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The role of walking experience on whole-body exploration and problem solving

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ABSTRACT

One hundred and six infants with varied independent walking experience faced the problem of navigating a tunnel to reach a caregiver. Solving the task required infants to switch from standing to crawling so they could fit their bodies into the tunnel. Spontaneous exploratory behaviors were documented. Infants who did not immediately go through the tunnel received a strict 15-step training protocol to highlight relevant details of the task. Age and walk experience were entered as predictors into a series of stepwise regressions on measures of exploratory and problem-solving behaviors. In general, older infants were more successful than younger infants in completing the task. A significant nonlinear relationship was documented between walk experience and some outcome measures. Infants with a moderate amount of walk experience had more difficulty than those with very little or a lot. Microgenetically documenting problem solving as a function of experience revealed that attention is taxed during mastery of a motor skill. Availability of attentional resources, in turn, impacted walkers' exploratory behaviors and ability to maintain problem-solving strategies.

1. Introduction

Classically, problem solving has been conceptualized as the search for a solution within a clearly defined problem space—such as when completing a puzzle in a lab. Real-life experiences with problem solving are not always clearly defined though; they require the individual to first discern what the problem is, then hone their scope to relevant information, and finally judge the effectiveness of possible solutions (Ball & Litchfield, 2013; Kirsh, 2009). An embodied or situated theory of problem solving takes these nuances in stride by incorporating the context in which the problem and problem-solver are embedded (Kirsh, 2009). Accordingly, problem solving can be defined more generally as the process of information gathering and strategy development to facilitate interactions with the environment (Zhang, Ding, Lee, & Chen, 2017).

A relatively recent trend for studying problem solving in infancy is the use of whole-body problem solving (e.g., Berger, Adolph, & Lobo, 2005; Keen, 2011). Such research designs require the coordination of perceptual-motor and cognitive skills to solve locomotor problems. For example, whole-body exploration and information gathering may involve trying out different postures or haptically exploring surfaces (Berger et al., 2005); moving from one place to another to reach a goal (Adolph, Tamis-LeMonda, Ishak, Karasik, & Lobo, 2008); or navigating around obstacles (Comalli, Persand, & Adolph, 2017). This approach allows researchers to observe details of the problem-solving process in a population for whom typical problem-solving tasks, such as arithmetic and word problems that rely heavily on verbal ability, would be inappropriate (e.g., Jõgi & Kikas, 2016).

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Such whole-body tasks also enable researchers to assess problem-solving ability in comparable scenarios across ages. Toddlers, children, and adults have been challenged to maneuver around barriers (Schmuckler, 1996; Van der Meer, Johnson, Bremner, & Slater, 1997), judge the traversability of surfaces (Joh & Adolph, 2006), and climb or descend stairs (Berger, Chin, Basra, & Kim, 2015; Cesari, Formenti, & Olivato, 2003). Cross-sectional studies provide snapshots of development and reveal similarities in the sequence of problem solving across ages. Initially, information is gathered, via exploration, to determine the goal and guide preliminary strategies. The oldest and most well-practiced strategies in an individual's repertoire are selected first. However, if these familiar strategies turn out to be ineffective, additional exploration or strategic change is prompted (Chen & Siegler, 2000; Lemaire & Siegler, 1995). For example, toddlers, children, and adults all visually inspected a looming barrier crossing their path (Van der Meer et al., 1997). If the barrier was sufficiently high, all maintained the strategy of walking uninterrupted, but if the barrier was too low, all age groups devised alternate solutions.

In contrast, the ways that adults, children, and toddlers modified their initial strategies to circumvent the barrier varied greatly. Adults only ducked when absolutely necessary and did so within a small margin of error. Toddlers displayed the most varied, but creative solutions in avoiding the barrier and reaching their goal (Van der Meer et al., 1997). Similarly, 16-month-old walking infants also showed creativity at whole-body problem solving. Because they refused to cross a narrow (18 cm) bridge in the absence of a handrail when faced with the problem of crossing bridges of various widths (Berger & Adolph, 2003), researchers subsequently hypothesized that they would also refuse when the only tool available was a sub-optimal foam "wobbly" handrail (Berger et al., 2005). In fact, infants devised creative solutions for using the wobbly handrail and were able to successfully cross the narrowest bridges (10 cm wide) more often than predicted (Berger et al., 2005). Moreover, the more experience infants had walking, the more successful they were at crossing the bridge and the less likely they were to fall, providing evidence for the cascading influence of even incremental changes in ability on problem solving (Berger & Adolph, 2003; Berger et al., 2005).

