When Infants Take Mothers' Advice: 18-Month-Olds Integrate Perceptual and Social Information to Guide Motor Action

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The social cognition and perception–action literatures are largely separate, both conceptually and empirically. However, both areas of research emphasize infants' emerging abilities to use available information—social and perceptual information, respectively—for making decisions about action. Borrowing methods from both research traditions, this study examined whether 18-month-old infants incorporate both social and perceptual information in their motor decisions. The infants' task was to determine whether to walk down slopes of varying risk levels as their mothers encouraged or discouraged walking. First, a psychophysical procedure was used to determine slopes that were safe, borderline, and risky for individual infants. Next, during a series of test trials, infants received mothers' advice about whether to walk. Infants used social information selectively: They ignored encouraging advice to walk down risky slopes and discouraging advice to avoid safe slopes, but they deferred to mothers' advice at borderline slopes. Findings indicate that 18-month-old infants correctly weigh competing sources of information when making decisions about motor action and that they rely on social information only when perceptual information is inadequate or uncertain.

Keywords: infant locomotion, perceptual exploration, social cognition, affordances

Two sources of information are available to infants for making decisions about action: perceptual information generated by infants' own exploratory movements and social information offered by infants' parents and other people. An eager infant poised at the top of the stairs as mother screams "No!," a timid infant who is encouraged to attempt the daunting playground slide, a crawling infant whose parent's silence conveys that it is okay to roam, and a beginning walker reluctant to take steps into mother's open arms must decide whether to descend, slide, crawl, and walk on the basis of the available perceptual and social information.

Sometimes perceptual and social cues are concordant, offering redundant information that specifies the way to act (e.g., when parents nod toward an inviting toy or say "No, no" toward a menacing dog). Other times, perceptual and social information are at odds, specifying opposing courses of action (e.g., when parents

warn their toddlers to stay away from an empty street or encourage their infants to crawl onto the unfamiliar surface of a sandy beach). Discordant perceptual and social information is especially interesting because infants confront an interpretive challenge: They must decide how to weigh and integrate competing sources of information. In such situations, infants might assign priority to social information and defer to mothers' advice, regardless of their own perceptual assessment of the situation. Alternatively, infants might rely on perceptual information and ignore their mothers' social messages. A third possibility is that infants assess social and perceptual cues on a case-by-case basis, relying selectively on social information when perceptual cues leave them uncertain about how to act. On this last account, infants must be able to generate and use perceptual information to gauge affordances for action, understand and use the social advice offered by others, and determine the relative importance and accuracy of each source of information for coping with the task at hand. If so, infants' response to social and perceptual information will lean more toward one source of information versus the other, depending on their level of uncertainty.

Although infants face the problem of evaluating perceptual and social information in most everyday actions, few studies have examined this process. The gap in the literature reflects the long-standing rift between studies of perceptual–motor development and research on social–cognitive development. Although researchers from both areas share a common interest in infants' developing ability to generate and use information for guiding action, typical research programs are grounded in different methods, analyses, and theoretical frameworks. The current study draws on the strengths of the disparate traditions in social cognition and perception–action research by examining infants' decisions for

walking down slopes of varying degrees as their mothers provide encouraging and discouraging social messages.

Social Cognition Research

The literature on social cognition emphasizes infants' emerging understanding of other people as repositories of knowledge who can adopt varying cognitive and emotional perspectives toward objects and events (e.g., Baldwin & Moses, 1996; Moses, Baldwin, Rosicky, & Tidball, 2001; Tamis-LeMonda & Adolph, 2005). With the realization that caregivers can provide useful social information, infants increasingly turn to them for guidance when they are unsure about how to respond. Infants' capacity to benefit from others' social advice enormously expands opportunities for learning because infants need not rely solely on learning through self-discovery; now infants can seek others' advice in ambiguous situations and respond to unsolicited advice about how to act (Moses et al., 2001).

A common method for studying infants' use of social information derives from the experimental paradigm first introduced by Klinnert, Campos, Sorce, Emde, and Svedja (1983). Infants view a novel object or person (e.g., mechanical toy or stranger), usually selected to be ambiguous. Because a primary aim is to describe infants' changing ability to benefit from various types of social information, the sources of social information are carefully manipulated and controlled. Typically, mothers are instructed to pose specific facial expressions (in most studies, expressions of fear and joy) toward the stimulus, sometimes accompanied by speech, and variations in body position and eye gaze.

In general, findings from the ambiguous object–stranger paradigm indicate that infants respond in line with their mothers' messages. For example, infants are more likely to avoid toys and strangers when their mothers pose facial expressions of fear or anger and to approach when their mothers display joy (Feinman, Roberts, Hsieh, Sawyer, & Swanson, 1992; Saarni, Campos, Camras, & Witherington, 2006). Despite controversy over the precise age at which infants understand the referential nature of social information, most scholars agree that by 12 months of age, infants respond differentially to social messages and, by 18 months, infants intentionally seek and use others' social messages (e.g., Baldwin & Moses, 1996; Corkum & Moore, 1998; Moore & Corkum, 1994).

In a widely cited study, Sorce, Emde, Campos, and Klinnert (1985) examined 12-month-old crawling infants' responses to their mothers' emotional signals on a 30-cm apparent drop-off on the "visual cliff." The height of the drop-off was deemed ambiguous because infants paused at the edge and looked toward their mothers in pilot work. The surface was covered with safety glass to prevent infants from falling; hence the danger was only apparent. As infants crawled toward the apparent drop-off, mothers stood at the far side of the apparatus and posed static facial expressions of fear, anger, interest, or joy. Within the 120-s trials, more infants crawled over the safety glass when their mothers displayed joy (74%) or interest (73%) than when their mothers displayed fear (0%) or anger (11%).

However, a subsequent study failed to replicate these findings with 12-month-old crawling infants on a 25.7-cm drop-off on the visual cliff (Bradshaw, Goldsmith, & Campos, 1987). Most infants (63%) avoided, rather than crossed, the apparent drop-off when

their mothers posed positive facial expressions. Similarly, a recent study (Vaish & Striano, 2004) revealed findings discrepant with the original Sorce et al. (1985) study. Latency to cross onto the visual cliff was longer ($M = 215$ s) than in Sorce et al. (1985) in response to positive facial expressions. The mean latency exceeded the entire trial length (120 s) in Sorce et al. (1985) and would have been coded as avoidance.

