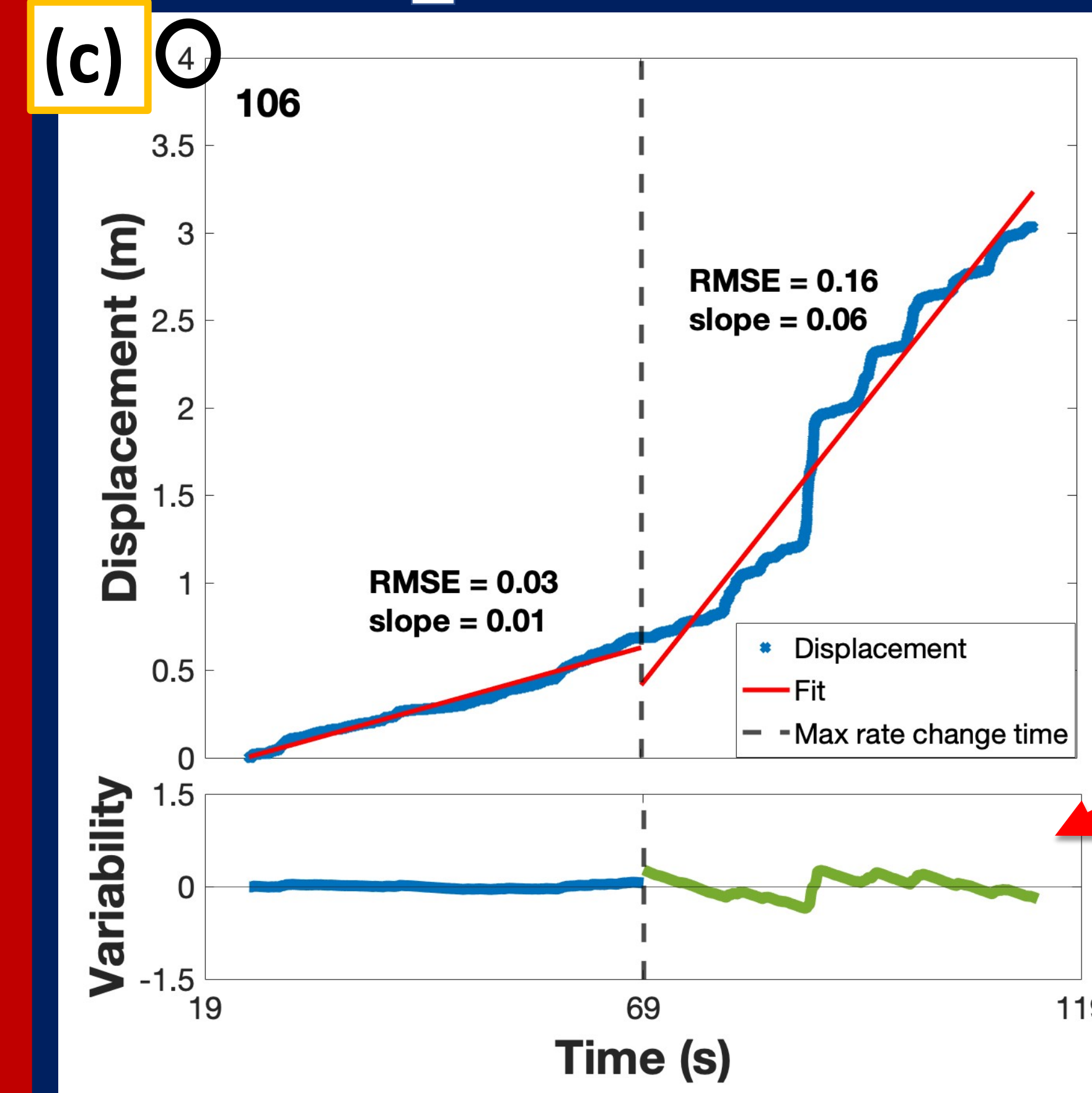


Fig. 2

### Growers



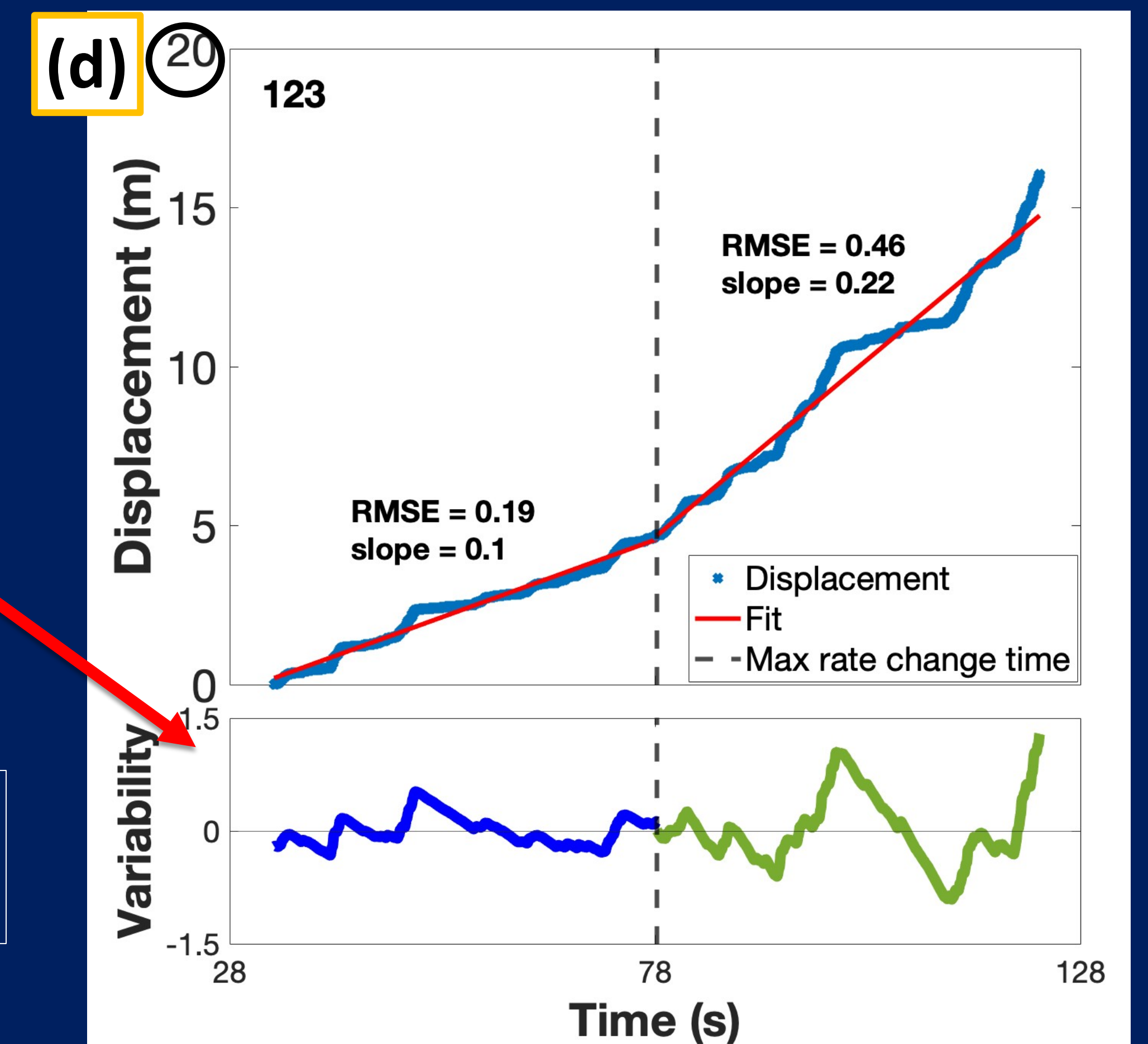
These infants' movements became less stable, reflecting increased exploration after the critical point.

Some of the infants that increased fluctuations were generally inactive (< 25<sup>th</sup> percentile in terms of overall tethered movement rate) such as 106.

This infant transitioned from passively observing to actively probing its relationship to the environment.

Whereas other infants that increased fluctuations were the most active babies (> 75<sup>th</sup> percentile movement rate), e.g., infant 123. As exploration/play intensifies, movement destabilized.

'Growers' were among the least or most active infants.



## CONCLUSION

- Individual infants navigate functional coupling with the world in different ways.
- Some infants' movements became more stable (reflecting **organized control**) whereas others became more variable (reflecting **exploration and/or play**).
- Infants whose movement became more variable were among the least and most active infants during interaction with the mobile, suggesting that a **behavioral niche** exists which supports realization of agency and stabilization of control.

Fully capturing the emergence of agency in healthy infants may reveal new methods for preventive care and early treatment of infants at risk for disorder.

## REFERENCES

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