Expertise ultimately affords certain advantages as skills become automatized and require less attention; this happens repeatedly over the course of the first year with the acquisition of each new motor skill, such as learning to sit independently around 6 months (Harbourne & Stergiou, 2003) and cruising at 9 months (Atun-Einy, Berger, & Scher, 2013). From one motor skill to another, novice reachers, crawlers, and walkers consistently have difficulty choosing and maintaining optimal strategies even if the necessary skills are within their repertoires (Berger et al., 2015; Berger, Harbourne, Arman, & Sonsini, 2019, respectively). For example, novice walkers, as compared to experts, were more likely to attempt to walk down a short flight of stairs rather than use the safer and more stable strategy of scooting or backing down. If novice walkers did begin their stair descent using a more optimal strategy, then they struggled to maintain it through the duration of the trial and frequently reverted back to riskier stair descent strategies, whereas expert walkers maintained their descent strategy down the full flight (Berger et al., 2015).

Research on the development of problem-solving ability has overwhelmingly focused on endpoints of development. However, this approach does not inform the process by which skills are acquired. Microgenetic analyses emphasize observing and understanding the processes of change (Adolph et al., 2008; Gill, Adolph, & Vereijken, 2009; Van Geert & Van Dijk, 2002). Microgenetic analyses typically address this issue by incorporating densely sampled observations and trial-by-trial assessment (Chen & Siegler, 2000). For example, in Kwong & Varnhagen's (2005) assessment of the development of spelling strategies, children were taught nonwords and tested on them 3 times a week for 4–7 weeks. After each test, children retrospectively reported the strategy they used to remember. All children improved, but also had different, and often nonlinear, trajectories for reaching that point (Kwong & Varnhagen, 2005). However, sometimes change is visible in the short term and learning or strategy choice does not require long time frames to develop. A "small-scale" microgenetic approach can document change over the course of just a few minutes (Oakes & Plumert, 2002, p. 531).

While capturing the process of learning, microgenetic methods' reliance on verbal report of strategies limits the extent to which they can be applied to pre- or non-verbal populations such as infants. However, tasks that make the entire process visible, such as whole-body problem solving, can address this limitation. The use of densely sampled observations during the development of a specific motor milestone can further elucidate the impact of fluctuating expertise on strategy development and bring patterns of individual differences and incremental improvement to light (Chen & Siegler, 2000).

1.1. Current study

The goal of the current study was twofold: (1) to examine the process of problem solving as it unfolds in real time and (2) to explicitly examine the role of expertise in problem solving as it fluctuates over the development of walking as a function of experience. To accomplish the former, infants were encouraged to solve the problem of navigating a tunnel to reach a caregiver waiting at the other end. This task was designed to make the underlying problem-solving process visible via exploratory behaviors, initial strategy choices, and strategy maintenance. The success of these strategies all required gross motor behaviors. The latter objective was met by examining the relation between walk experience and infants' response to the task.

Two recent studies confirm that this task is appropriate for crawling and walking infants of this age range (Berger & Scher, 2017; Berger, 2010). In both instances, infants displayed a variety of problem-solving behaviors and abilities. Groups of expert crawlers and walkers found the task the least challenging while infants who were within just a week of having given up crawling had difficulty solving the tunnel task. As such, we hypothesized that previous experience would impact all aspects of problem solving, from exploration and initial strategies through strategy refinement. Specifically, we hypothesized that walk experience would have a nonlinear relationship with navigating the tunnel driven by infants' fluctuating ability to switch between crawling and walking. We expected the newest walkers to find our task the least challenging because they were still actively switching back and forth between crawling and walking. We expected infants with moderate walking experience to find the task increasingly difficult because they had recently given up crawling. Finally, we expected expert walkers to find the task straightforward once again.

Table 1
Participant information.