Studies based on traditional social cognition paradigms, moreover, are limited for evaluating infants' ability to integrate perceptual cues with caregivers' social messages because in most investigations, the available perceptual information did not vary. All infants viewed the same toy, stranger, or apparent drop-off, on the basis of the assumption that the stimuli were equivalently uncertain for all infants. Sorce et al. (1985) attempted to vary perceptual information by testing samples of infants at the edge of safe-looking (0 cm) and ambiguous-looking (30 cm) drop-offs on the visual cliff. Most of the infants did not glance toward their mothers at the 0-cm increment and thus did not see mothers' facial displays. Moreover, a priori determinations of relative risk do not reflect the immense variation in motor abilities in individual infants at a given age (for reviews, see Adolph & Berger, 2005, 2006). If infants truly weigh and integrate social and perceptual information in making decisions about action, their responses to mothers' messages should vary with the uncertainty of the situation. Infants should be most likely to defer to their mothers' advice when they are uncertain about how to appraise a situation independently. However, a proper test of this hypothesis requires researchers to quantify uncertainty for individual infants so as to test infants' responses to mothers' messages in both unambiguous and ambiguous situations.

Perception–Action Research

Whereas social cognition researchers focus on infants' use of social information, perception–action researchers examine infants' use of perceptual information in making decisions about action (for reviews, see Adolph & Berger, 2005, 2006; Bertenthal & Clifton, 1998). In the standard paradigm, infants' perceptual exploration and motor decisions are evaluated under varying environmental constraints such as variations in object distance, size, shape, and orientation in the case of reaching and grasping actions and variations in surface properties in the case of balance and locomotion (cliffs, slopes, stairs, gaps, bridges, barriers, deformable waterbeds and foam pits, slippery surfaces and shoes, etc.). In many test situations, it is possible to vary environmental properties continuously (e.g., slopes varying in 2° increments from 0°–90°, gaps varying in 2-cm increments from 0–90 cm). At the uncertain and riskier increments, experienced infants typically test possibilities for balance and locomotion by engaging in extended visual inspection, touching the obstacle with hands and feet, and swaying and rocking at the edge of the obstacle. On the basis of the rich arrays of visual, vestibular, and tactile information that are generated by their exploratory behaviors, infants decide whether to continue with their current method of locomotion, modify their gait patterns, adopt an alternative strategy (e.g., slide down slopes in a sitting position), or avoid the obstacle altogether.

Differences in infants' abilities to gauge affordances for balance and locomotion depend largely on the duration of their everyday locomotor experience: More experienced infants explore more

selectively and efficiently and their motor decisions are more accurately tuned to the biomechanical constraints on action (Adolph, 2002, 2005; Adolph & Berger, 2006). For example, when presented with slopes of varying steepness, experienced walkers match the probability of walking to the probability of success—they walk down safe slopes and slide down or avoid risky ones. In contrast, novice walkers display high error rates, plunging down impossibly steep slopes repeatedly (Adolph, 1997; Adolph, Tamis-LeMonda, Ishak, Karasik, & Lobo, 2007).

In contrast to the social cognition literature, perception–action researchers do not always rely on between-subject designs, observations from single trials, and a one-size-fits-all approach to testing infants' decisions about motor action. Instead risk—the probability of success—is estimated individually for each infant across dozens of trials. For example, using psychophysical procedures to estimate a motor threshold, researchers have estimated the degrees of slopes, widths of gaps, heights of barriers, and so on that are possible, impossible, and borderline for each infant (Adolph, 1997, 2000; Adolph & Avolio, 2000; Adolph et al., 2007; Kingsnorth & Schmuckler, 2000; Mondschein, Adolph, & Tamis-LeMonda, 2000). This individualized approach reveals that although experienced sitters, crawlers, and walkers respond adaptively to varying affordances for action, infants vary enormously in their reaching, crawling, and walking abilities even when tested at the same chronological age. Some 14-month-olds can walk down 28° slopes successfully, and others can manage only 4° slopes, but most recognize the limits of their abilities regardless of their level of walking skill.

Perception–action studies, however, tend to ignore the social context of motor action (Tamis-LeMonda & Adolph, 2005). Conceptually, infants are treated as solitary agents when, in reality, the testing situation involves social interaction. Infants' caregivers typically serve as their goals, offering toys and positive encouragement to entice infants to navigate the obstacle. Thus, an interesting contrast would be to examine how infants respond in the context of maternal discouragement. Whereas studies on infants' social cognition rarely manipulate perceptual information by varying environmental constraints, perception–action studies rarely manipulate social information by offering infants varying social messages. Consequently, researchers know little about how infants weigh available perceptual information against different social messages in the process of arriving at a course of action.

Current Study

We merged the disparate methods and constructs of social cognition and perception–action research to examine infants' use of perceptual information generated by their own spontaneous exploratory activity with unsolicited social information provided by their mothers. We focused on infants' use of unsolicited social information because of the low base rates of infants' seeking social information. Because experienced 18-month-old walking infants might not seek mothers' advice on slopes that are shallow or deep, a focus on solicited social information would result in subject attrition if the entry into the study depended on infants' information seeking.

We asked whether infants integrate perceptual and social information in the context of a potentially risky motor task, in which infants were encouraged and discouraged by their mothers to walk down slopes varying in slant. In a preliminary normalization phase of the study, we used a psychophysical procedure to determine slopes that were safe, risky, and borderline for each infant. Safe slopes were well within each infant's ability and risky slopes were well beyond their ability, so these increments should be well specified by perceptual information. Borderline slopes were at the outer limits of each infant's ability, so these increments should be relatively ambiguous. In a subsequent test phase, mothers encouraged their infants to walk and discouraged them from walking down slopes at these individualized risk levels. We tested 18-month-olds because, by this age, infants have several months of walking experience and respond adaptively to perceptual information (Adolph & Berger, 2006) and 18-month-olds use social information effectively (Baldwin & Moses, 1996; Moore & Corkum, 1994).

In real life situations, the information available to infants depends on infants' spontaneous perceptual exploration (looking, touching, position shifts, etc.) and on the dynamics of mother–infant interactions (mothers' vocalizations, gestures, facial expressions, etc.). Therefore, our study was designed as a laboratory analogue of infants' everyday locomotor actions and the natural ways that mothers communicate about safety and danger (Karasik, Tamis-LeMonda, Adolph, & Dimitropoulou, in press; Tamis-LeMonda, Adolph, Dimitropoulou, & Zack, 2007). Infants were free to explore and locomote as they chose: On every trial, they could visually and tactually explore the surface and surrounds, remain on the starting platform, attempt to walk, or descend using alternative strategies (e.g., backing, crawling). Slopes were not covered in safety glass; thus, errors in judgment resulted in the aversive consequence of falling (an experimenter rescued infants to prevent injury).

Similarly, the social information provided by mothers was largely unconstrained. Aside from being told when to encourage and when to discourage walking, mothers were free to communicate their social message using whatever facial expressions, voice intonation, words, gestures, and body movements they chose. Moreover, mothers provided unsolicited advice—they encouraged and discouraged regardless of whether infants solicited advice spontaneously. Outside the laboratory, caregivers attempt to regulate infants' behaviors by imposing unsolicited social information as well as in response to infants' bids for help (Feinman et al., 1992; Tamis-LeMonda et al., 2007).

