People obtain information through purposeful interaction with the environment in a process known as exploration. Such active exploration is a key construct in theories of perception and development. The overarching goal of my research program is to understand the real-time and developmental processes that underlie how people gather perceptual information—explore—when observing scenes, guiding motor actions, and engaging in social interactions. I have pursued 3 main lines of research:

1. The development of visual exploration
2. How motor exploration shapes real-life opportunities for learning
3. How exploratory behavior calibrates perception of action possibilities

Furthermore, I have made significant methodological contributions, such as pioneering the first mobile eye-tracking method for studying infants' naturalistic visual exploration, developing a text-message-based survey system for estimating infants' posture and activity in the home, and creating a machine-learning classification system for automatically measuring infants' body position in the home from wearable inertial sensors. I support open science by developing and sharing research software and by contributing datasets to Databrary and OSF repositories.

Line 1: The development of visual exploration

What influences where people choose to look when visually exploring scenes, and how do those influences change over development? My research considers how scene factors, task constraints, and the motor coordination influence visual exploration.

Bottom-up and top-down influences on attention Prior work suggests that the visual appearance of a target (bottom-up influences) captures the eye gaze of young infants, but older infants' gaze is driven more by a target's meaning (top-down influences). Across a series of four papers, my mentees and I challenged this view based on recordings of infant, child, and adult eye movements while watching video clips (Franchak et al., 2016, Infancy; Kadooka & Franchak, 2020, Dev. Psych.; Franchak & Kadooka, in press, Infancy; Jing et al., in press, JECP). Using a wider set of videos and range of ages than in previous studies, we failed to find evidence of a global age-related shift in attention from bottom-up to top-down features. Instead, participants of all ages prioritized which features are most important to attend to from moment to moment, which varied according to the scene. Moreover, we found that media conventions (e.g., centering of faces in the scene) more strongly influence fixations to faces in videos compared with bottom-up saliency in both infants and children. These findings have implications for using social attention as a biomarker for autism and also for designing educational media to better direct children's attention.

Exploring with eyes, head, and body Beyond screen-based tasks, it is important to consider that looking is a motor action—observers must coordinate movements of their eyes, heads, and bodies to explore in all directions (Franchak, 2020, Psych. of Learning & Motivation). How does the motor act of looking shape how observers visually explore, and how do motor influences change over development? In earlier work, I used mobile eye trackers (Figure 1, left) to reveal that infants' and children's body size and position shapes what they see (Franchak & Adolph, 2010, Vis. Research; Franchak et al., 2011, Chi Dev; Kretch, Franchak, & Adolph, 2014, Chi Dev). Notably, a paper in Developmental Science described how infants' real-time body position affects social gaze (Franchak et al., 2018): Infants less often see caregivers' faces while infants are crawling than while they are sitting or upright. We extended this to ask how infants learn to orient their heads to center information in view—a previously unstudied aspect of attention development. Figure 1 (right) illustrates our finding: Infants can more easily center objects in view when they are in a sitting position compared with when they are prone (Luo & Franchak, 2020, PLoS ONE). I also identified developmental changes in how infants orient their heads to center faces versus objects (Franchak et al., in revision). Older but not younger infants center objects in view at the expense of caregivers' faces, which facilitates looking at objects for guiding reaching movements (Franchak & Yu, 2015, Proc. Cog Sci Society).

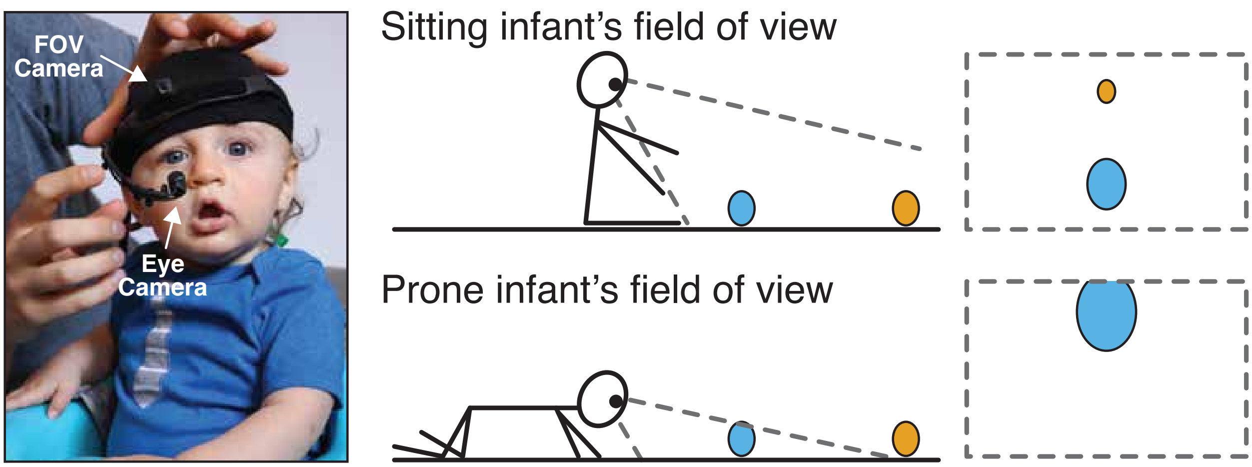

Figure 1: Left: Infant wearing mobile eye tracker; cameras capture the eye and field of view. Right: Differences in visual experiences of objects for infants in sitting versus prone postures.