	N	Gender	Tunnel experience	Age in months *M(SD)*	Walk experience in days *M(SD)*	Walk experience quartiles (in days) 25% 50% 75%
Full sample	106	64 males 41 females	58 without 31 with	13.76 (1.92)	29.99 (23.37)	13 24 37.5
Partial sample	79	49 males 30 females	42 without 24 with	13.5 (1.84)	18.69 (9.34)	10 17 27

2. Method

2.1. Participants

One hundred and eleven infants participated in the task but five were excluded from analyses, 3 due to experimenter error and 2 due to fussiness. The remaining 106 participants were age 9–18 months (M = 13.76 months). Criterion for participation was the ability to walk 10 feet across a room without stopping to rest or falling. Once this was confirmed via parental report, families were invited to partake in the study.

Parents or guardians were interviewed about infants' motor milestone achievement and experience. Walk experience was calculated from the first day they met criterion until the date of participation (walking experience range = 3–107 days, M = 29.99 days). Thirty-one infants had prior experience with tunnels, 58 had no prior experience with tunnels, and 17 did not report. (See Table 1, Row 1)

Maternal and paternal education ranged from high school diploma to graduate degree, with the majority of parents having a college (23% of mothers and fathers) or graduate degree (31% of mothers and 26.2% of fathers). Our sample comprised: Caucasian (30.4%), Hispanic (2.5%), African American (2.5%), South Asian/Indian (2.5%), American Indian/Alaskan Native (2.5%), other (1.3%), and more than one racial or ethnic group (12.7%). 2.5% chose not to answer and data was missing for 43%.

The study was conducted in families' homes or the Child Development Lab at [blinded] Families were recruited through word of mouth, published birth announcements, research participation credit for parents enrolled in an introductory psychology course, events at branches of the public library, and local farmers' markets. The data set includes 45 participants who were recruited exclusively for this study, as well as participants from three other studies that used the same tunnel task procedure and protocol: 25 from Berger and Scher (2017); 11 from an ongoing study on the impact of the timing of sleep on learning; and 40 from an ongoing study on the impact of the quality of sleep on learning. All research was approved by the Institutional Review Board of the [blinded] and parents or guardians provided written informed consent for participation and video recording.

2.2. Procedure

A researcher placed infants upright on two feet at one end of a nylon tunnel measuring 47 cm (18.5 in.) in diameter and 180 cm (71 in.) in length. Parents waited at the other end. The tunnel came to approximately infants' shoulder height, requiring them to change postures from standing to crawling to fit inside. Parents called to their infant and encouraged them to come to them, offering toys and praise. A strict 15-step training protocol controlled when and how the experimenter highlighted relevant details of the task (see also Berger & Scher, 2017). The session ended once infants crawled through or completed training without success.

Three phases of prompts comprised the Training Protocol which provided progressively more information about how to navigate the tunnel (see Fig. 1); each phase was comprised of a maximum of 5 steps. An experimenter advanced through the steps in response to infant attempts to circumvent the tunnel. To begin, the experimenter placed the infant on two feet at the entrance to the tunnel. During the first phase, experimenters returned infants to the starting position, standing at the entrance, if they tried to go around. They moved to the second phase if infants failed to crawl through the tunnel after 5 standing prompts. In the second phase, experimenters placed infants on hands-and-knees at the start of the tunnel. If infants still did not crawl through the tunnel after 5 hands-and-knees prompts, the experimenter moved to the third and final phase. During the third phase, experimenters placed infants on hands and knees and rolled a ball through the tunnel to the end, highlighting the correct path through. A new ball was rolled at each of the 5 prompts in phase three. If all 15 prompts were deployed and the infant still did not navigate the tunnel, the session was ended.

2.3. Video recording and coding

The session was digitally recorded, using a handheld camera to ensure that infants' bodies were fully visible at all times. A research assistant coded all data from video using Datavyu (http://datavyu.org), a computerized coding system that records durations and frequencies of behavior. We coded three broad categories of exploratory behaviors: postural shifts, haptic exploration, and social referencing. Postural shifts were whole-body movements comparing the fit between infants' bodies and the tunnel. Haptic exploration was defined by infant exploration of the tunnel with their hands, manipulating it in a variety of ways. Fig. 2 depicts examples of the types of haptic exploration. Number of exploratory behaviors were also denoted. Social referencing were instances in which the infant looked back to the experimenter to try and gather more information.