As a central test of infants' ability to weigh and integrate social and perceptual information, the study design enabled us to examine infants' behaviors when social and perceptual information were concordant versus discrepant. If infants base their decisions for action primarily on perceptual information, decisions to walk should vary only with risk, not with mothers' social messages. If infants base their decisions primarily on social information, then infants should attempt to walk when their mothers encourage walking and avoid walking when their mothers discourage walking, regardless of risk level. However, we knew from previous work that experienced walkers ignore discordant social information on risky slopes, that is, attempt rates are low in the face of maternal encouragement. Finally, if infants integrate social and perceptual information in forming decisions about action, then their use of social information should be selective: Infants should ignore mothers' advice to walk on slopes that are clearly risky and

to not walk on slopes that are clearly safe but heed mothers' advice on borderline slopes where perceptual information is uncertain.

As in previous work from the perception–action tradition, we investigated the perceptual information that might underlie infants' motor decisions. We assessed infants' latency to make a motor decision and their exploratory touching and shifts in position on the starting platform. We also coded the affective and social responses that might accompany infants' motor decisions, including positive–neutral and negative facial and vocal affect, and vocalizations and manual gestures directed toward their mothers. Earlier work sets a strong, empirical precedent for the inclusion of such measures as indicators of wariness in uncertain situations (Sroufe, 1977).

Method

Participants

Families were recruited from a greater metropolitan area via mailing lists, brochures, and referrals. They received small souvenirs as thanks for their participation. A strict inclusion criterion was implemented, in that only infants who completed both phases of the study (initial psychophysical procedure and subsequent test trials) were included. Twenty-four mothers (*M* age = 35.71 years, *SD* = 5.37) and their infants (13 girls, 11 boys) met this criterion. Data from an additional 22 infants were excluded: 7 infants became fussy during the psychophysical procedure; 14 infants completed the psychophysical procedure but could not complete the test trials (7 during the encourage condition, 4 during the discourage condition, and 3 were too fussy to begin test trials); and 1 infant completed the psychophysical procedure but data from test trials were accidentally not recorded. The overall attrition rate for the psychophysical procedure (7/46 = 15%) is similar to that in previous cross-sectional studies using a psychophysical procedure with infants on slopes (e.g., 24.26% in Adolph & Avolio, 2000). The attrition rate for the test trials (11/39 = 28%) compares favorably to previous work with social messages on the visual cliff (40% in Sorce et al., 1985; 49% in Vaish & Striano, 2004). Infants in the current study contributed approximately 30 trials in the psychophysical part of the experiment and then 24 subsequent test trials compared with only 2 test trials total in previous studies varying social messages on the visual cliff.

Infants' age averaged 18.08 months at the time of testing (*SD* = 0.21). Most families were White, middle class, and highly educated (62% of parents held professional or graduate degrees). All mothers spoke English as the primary language at home and were infants' primary caregivers. With the help of baby books and calendars, mothers reported infants' locomotor experience during a structured interview (Adolph, 2002). Walking onset was defined as the date when infants were first able to walk continuously a distance of at least 10 feet without support. Infants' walking experience ranged from 2.17 months to 8.38 months (*M* = 5.70 months). Experience data from one infant were not reliable and were excluded from analyses.

Sloping Walkway

Infants were tested on an adjustable, sloping walkway (see Figure 1). A flat starting platform (86 cm wide × 182 cm long) and
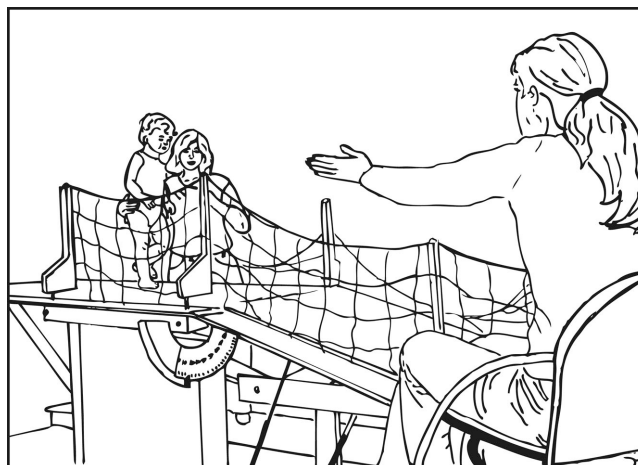

Figure 1. Walkway with adjustable slope. Infants began in a standing position on the flat starting platform. The middle portion of the walkway adjusted in 2° increments from 0° to 90°. During test trials, mothers sat on a raised platform adjacent to the flat landing platform. An experimenter followed alongside infants to ensure their safety.

flat landing platform (86 cm wide × 91 cm long) were connected to a center sloping ramp (86 cm wide × 91 cm long) with piano hinges. An electric garage door opener, operated with a push-button remote, adjusted the height of the landing platform from 116 to 25 cm. The height of the starting platform remained fixed at 116 cm. As the landing platform lowered, the degree of slope adjusted from 0° to 90° in 2° increments. Plush carpeting covered the walkway to provide traction and padding for safety. Wooden posts at each corner of the walkway provided infants with additional support. Nets extended along the sides of the walkway as a safety precaution.

Procedure

Infants were tested in two phases. In an initial normalization phase, we used a psychophysical procedure developed in previous work (e.g., Adolph, 1995, 1997) to normalize risk levels to each infant's ability to walk down slopes. To encourage infants to demonstrate the limits of their walking ability, mothers and experimenters told infants to walk, applauded their efforts, and offered toys and dry cereal as incentives to descend. On the basis of the individualized estimates of risk levels, in a subsequent test phase, mothers offered encouraging and discouraging social information on safe, risky, and borderline slopes. To highlight mothers' social message, experimenters did not speak or gesture to infants during the test trials, large screens hid infants' view of distracting areas of the laboratory, and toys and food were removed so that mothers' messages provided the sole incentive to descend.

In both phases, an experimenter walked alongside infants to ensure their safety (shown in Figure 1). An assistant videotaped infants from the side of the walkway to capture a full view of their locomotor and exploratory movements. During the test trials, a second assistant videotaped infants from the bottom of the walkway for a close-up view of their faces. A third camera stationed at the top of the walkway was operated remotely to record mothers' faces and torsos. A shotgun microphone directly above the walk-

way enhanced the quality of infants' vocalizations and mothers wore wireless microphones to pick up their messages. The various camera views and sound signals from infants' and mothers' microphones were mixed online onto a single audio and video stream for later coding and analyses.

Normalization phase: Psychophysical procedure. Infants began each trial in a standing position on the starting platform. Mothers stood at the end of the landing platform and coaxed their infants to walk. Trials began after the experimenter released infants on the starting platform and infants oriented toward the landing platform. Trials ended when infants reached the landing platform or after 30 s if infants avoided descent.