Ongoing projects in my lab investigate how the coordination of eyes and head support visual exploration and how such coordination develops from infancy to adulthood. By pairing inertial sensing (to measure head rotation) with mobile eye tracking, my mentees and I found that adults' search in a large outdoor environment is driven more by modifying head movements compared with eye movements (Franchak et al., 2021, PLoS ONE). We have also discovered that the need to engage lower effort (eyes) versus higher effort (head, body) effectors to visually explore shapes adults' real-time information-gathering decisions when visual targets are placed in different locations (Luo & Franchak, in press, Collabra: Psychology).

Methodological contributions To facilitate this work, I led the development of the first mobile eye tracking methodology (i.e., Figure 1) to measure visual exploration in freely-moving infants (Franchak et al., 2011, Chi Dev). I have co-organized two pre-conference workshops, contributed three tutorial papers (Franchak, 2017, Cambridge Ency.; Slone et al., 2018, JOVE; Franchak & Yu, 2022, Advances in Child Devel.), and collaborated on the development of computer vision analyses (Lee et al., 2014, IEEE CVPR) to help other researchers adopt the method. I actively maintain open source software tools that aid mobile eye tracking analyses. I was recognized as an APS Rising Star and a Visiting Scholar at the McPherson Eye Research Institute in recognition of these contributions.

Line 2: Motor exploration shapes real-life opportunities for learning

Infants' opportunities for learning about objects and people in daily life depend on what they see. If the motor system influences visual exploration, what are the potential consequences for development? In a position paper (Franchak, 2020, Curr. Opin. Psych.), I hypothesized that differences in the time that infants spend in different body positions—creating different opportunities for seeing faces and objects—may facilitate later development of language and spatial cognition.

Measuring infants' daily experiences with ecological momentary assessment I devised a novel ecological momentary assessment (EMA) method to measure body position in 3-, 6-, 9-, and 12-month-olds infants by notifying caregivers throughout the day via text message to ask about infants' current position (Franchak, 2019, Infancy). Older infants spent more time upright compared with crawling, which we previously showed facilitates infants' view of faces and objects. Moreover, motor development (learning to sit and walk) altered body position rates, which in turn changes infants' opportunities for learning about faces and objects. At the 2022 International Congress on Infant Studies, we presented findings from a longitudinal EMA study indicating that the onset of walking doubles the time infants spend holding objects while upright, which may facilitate carrying and social sharing with objects. Recently, I was granted a $250k Opportunity Award from the James S. McDonnell Foundation to gather richer data about infants' experiences using a new "video EMA" method. Repeated sampling of "video snippets" will allow us to link the frequency/timing of object experiences to subsequent learning of object labels.

Detecting infants' motor experiences with inertial sensing To better characterize infants' everyday motor experiences, my mentees and I developed and validated a new technique using wearable inertial sensors and machine learning classification to continuously measure infants' body position in the home (Franchak, Scott, & Luo, 2021, Frontiers in Psychology). Currently, data collection is ongoing in the 3rd year of a 4-year, $755k NSF Developmental Sciences grant to use the new inertial sensing method combined with day-long audio recording to test whether changes in body position following the onset of independent sitting and independent walking facilitate vocabulary development. Furthermore, I was awarded an NICHD PLAY Project subaward to collect video observations of everyday infant-caregiver play in the home (including body position and object experiences). These rich, multi-modal datasets will be openly shared on Databrary to create testbeds for constraining theories and generating hypotheses about developmental mechanisms based on home experiences.

Line 3: Exploratory behavior calibrates perception of action possibilities

Possibilities for action depend on the fit between the body and the environment. For example, whether it is possible to walk under a tree branch without hitting the head depends on body height relative to the height of the branch. Perceiving possibilities for action is a challenge because bodies change in size, requiring recalibration of perception.

Real-time learning from exploratory practice My studies reveal that successful recalibration to changes in body size depends on whether people explore in ways that generate information about how action possibilities have changed. My mentees and I published 5 papers while at UCR to disentangle why practice performing an action leads to recalibration for some actions but not for others (Franchak, 2017, APP; Labinger et al., 2018, PLoS ONE; Franchak & Somoano, 2018, EBR; Franchak, 2020, QJEP; Gagnon et al., 2021, IEEE VR). Does practice simply provide a way to generate movement experience, or is outcome feedback (successfully performing vs. failing) important for recalibration? In a "squeezing through doorways task", I found that participants who only received movement experience without outcome feedback (walking around the lab and pressing the backpack against a wall) failed to recalibrate, suggesting that practice recalibrates perception because it provides outcome feedback. In later papers we showed that the role of outcome feedback is task-dependent: Outcome feedback does not calibrate perception in a fitting (compared to squeezing) version of the task, and the role of feedback differs for judgments of vertical versus horizontal reaching.

Development of exploration for perceptual-motor recalibration Perception of possibilities for action improves through infancy and childhood (Franchak & Adolph, 2012, Dev Psych; Ishak et al., 2014, JECP). More recently, I showed that the ability to recalibrate improves from 4 to 11 years (Franchak, 2019, JECP). Although 11-year-olds show an adult-like ability to perceive their unaltered abilities, they lag behind adults in a recalibration task. My work implies that changes in body size may increase the likelihood of motor errors; children's deficit in recalibration may contribute to higher rates of accidental injury in childhood.