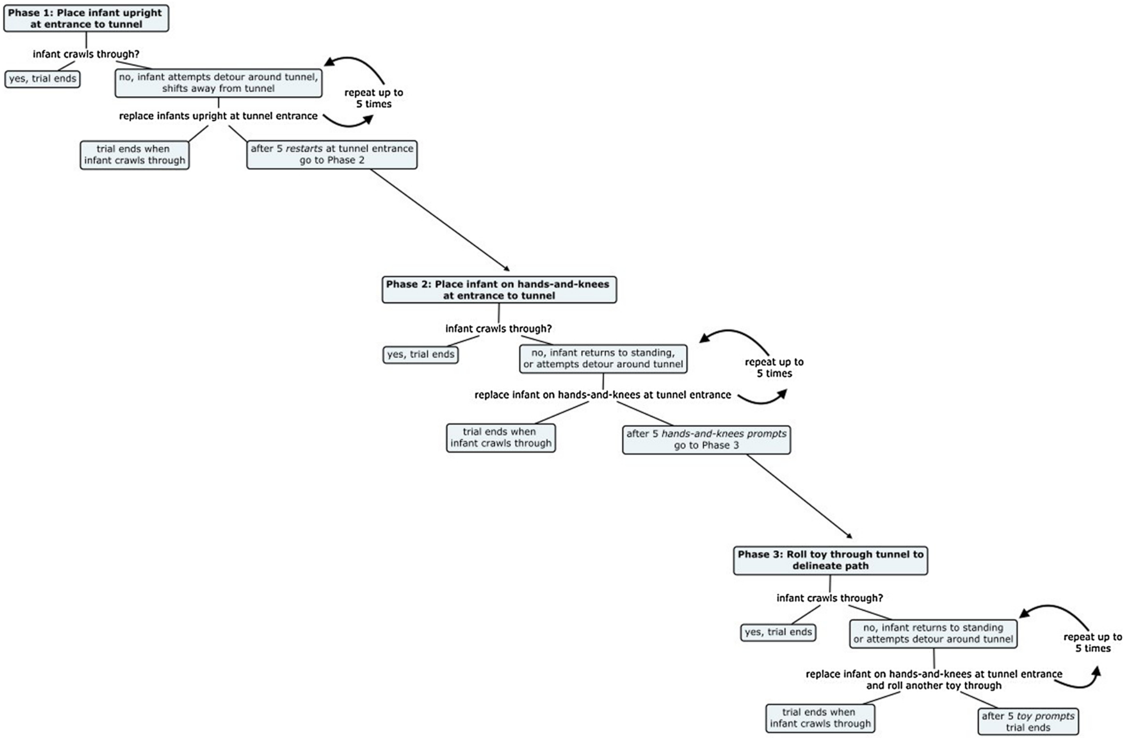

Fig. 1. Schematic diagram of the tunnel training procedure. Reprinted with permission from *Journal of Experimental Child Psychology, 162*, S. E. Berger and A. Scher, Naps improve new walkers' locomotor problem solving, p. 295. Copyright © 2017 by Elsevier.

Primary outcome measures focused on the process of learning how to navigate the tunnel. *Total prompts* were the number of steps needed in the training protocol. *Latency* encompassed how long it took infants to devise and revise strategies. *Time-in-tunnel* captured the duration of strategy maintenance and time to finish navigating the tunnel. *Shifts* in posture while in the tunnel demarcated the frequency with which infants oscillated between postures while inside the tunnel and physical errors involving a *mismatch* between body and tunnel reflected a failure to maintain the correct strategy. Table 2 provides a full list of behavioral codes and their operational definitions.

A secondary coder independently reviewed 25% of the videos. For categorical measures such as exploratory behaviors or body mismatch, percent of agreement rated from 90.3 to 93.5%. Interrater reliability between coders on continuous measures was calculated as a correlation ranging from 0.97 to 1.00, indicating high reliability.