Protocols began with four warm-up trials at 0° to teach infants the game of walking over the platform and to acclimate them to the raised walkway. Then, starting with an easy 4° baseline slope, an assistant increased or decreased the degree of slope depending on the outcome of the previous trial. The assistant coded each trial online as a success (walked safely), failure (tried to walk but fell), or refusal to walk (avoided descent or slid down). Failures and refusals were treated as equivalent unsuccessful outcomes. After successful trials, the experimenter increased the slant by 6°. After two consecutive unsuccessful trials, the experimenter decreased the degree of slant by 4°. Easy 4° baseline trials were interspersed throughout the protocol to maintain infants' motivation to walk. The rule of "plus 6°, minus 4°" continued until reaching a ≥67% criterion for estimating the limits of infants' ability, their borderline slope: the steepest slope at which infants walked successfully on at least two thirds of trials and unsuccessfully on at least two thirds of trials at the next 2°, 4°, and 6° increments. Because protocols were tailored to infants' individual propensities, infants received different numbers of trials during the normalization phase ($M = 31.08$ trials, *range* = 21 to 49 trials).

Test phase: Social messages. Before starting the test phase, an experimenter explained the encouraging and discouraging conditions to mothers. Mothers were instructed to use words, gestures, and facial expressions in whatever way seemed natural to communicate encouragement and discouragement to their infants. In the encouraging condition, the experimenter told mothers to "get their infants to try to walk down the slopes;" she told mothers to treat the task like the dozens of everyday situations in which they encourage their infants to tackle new challenges. In the discouraging condition, the experimenter told mothers to "prevent their infants from trying to walk down the slopes, to treat the walkway as if it were a sheet of ice that would jeopardize infants' safety." Mothers were instructed to disregard the steepness of the slopes when delivering their messages, so as to ensure that their communications were consistent across risk levels. Mothers were assured that the experimenter would catch their infants if they started to fall.

During the test trials, mothers sat in a chair placed on a raised platform alongside the landing platform (see Figure 1), situating them at infants' eye level but out of reach. An assistant rang a bell to signal mothers to begin encouraging or discouraging their infants while the experimenter held infants stationary at the top of the slope for 2 s. This ensured that infants would receive a social message at the start each trial. After the experimenter released the infants, mothers were free to continue delivering their message according to their own judgment of whether infants were likely to walk or refuse to walk down the slope. This permitted infants the opportunity to gather perceptual information while attending to unsolicited social information from mothers. Trials ended when infants reached the landing platform or after 30 s. Experimenters did not speak during the test trials.

Encouraging and discouraging conditions were counterbalanced across sex with half of the boys and half of the girls receiving each condition order first. Infants received 24 test trials in total. Five slope increments were presented in four quasi-random orders in each condition: 2 trials on safe slopes 10° shallower than infants' borderline slope, 2 trials on risky slopes 10° steeper than infants' borderline slope, 3 trials on borderline slopes at the limits of infants' ability, and 2 trials on 4° and 2 trials on 50° slopes to anchor infants' motor decisions. The borderline slopes were of particular interest because we expected infants to be most likely to defer to their mothers' messages at the increment at which they were most uncertain of their ability to walk. In addition, infants received a 4° baseline trial (always with mothers encouraging) at the end of each condition to maintain their interest and motivation to walk. Thus, infants received 2 more encouraging than discouraging trials.

Data Coding

Content of mothers' message. For each test trial, coders scored encouragement whenever mothers either verbally coaxed their infants to walk down the slope (e.g., "Come on," "Come here," "Walk down") or used manual gestures to beckon their infants with outstretched or waving arms (including clapping). Discouragement was coded whenever mothers used words or gestures to prohibit their infants from walking (e.g., "No," "Don't," "Stop," "Sit down," "Don't walk" or wagged a finger back and forth to indicate "No, no"), instruct their infants to remain on the starting platform (e.g., "Stay there," "Wait," or held out her hand or finger to indicate "Stop" or "Stay"), or describe the dangers of the slope (e.g., "It's steep," "You'll fall"). Coders agreed on 99.7% of the trials, ($\kappa = .993$, $p < .01$).

Motor decisions. Two coders independently scored every test trial from each infant as successful attempts to walk, failed attempts to walk, or refusals to walk (infants slid down in sitting, backing, headfirst prone, and kneeling positions or avoided descent). Coders agreed on infants' attempts and method of descent on 95% of test trials ($\kappa = .93$, $p < .01$).

Decision time. Two coders scored decision time for each test trial on the basis of infants' latency to initiate descent. Latency could range from 0 s (immediate decision) to 30 s (maximum trial length). The correlation between coders' scores of infants' latency was .97 ($p < .01$).

Perceptual exploration. During the time infants hesitated, they sometimes generated perceptual information by touching slopes and by testing alternative locomotor positions. Two coders scored the portion of each test trial while infants remained on the starting platform for touching (by rubbing their hands across the slope or probing the slope with their feet, all the while looking at the slope) and frequency of position shifts (squatting, kneeling, sitting, crawling on hands and knees, and lying prone facing down the slope or with the feet toward the landing platform). Coders agreed on 93.7% of test trials for touching ($\kappa = .81$, $p < .01$) and 92.7% for position shifts ($\kappa = .96$, $p < .01$).

Facial and vocal expressions. Facial affect was classified as either negative or positive–neutral; both types could occur in a single trial. Negative facial affect included downward curls of the mouth, frowns, and scrunched eyebrows. All other facial expressions, ranging from broad smiles to flat affect, fell into the positive–neutral classification. Vocalizations included any affective or linguistic sounds that infants produced. They were categorized as negative or positive–neutral affect. Negative vocalizations included whining, whimpering, and crying. Any sounds that were not negative, including babbling and laughing, were coded as positive–neutral vocal affect.

Gestures. Gestures included several communicative manual and head movements: "pick-me-ups" (outstretched arms toward mother or experimenter), "points" (fingers extended in the direction of the slope or infants' mother, sometimes showing their mother an object or part of their body), clapping, head nods ("yes"), and head shakes ("no"). Coders agreed on 93.1% of test trials for facial affect ($\kappa = .94$, $p < .01$), 98.1% for vocal affect ($\kappa = .96$, $p < .01$), and 96.4% for gestures ($\kappa = .89$, $p < .01$).

Results

To verify the results of the online psychophysical procedure, we rescored infants' success at walking down slopes from videotapes using a computerized video coding system, MacSHAPA (www.openshapa.org), that records the frequencies and durations of specific behaviors (Sanderson et al, 1994). A second coder scored 25% of each infant's psychophysical trials. Coders agreed on 97.3% of trials ($\kappa = .95$, $p < .01$). Borderline slopes calculated from the video coding showed discrepancies of $\pm 2°$ with 3 of the 24 estimates calculated online. Given the small size of the discrepancies, we retained these infants' data in the analyses of test trials.

