

OPINION

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# How Do Babies Realize They Can Influence the World?

An infant's aha! moment may hold secrets to the origins of agency

BY ALIZA SLOAN & SCOTT KELSO



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Sometimes the simplest questions are the hardest to answer. How, for example, do you decide to wiggle your fingers? Quite a lot is known about the neural structures and muscles involved—the puppet and the strings, as it were—but what about the puppeteer?

Humans act with purpose, but much is still unknown about how we become purposeful agents—that is, how we develop the ability to willfully make things happen. In a recent study to probe agency's mysterious roots, we tried to catch infants in the act of discovering their own agency. As we reported last September in the *Proceedings of the National Academy of Sciences USA*, we identified these aha! moments and the events surrounding them, thereby revealing the process of agency formation for the first time.

For more than 50 years, researchers have used a very simple method to investigate learning in infancy. They place a baby into a crib with a mobile suspended above. Then a scientist ties one end of a string to the mobile and the other to the infant's foot. Now if the baby moves, the toy will, too. By observing babies in this setup in multiple sessions, scientists can watch as the infants learn and recall a simple cause-and-effect interaction: kick a foot and the mobile moves.

We revisited that setup with the intention of identifying the moment when babies first realize they can control the mobile's motion. We worked with 16 infants who were three to four months of age and measured the movements of both infant and mobile in three-dimensional space using cutting-edge motion-capture technology.

As past baby-mobile experiments had demonstrated, infants kicked

significantly more when their foot was tethered to the mobile than when it was not. But did the infants actually know that their movements were propelling the mobile? After all, they were too young to speak for themselves, so we had to consider other possible explanations for what might have been happening.

One clue came when an experimenter pulled the string to make the mobile move instead. Infants moved less in those situations than when the mobile was stationary. That finding rules out the idea that babies simply kick in excitement when they see the mobile moving. In fact, our data showed it was the highly coordinated exchange between the tethered infant and the mobile—foot and mobile moving together—that seemed to prompt a baby's activity.

Furthermore, when we freed the babies' foot from the mobile, they kept on kicking at the highest rate reached while tied to it, strongly suggesting that they expected the toy to respond. Some infants were visibly frustrated when that did not happen.

At some point during tethering, then, the infants must have figured out that they were in control—that they had agency. To pinpoint this moment, we developed an algorithm that we called our aha! detector to search for spikes in the rate of foot movement during tethering. For some infants, we found a sudden burst of activity coupled with dramatic changes in the rate of movement—including pauses and abrupt increases or decreases in speed. Such fluctuations and shifts are a typical signature of complex systems—from stock markets to brain activity—that are on the verge of change. We believe those initial spikes in activity coincided with those babies' aha! discovery.

Our observations also pointed to a notable pattern: in the first minute or so of tethering, each time the mobile responded to their movements, infants froze and waited for the mobile to stop before kicking again. The mobile's unfamiliar and unexpected movement triggered a strange, dynamic dance on the babies' part: move, pause, move, pause. We suspect that they were, in a sense, running their own experiment: "if I do this (kick), I see that (the mobile moves)," and, conversely, "if I do not kick, I do not see the mobile move."

Importantly, not every infant behaved in the same way. In fact, one child showed no such signs of discovering how her behavior might affect the mobile, even though she doubled her activity while interacting with it. This setup and our pattern-finding approach could therefore help us understand and predict individual paths of motor and cognitive development for both healthy infants and those at risk of developmental delays.

But what does any of this tell us about the origins of agency? Quite a lot, we would argue. Several years ago one of us (Kelso) proposed that the birth of agency is a dynamical, self-organizing process and, together with the late physicist Armin Fuchs, developed a model of it. To break that down: "dynamic" means that patterns and relationships evolve over time. "Self-organization" refers to the fact that many complex systems in nature organize themselves into specific forms without any instructions. In these cases, to return to our opening question, there is no concrete puppeteer pulling the strings. Rather, patterns emerge and change spontaneously in systems that are open to exchanges of energy, matter and information with their surroundings. As such, our theory is that when an organism (here, a baby)

and its environment (the mobile) interact, they form a self-organizing dynamical system. Goal-directed action emerges spontaneously when the organism realizes that its movements cause the world to change.

Our findings align beautifully with our theory. The babies' initial movements consisted of squirming and thrusting without discernible purpose or direction. But once tethered to the mobile, the more intensely they moved, the more their attention was drawn to the effect their kicking had on it (both by feeling the tug of the string and seeing the mobile respond in kind). When a baby's attention to its relationship with the toy reached a critical level, it realized it could make the mobile spin. Spontaneous movements became purposeful action. At that point of transformation, we observed a burst of foot activity and tight coordination between the infant and mobile.

Historically, the entire issue of purpose and agency in living things—and, dare one say, "[free will](#)"—has been clouded in philosophical debate and controversy. Many arguments fall into one of two extremes: either there must be an inner director—a self that makes decisions—or free will does not actually exist because the environment and circumstances predetermine a person's behavior. But our infant study emphasizes how understanding the *relationship* between an organism and its environment is essential to uncovering the origins of directed behavior. As our model proposes, the experience of agency emerges *only* when an organism (the baby) senses it is coupled to its environment (in this case, the mobile setup). In this way of thinking, the interaction and relationship between the two are crucial for purpose to arise.

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