2.4. Data analysis

One of the 106 infants never figured out how to navigate the tunnel even after receiving all phases of the protocol. He received the maximum score of 15 and was included in the analyses. His latency and time-in-tunnel values were recorded as null. Table 1 (Row 1) includes the quartiles of the distribution of infant walking experience and Fig. 3 displays the frequency counts. Seventy five percent of the data fall below 38 days of experience.

Because the distribution was visibly skewed, Kolmogorov-Smirnov tests of normality were run and confirmed non-normality, $D(106) = .151$ $p < .001$. The sample was then restricted to only include infants with less than 38 days of walk experience and tests of normality were run again, $D(79) = .091$, $p > .05$. This time normality was achieved, supporting further analyses which assume the normal distribution (Ghasemi & Zahediasl, 2012). Participant characteristics for the subsample are reported in Table 1, Row 2.

Our first hypothesis centered around the idea that prior experience would impact all stages of problem solving. The primary measure of prior experience was walk experience, but 30% of infants also had past experience specific to our task. As such, we ran a series of independent sample ttests to determine infants who had prior tunnel experience performed differently than those without. Both total prompts and body mismatches were significantly different ($t = -2.17$, $p < .01$ and $t = -1.26$, $p < .01$, respectively). In subsequent analyses, tunnel experience was dropped as a predictive factor for all other outcome measures. Doing so increased our sample size because 13 infants did not report previous tunnel experience and would otherwise be excluded.

A series of stepwise regressions assess the predictive value of walk experience as a linear and quadraic factor on exploratory behaviors and problem-solving measures. To account for general development, age was always factored into the regression first. Exploratory behaviors included postural shifts, haptic exploration, and social referencing. Problem-solving measures included number of prompts, latency, tunnel shifts, body-tunnel mismatch, and time spent in the tunnel. Because body-tunnel mismatches

Fig. 2. Examples of haptic exploration: (A) lift or up/down shake, (B) finger opening, (C) side/side shake, (D) pat or rub top, (E) pat or rub side, and (F) touch inside below or (G) above midline.

were binary, a logistic regression was used for this analysis and predictors were added stepwise if they met likelihood ratio criteria. Table 3 summarizes the significant predictors and coefficients.

3. Results

3.1. Exploration

3.1.1. Postural shifts

Sixty-seven of 79 infants engaged in postural shifts (range: 0–35; $M = 6.01$). Only age was a significant predictor ($R^2 = .16$, $F(1, 76) = 14.44$, $p < .001$) (see Table 3, Column 2).

3.1.2. Haptic exploration

Thirty-eight infants engaged in some form of haptic exploration. Age was a significant predictor of the types and number of exploratory behaviors ($R^2 = .067$, $F(1, 77) = 5.53$, $p < .05$ and $R^2 = .053$, $F(1, 77) = 4.34$, $p < .05$, respectively; see Table 3,

Table 2
Operational Definition of Behaviors.

Behavior	Definition
Postural shifts	The number of changes in posture as infants explored how their body fit relative to the tunnel
Exploratory types	The number of nonrepeating exploratory strategies that were employed including: ● lift ● finger opening ● up/down shake ● side/side shake ● push away ● pat top ● rub top ● rub side ● touch inside (above or below midline)
Number of exploratory behaviors	Total individual exploratory behaviors the infant displayed.
Social referencing	The number of times infants looked back to the experimenter while gathering information about the task.
Total prompts	The number of steps (out of 15 possible) needed in the training protocol
Latency	Total time from when the experimenter placed the infant at the entrance to the tunnel until they entered (if unsuccessful, marked as null)
Tunnel Shifts	The number of changes in posture that occurred once infants were inside the tunnel
Body-tunnel mismatch	Misjudgment of the fit between infant's body and the tunnel while attempting to navigate the tunnel, including ● entering the tunnel while standing ● dragging one's head along the inside of the tunnel ● standing up inside the tunnel ● hitting one's head while exiting the tunnel
Time-in-tunnel	Total time from when the infant entered the tunnel until they exited (if unsuccessful, marked as null)