As shown in Figure 2, infants' walking abilities varied widely, highlighting the need to individualize risk level for each infant. Borderline slopes ranged from 12° to 40° ($M = 24°$), meaning that safe slopes for some infants were impossibly risky for others.
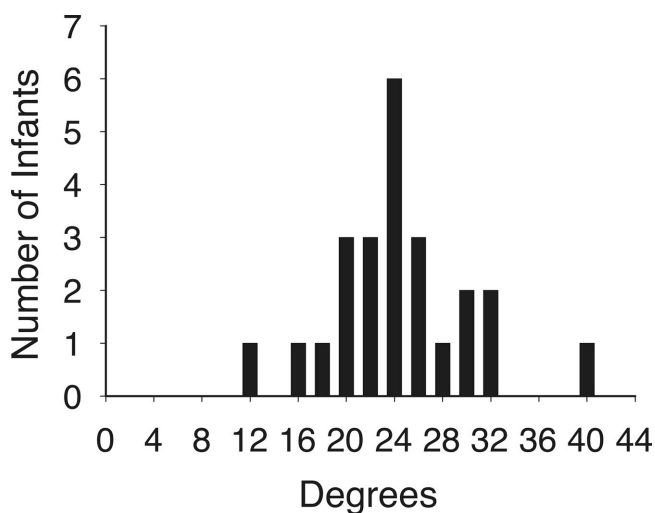

Figure 2. Distribution of borderline slopes derived from the psychophysical procedure (the steepest slope each infant walked down successfully on $\geq 2/3$ trials).

Infants with longer durations of walking experience had steeper borderline slopes, providing an independent verification of the estimates of borderline slopes, $r(22) = .49$, $p < .02$.

Mothers' Message

During the initial stages of study design we were concerned that mothers might be unable to transition fluidly between encouragement and discouragement in the same laboratory task. Therefore, trials were blocked into encouraging and discouraging conditions so that mothers did not switch messages from trial to trial. We were also concerned that mothers might unintentionally vary their messages as a function of risk, despite our instructions to ignore the degree of slant (e.g., displaying lower levels of encouragement on risky slopes than safe ones). Therefore, a manipulation check was conducted prior to the main study analyses to verify that mothers carried out the instructions to encourage and discourage similarly across safe, borderline, and risky slopes.

Specifically, 18 lab members (14 women, 4 men) watched 70 video clips of 13 mothers (randomly sampled from the current participants) encouraging and discouraging their infants. Lab members had at least 6 months of experience coding the sorts of variables reported in the current study. Half of the video clips were from the encourage and half from the discourage condition. In each condition there were equal number of safe, borderline, and risky trials. The video clips were edited using Adobe Premiere 6.5 so that coders could see only mothers' faces and torsos and hear their messages. Infants' behaviors and information about the slope were edited out of the video frame. Coders were shown the first 5 s of each of the 70 trials, one clip at a time. Clips were limited to the first 5 s because discouraging trials tended to be longer because of infants' longer latencies, which might bias coders' accuracy upward. A 5-s period also ensured that infants received the social message since mothers were given time to deliver their message before infants were released onto the slope.

On the basis of these clips, the coders' task was to identify the social message condition (encourage or discourage) and the risk level of the slope (safe, borderline, or risky). Coders were allowed to view clips a second time if they requested to do so. Findings of the manipulation check revealed that coders were at chance levels when attempting to judge risk level ($M = 35\%$, $SD = 4.9$; chance = 33%). That is, even experienced coders could not judge the risk level based on mothers' behaviors. However, coders accurately identified the social message on 89% of the video clips ($SD = 3.0$; chance = 50%).

Analyses contrasting mothers' verbal and gestural behaviors on the basis of the videotaped coding of the two conditions further supported this high level of subjective accuracy in the manipulation check. Mothers encouraged their infants on 93.7% of the encouraging test trials and discouraged their infants on 93.5% of the discouraging test trials. Approximately 20% of test trials contained both types of social information; mothers encouraged on 19.9% of the discouraging trials and discouraged on 20% of the encouraging trials. These discrepant trials were due to mothers encouraging other forms of descent (e.g., sliding down) in the discouraging condition and discouraging these same alternative strategies in the encouraging condition. A 2 (condition) × 2 (encouraging vs. discouraging message type) analysis of variance (ANOVA) on mothers' messages revealed only a significant in-

teraction, $F(1, 23) = 317.93$, $p < .001$, confirming that mothers' messages were appropriate to the target condition.

On 20 of the 481 test trials (4%), mothers did not deliver either an encouraging or discouraging message. In all cases, infants' latency was less than 4 s, and in the brief instance that mothers had to get their message across, they used that time to orient their infants (e.g., "Lily!" "Hey").

Do Infants Take Mothers' Advice?

Note that the five risk levels included both normalized ($-10°$ relative to the borderline increment, the borderline slope, and $+10°$ relative to the borderline) and absolute degrees of slope ($4°$ and $50°$). However, the increments were ordered by increasing risk: $4°$, $-10°$, borderline, $+10°$, and $50°$, with two exceptions. The $4°$ slope was shallower than the $-10°$ slope for all infants except the one with the $12°$ borderline slope (she received $-10°$ trials at $2°$ and $4°$ trials and baseline trials at $4°$). The $50°$ slope was steeper than the $+10°$ slope for all infants except the one with the $40°$ borderline slope (he received 8 trials at $50°$; 4 trials counted toward the $+10°$ risk level and 4 trials toward the $50°$ risk level).

Initial analyses showed no effects of condition order or risk order on infants' behaviors ($ps > .10$). Thus, we collapsed the data across presentation orders for further analyses. For each behavioral variable, data were subjected to a 2 (social message condition: encouraging vs. discouraging) $\times$ 5 (risk levels: $4°$, $-10°$, borderline, $+10°$, $50°$) repeated measures ANOVA. Main effects for risk were further analyzed for linear and quadratic trends only across the three normalized risk levels because the intervals between the normalized and absolute degrees of slope differed across infants. Interactions were followed up with paired t tests between conditions at each risk level. Because each set of post hoc tests required five comparisons (between conditions at each of the five risk levels), a Bonferroni-adjusted alpha level of $p < .01$ was used to correct for experiment-wise error rates (overall $p = .05$).