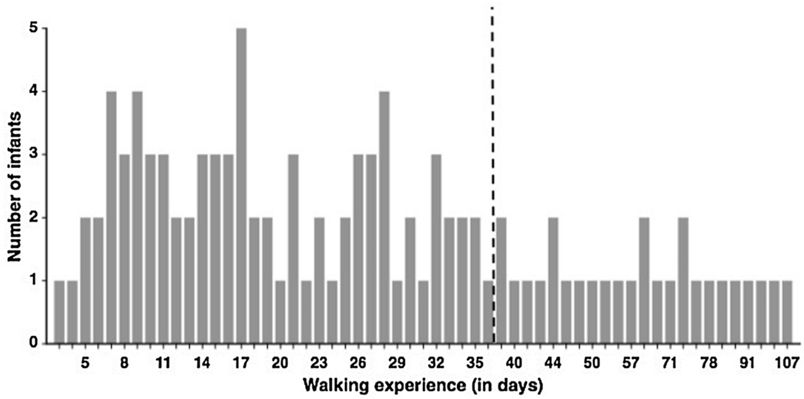

Fig. 3. Frequency distribution of infants with each amount of walking experience. The dashed line indicates the cutoff point for the subsample.

Column 3–4). Fig. 5 displays the sequence of exploratory behaviors for each participant, sorted by age and number of prompts in the training protocol.

3.1.3. Social referencing

Twenty-eight infants looked back to the experimenter while gathering information about the task. Age and the quadratic of walk experience were entered into the stepwise regression, (R^2 = .105, $F(2, 76) = 4.436$, $p < .05$; see Table 3, Column 5). Fig. 4A displays the quadratic.

3.2. Training

Thirty-three infants went through the tunnel immediately, while the remaining 46 infants needed training to solve the tunnel task. Only age was a significant predictor in the stepwise regression (R^2 = .136, $F(1, 64) = 10.09$, $p < .01$; see Table 3, Column 6).

Latency spanned the time from when infants were first placed standing at the entrance of the tunnel until they entered. Both age and walk experience, as a quadratic term, were significant (R^2 = .195, $F(2, 76) = 9.2$, $p < .001$; see Table 3, Column 7). Fig. 4B displays the quadratic.

Table 3
Summary of significant predictors in stepwise regressions.

Predictor variables	Outcome variables								
	Postural shifts	Types of exploration	Number of exploratory behaviors	Social referencing	Total prompts	Latency	Tunnel shifts	Body mismatch	Time in tunnel
Age	$\beta = -.055^{c}$	$\beta = -.011^{a}$	$\beta = -.078^{a}$	$\beta = -.006^{a}$	$\beta = -.038^{b}$	$\beta = -.88^{c}$	$\beta = .02^{a}$	$\beta = .011^{a}$	n.s.
Walk experience	n.s.	n.s.	n.s.	$\beta = -.007^{a}$	n.s.	$\beta = -.34^{c}$	n.s.	$\beta = .009^{a}$	n.s.
Tunnel experience	–	–	–	–	n.s.	–	–	n.s.	–

Note. $^{a}p < 0.05$, $^{b}p < 0.01$, $^{c}p < 0.001$.

3.3. *Strategy maintenance*

The number of times that infants shifted posture while in the tunnel, the time spent in the tunnel, and mismatches between body and tunnel captured infants' ability to maintain their strategy for navigating the tunnel. Age was predictive of shifts within the tunnel ($R^2 = .05$, $F(1, 77) = 4.12$, $p < .05$; see Table 3, Column 8). Age and the quadratic of walk experience were predictive of making a body-tunnel mismatch in the logistic regression ($\chi^2(2) = 8.62$, $p < .05$; see Table 3, Column 9). No variables were significantly associated with time spent in the tunnel (see Table 3, Column 10).

4. Discussion

In this study, we asked infants with varied amounts of independent walking experience to solve the problem of navigating a tunnel to reach a caregiver at the other end. To do this, infants needed to switch from walking to crawling to fit their bodies into the tunnel and maintain this posture to navigate through the tunnel to the other end. We hypothesized that prior tunnel experience and current level of walking expertise would predict problem-solving ability at all points, from information gathering and initial strategies to strategic change and strategy maintenance.

Unsurprisingly, age was predictive of all variables except time spent in the tunnel. The pattern was consistent: older infants were faster and more successful in devising and maintaining solutions to the full-body problem-solving task. As predicted by an embodied cognition account, there was a non-linear relation between walk experience and several outcome measures including social referencing, latency to enter the tunnel, and whether there was a body-tunnel mismatch. Fig. 4 infants with only a moderate amount of experience struggled the most with our task. They looked more frequently to the research assistant for help, took longer to explore and implement the solution, and were more likely to mismatch their body to the tunnel.

The process of mastering a new locomotor posture taxes infants' attentional resources (Berger, 2010; Berger, Cunsolo, Ali, & Iverson, 2017; Berger et al., 2019; Chen, Metcalfe, Jeka, & Clark, 2007). A finite amount of attentional resources results in tradeoffs in performance because, when engaged in multiple tasks simultaneously, success on one task comes at the expense of the other (Beilock & Gray, 2012; Berger, 2010; Bisagno & Morra, 2018; Hesse & Deubel, 2011; Rowe & McKenna, 2001). While not an explicit dual task, the tunnel task creates a situation where there is potential for competing attentional resources as infants had to inhibit their preferred locomotor modality, walking, in favor of crawling, as well as maintain this strategy for the duration of the task. From the moment infants were presented with the tunnel, all of the information they needed to solve the task was available to them and their own experience served as a natural variant of task difficulty. Our most novice walkers still actively switched back and forth between crawling and walking and experts were approaching the automatization of walking. Once new skills become automatized, the attentional resources used during mastery can subsequently be allocated elsewhere such as planning or inhibition (Berger et al., 2015; McCarty, Clifton, & Collard, 1999). Infants in the midst of transitioning between crawling and walking showed the greatest dual task cost suggesting that a significant portion of their attention was dedicated to maintaining the posture of walking.

Contrary to our expectation, walk experience was not associated with haptic exploration. Rather, as depicted in Fig. 5, there was individual variability in the sequence and number of haptic exploratory behaviors. Our goal as researchers was to facilitate infants' problem solving of a specific task. As evidenced by infants' not uncommon attempts to circumvent the tunnel and walk directly to the caregiver, some infants and researchers were likely not in the same problem space at the onset of the task. For these infants', exploration may have initially been directed towards one interpretation of the problem to be solved and then redirected as the problem, according to researchers' expectations, Strategy refinement based on new understanding of the problem at hand has been demonstrated in previous work. For example, when infants were prompted to navigate a walkway that looked solid, but was actually highly unstable, they quickly modified locomotor strategies or refused to cross (Gibson et al., 1987).

Like the infants on the walkway, our infants' understanding of the task and its required solution could be updated in real time as they explored or progressed through the training protocol. Fig. 5 demonstrations the way types of exploration became more varied as infants tried to reconcile their problem space with that of the experimenter. While motor skill is not necessarily associated with exploratory behavior (Marcinowski, Tripathi, Hsu, Westcott Mccoy, & Dusing, 2019), sufficient attention is needed to explore efficiently, tailor behaviors to the task at hand, and make use of this information. Applying the information gathered via exploration may have been more difficult for infants with a moderate amount of walking experience, hence their longer latencies.