Motor decisions. We indexed infants' motor decisions on the basis of the frequency of their attempts to walk (see Figure 3A). A 2 (social message condition) $\times$ 5 (risk levels) ANOVA on attempts to walk revealed main effects for condition, $F(1, 23) = 16.01$, $p < .01$, partial $\eta^2 = .41$, confidence interval (CI)$_{.95} = .07$, $.23$; risk level, $F(4, 92) = 92.73$, $p < .01$, partial $\eta^2 = .80$; and a Condition $\times$ Risk Level interaction, $F(4, 92) = 8.29$, $p < .01$, partial $\eta^2 = .27$. All effect sizes were large in magnitude. The main effect for condition confirmed that infants use social information from their mothers to guide their motor decisions. Overall, infants were more likely to walk when mothers encouraged ($M = .66$, $SD = .14$, CI$_{.95} = .50$, $.63$) than when they discouraged ($M = .39$, $SD = .21$, CI$_{.95} = .33$, $.50$). Nineteen infants displayed the group pattern of attempting more frequently in the encourage condition at the borderline slope (examples of individual infants' data are shown in Figures 4A–4C). Four infants ignored their mothers' advice; their curves were superimposed across risk levels (Figure 4D shows an exemplar infant). The remaining infant was inconsistent: He walked more frequently in the encourage condition at $+10°$ and more frequently in the discourage condition at $50°$. None of the infants deferred to mothers' advice by only walking when she told them to walk and refusing when she told them to refuse, regardless of risk level.

The main effect for risk level corroborated previous work showing that infants use perceptual information about the slope of the ground surface to guide their locomotor actions (e.g., Adolph, 1995). Follow-up analyses revealed a linear trend over normalized risk levels, indicating that attempts to walk decreased with increasing risk, $F(1, 23) = 349.20$, $p < .01$. The frequency of attempts to walk was high at the $4°$ slope ($M = .95$, $SD = .10$); 18 infants walked down the $4°$ slope on every test trial. But the proportion of attempts dropped to $.06$ ($SD = .15$) at the $50°$ slope; 20 infants never attempted to walk down the impossible $50°$ slope. Most infants' attempts were successful (80.7%). Failures were most common at the borderline (45.1% of failure trials) and $+10°$ slopes (23.5% of failure trials).

Most notably, the interaction effect showed that infants' motor decisions take both social information and risk level into account. As shown in Figure 3A, the largest disparity in attempts to walk was at the borderline slope at which risk of falling was most uncertain by definition. Infants were nearly three times more likely to attempt the borderline slope in the encouraging condition ($M = .74$, $SD = .35$, CI$_{.95} = .59$, $.89$) than in the discouraging condition ($M = .27$, $SD = .34$, CI$_{.95} = .13$, $.42$), representing a very large effect size. Post hoc comparisons confirmed that infants selectively deferred to mothers' social message only at the borderline slope, $t(23) = -6.04$, $p < .01$, $d = .26$, CI$_{.95} = -.63$, $-.31$; they ignored mothers' advice at the other increments.

Decision time. Infants' latency to make a motor decision was analyzed in a 2 (condition) $\times$ 5 (risk level) repeated measures ANOVA. Findings revealed main effects for condition, $F(1, 23) = 18.53$, $p < .01$, partial $\eta^2 = .45$, CI$_{.95} = -6.92$, -2.43, and risk level, $F(1, 92) = 15.25$, $p < .01$, partial $\eta^2 = .40$ (see Figure 3B). Mothers' encouraging social messages led infants to a quicker decision ($M = 4.36$ s, $SD = 4.87$, CI$_{.95} = 2.51$, 7.29), whereas discouragement caused infants to hesitate longer on the starting platform ($M = 10.07$ s, $SD = 8.45$, CI$_{.95} = 6.09$, 13.06). The time it took for infants to make a decision increased with risk. The fastest decisions were on the $4°$ slopes ($M = 2.32$ s, $SD = 3.23$) and slowest decisions were on the $50°$ slopes ($M = 11.46$ s, $SD = 9.76$). Trend analyses confirmed a linear trend for risk level across normalized slopes, $F(1, 23) = 29.71$, $p < .01$. All effect sizes were large.

Perceptual Exploration

Touching. Despite longer latencies in the discouraging condition, tactile exploration was related only to risk level. A 2 (condition) $\times$ 5 (risk level) repeated measures ANOVA on touching showed only a main effect for risk, $F(4, 92) = 7.73$, $p < .01$, partial $\eta^2 = .25$ (see Figure 3C). Touching increased between the $4°$ and borderline slopes and then decreased slightly on the $50°$ slope. Follow-up analyses revealed linear, $F(1, 23) = 5.57$, $p < .03$, and quadratic trends, $F(1, 23) = 21.13$, $p < .02$, across normalized risk levels. Infants were more likely to touch slopes with their feet (93.3% of touch trials) than with their hands (11% of touch trials), probably because they began trials in an upright position.