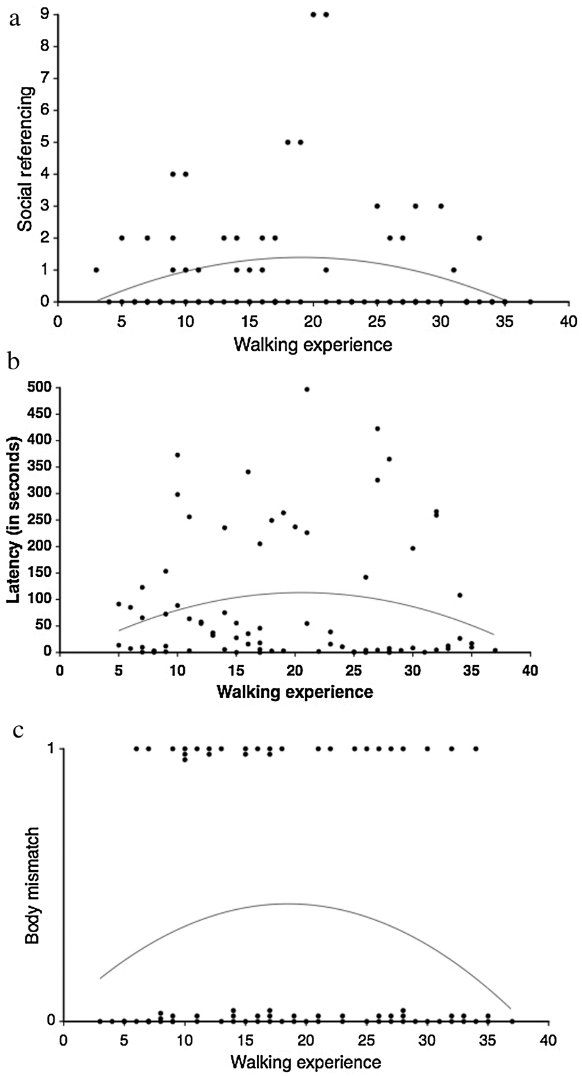

Fig. 4. Scatterplots of outcome variables that were significantly predicted by the quadratic of walking experience: (A) social referencing, (B) latency, (C) body mismatch.

4.1. Limitations and future directions

Additional work is needed to clarify the possible underlying mechanisms of the role of experience and novel problem solving. Infants with and without previous tunnel experience performed differently on some outcome measures (total training prompts and body-tunnel mismatch), but tunnel experience itself was not predictive within the regression. More specific metrics of when and how infants previously experienced tunnels may clarify this anomaly.

Future research plans to hold the amount of walk experience constant (within 7 days of having given up crawling in favor of walking) while allowing age to vary to tease apart the influence of general cognitive development and motor skill acquisition. Factors such as infants' age when they reached our criteria for walking or their experiences with other environments with obstacles such as playgrounds or gyms may be instrumental in their allocation of attention and subsequent problem-solving ability.

4.2. Conclusions

In sum, the current study delved into the specifics of the problem-solving process situated within fluctuating levels of expertise. This gross motor problem-solving scenario elicited a rich set of exploratory behaviors, strategies, and errors, as well as an observable solution. Our results suggest that expertise, and subsequently automaticity, benefit problem solving by mitigating the demand on attentional resources, but also highlight the role of experience in the strategy development.

The overall process of problem solving, and learning more generally, is an embodied experience; it requires a balance between what an individual brings to the scenario and the demands of the environment. Prompts and exploration are ineffective if attentional

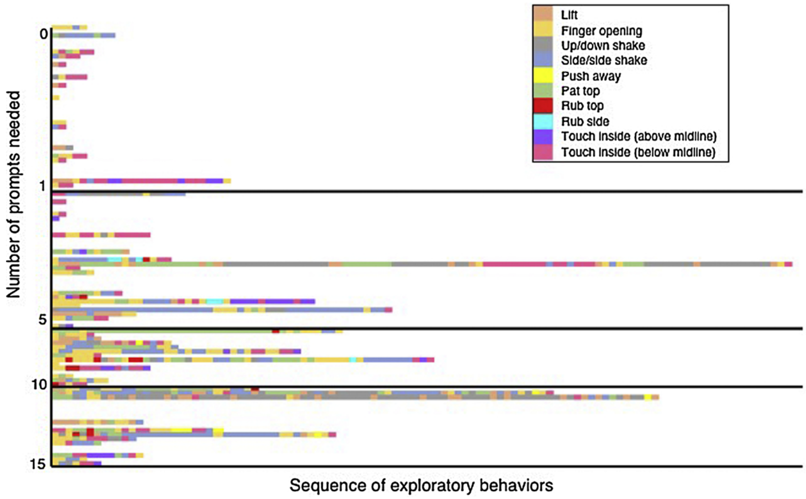

Fig. 5. Sequence of haptic exploratory behaviors for all infants ($N = 106$) ordered by the number of prompts needed in the training protocol.

resources are too taxed to make use of the information. Likewise, emerging motor skills enable new action, but infants struggle to plan and use their abilities efficiently as they build expertise. Our study adds to the burgeoning literature emphasizing the interaction between developmental domains such as attention and locomotor experience and its effect on infants' learning and performance.

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