Position shifts. A 2 (condition) $\times$ 5 (risk level) repeated measures ANOVA on the frequency of position shifts per trial revealed main effects for condition, $F(1, 23) = 8.74$, $p < .01$, partial $\eta^2 = .28$, CI$_{.95} = -.42$, $-.08$, and risk level, $F(4, 92) =$
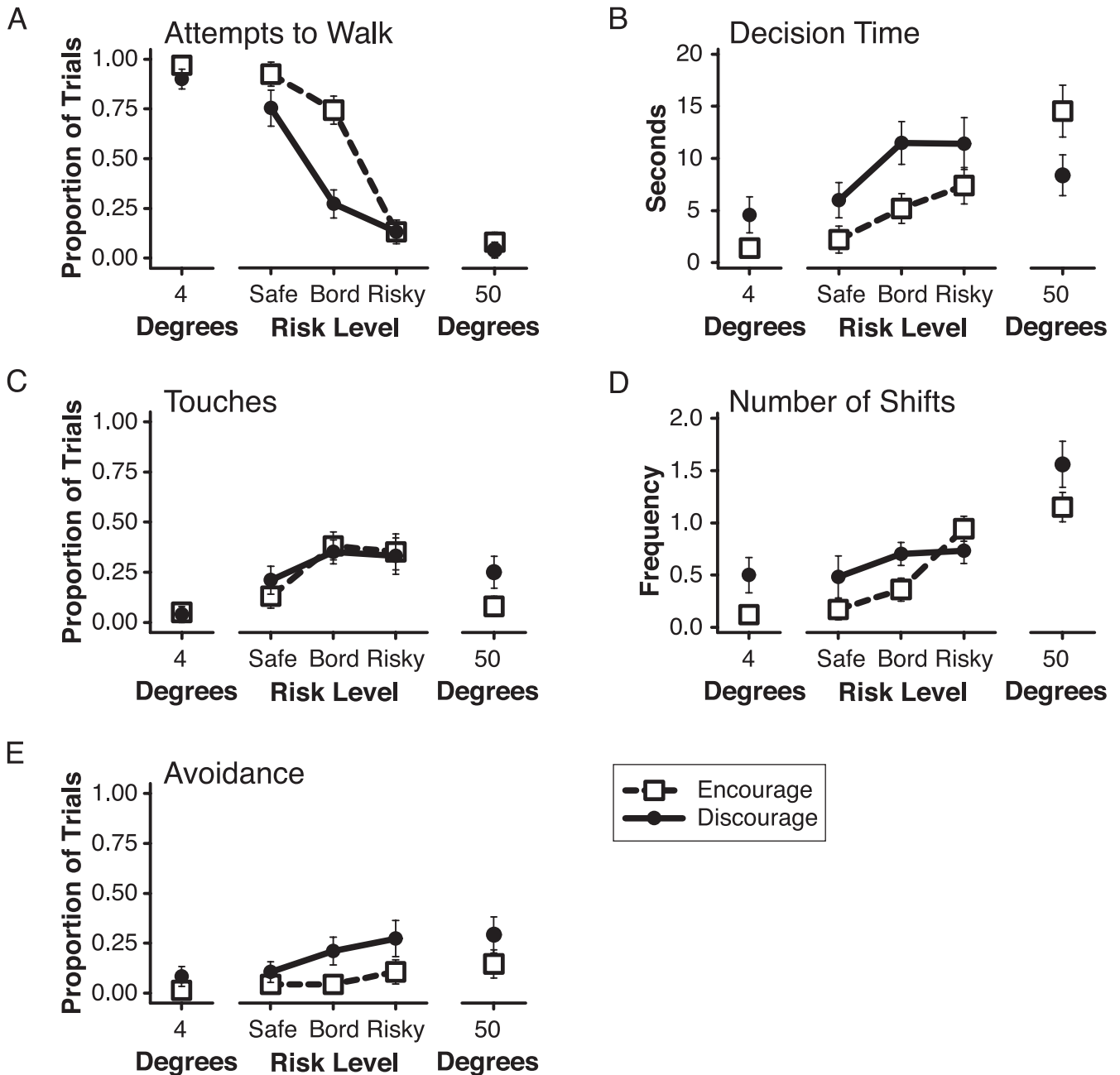
Figure 3. Motor decisions and exploratory behaviors by social condition and risk level. A: Proportion (Ppn.) of trials in which infants attempted to walk down slopes. B: Latency to begin descent. C: Proportion of trials in which infants touched slopes with hands or feet. D: Number of discrete shifts in position on the starting platform. E: Proportion of trials in which infants avoided descent. The *x*-axis is labeled with five slope increments in order of increasing slope and risk: 4° (absolute degree of slope), safe (10° shallower than infants' borderline slopes), borderline slope, risky (10° steeper than infants' borderline slopes), and 50° (absolute degree of slope). Error bars represent standard errors.

20.34, $p < .01$, partial $\eta^2 = .47$ (see Figure 3D). Again, all effect sizes were large. Infants shifted more in the discouraging condition ($M = .78$, $SD = .4$, $CI_{.95} = .62$, .97) than in the encouraging condition ($M = .46$, $SD = .30$, $CI_{.95} = .40$, .69). Shifts increased with risk level. Follow-up analyses showed a linear trend, $F(1, 23) = 43.24$, $p < .01$,

and a quadratic trend, $F(1, 23) = 7.37$, $p < .01$, across normalized risk levels. The number of position shifts ranged from zero to five. Infants tested two or more positions on 14.1% of test trials; multiple shifts were especially prevalent on the 50° slope. The most common shift was from standing to sitting (40% of shift trials).
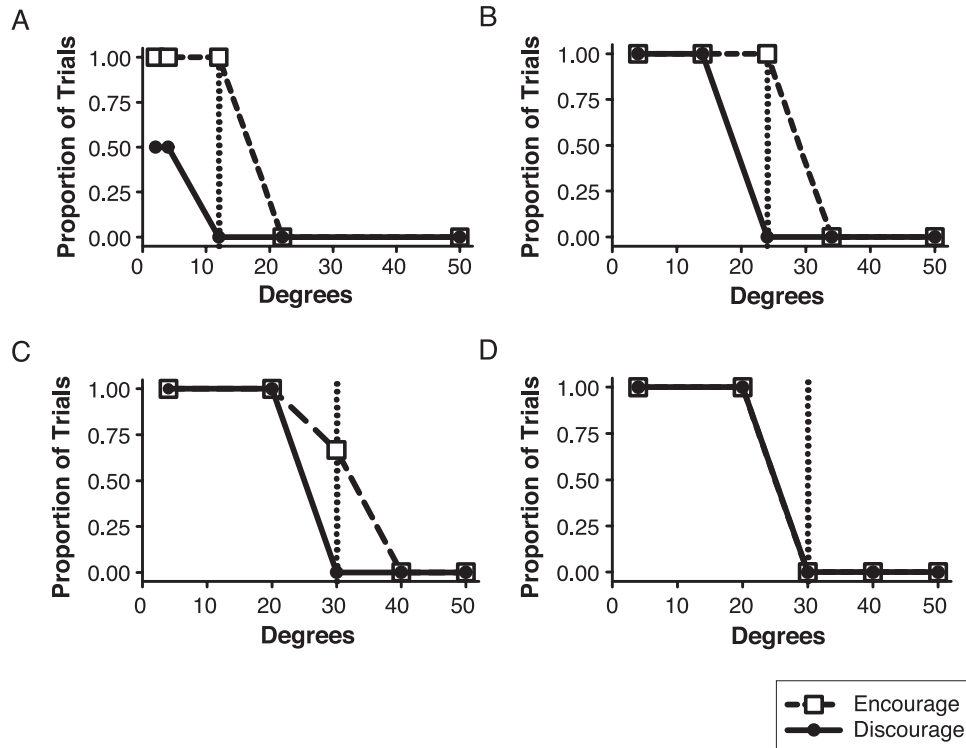
Figure 4. Exemplar graphs of infants' attempts to walk down slopes in each social message condition: infants with low (A), average (B), and high (C) borderline slopes whose attempt rates differed by social condition at the borderline slope. D: Infant whose attempt rates changed only with risk level. Dotted vertical lines represent each infant's borderline slope: 12°, 24°, 30°, and 30° for A, B, C, and D, respectively. Attempts are plotted against absolute degree of slope. Ppn. = proportion.

On trials when infants shifted position, they were more likely to descend using an alternative sliding position (73.8% of shift trials) than to walk (8.6% of shift trials) or avoid descent (17.6% of shift trials). The most common sliding positions were sitting (47.5% of refusal trials) and backing feet first (13.4%). As shown in Figure 3E, avoidance was more likely in the discouraging condition ($M = .19$, $SD = .06$, $CI_{.95} = .08$, .31) than in the encouraging condition ($M = .07$, $SD = .04$, $CI_{.95} = -.01$, .15). A 2 (condition) $\times$ 5 (risk level) repeated measures ANOVA on avoidance revealed main effects for condition, $F(1, 23) = 13.13$, $p < .01$, partial $\eta^2 = .36$, $CI_{.95} = -.19$, $-.05$, and risk level, $F(4, 92) = 4.58$, $p < .01$, partial $\eta^2 = .17$. Follow-up analyses confirmed a linear trend for risk level across normalized slopes, $F(1, 23) = 7.9$, $p < .02$.

Infants' Social Communication

Facial expressions. Infants' facial and vocal affect were primarily positive–neutral in both encouraging and discouraging conditions. Across risk and conditions, infants consistently displayed positive–neutral facial affect ($M = .98$, $SD = .07$, $CI_{.95} = -.19$, $-.05$) but rarely expressed negative facial affect ($M = .08$, $SD = .13$, $CI_{.95} = -.19$, $-.05$), $t(23) = 22.51$, $p < .01$, $d = 4.72$, $CI_{.95} = .81$, .97. Repeated measures ANOVAs with 2 (condition) $\times$ 5 (risk level) on infants' positive–neutral facial affect (see Figure 5A) and negative facial affect (see

Figure 5B) did not reveal any effects for condition, risk, or their interaction, suggesting that infants were equally positive–neutral and negative across levels of risk regardless of whether mothers encouraged or discouraged.

Vocalizations. Infants vocalized on only 28.1% of probe trials. As with facial affect, most trials with vocalizations included only positive–neutral vocalizations (82.2% of trials with vocalizations) rather than only negative vocalizations (5.2% of trials) or both positive–neutral and negative vocalizations (12.6% of trials). Only 10 of the 24 infants produced a negative vocalization. A 2 (condition) $\times$ 5 (risk level) repeated measures ANOVA on positive–neutral vocalizations revealed main effects for condition, $F(1, 23) = 4.91$, $p < .05$, partial $\eta^2 = -.18$, $CI_{.95} = -.18$, $-.01$, and risk level, $F(4, 92) = 11.33$, $p < .01$, partial $\eta^2 = .33$ (see Figure 5C). Infants were more likely to emit positive–neutral vocalizations in the discouraging condition ($M = .35$, $SD = .29$, $CI_{.95} = .22$, .46) than in the encouraging condition ($M = .23$, $SD = .22$, $CI_{.95} = .15$, .34). Trend analyses showed that positive–neutral vocalizations increased with normalized risk level, $F(1, 23) = 33.57$, $p < .01$.

A 2 (condition) $\times$ 5 (risk level) repeated measures ANOVA on infants' negative vocalizations did not reveal significant main effects or an interaction. Therefore, infants were not more likely to display negative vocalizations in the discouraging condition or on risky slopes (see Figure 5D). Moreover, infants
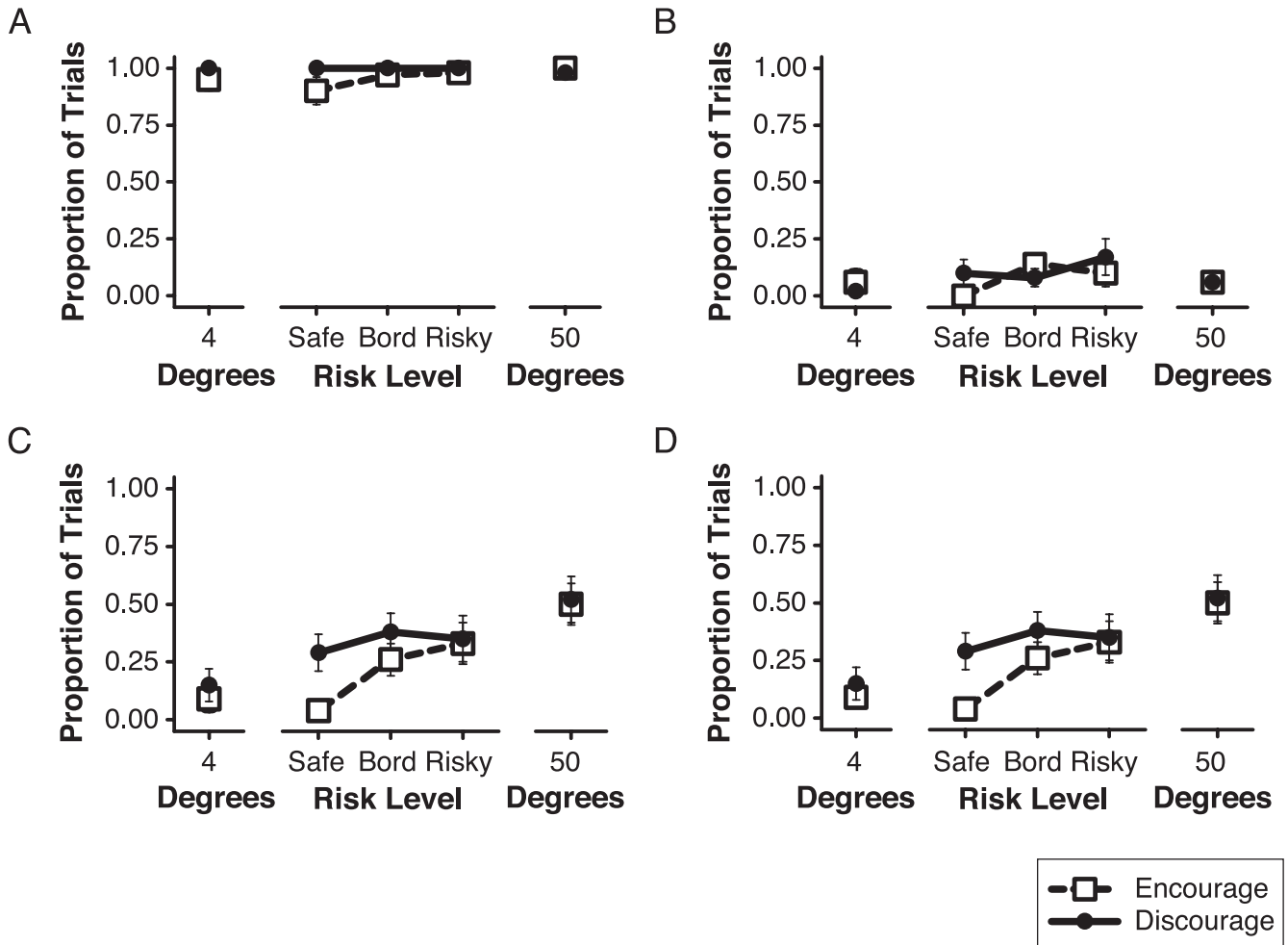
Figure 5. Facial and vocal affect by social condition and risk level. Proportion (Ppn.) of trials in which infants displayed (A) positive–neutral facial affect, (B) negative facial affect, (C) positive–neutral vocalizations, and (D) negative vocalizations. The *x*-axis is labeled with five slope increments in order of increasing slope and risk: 4° (absolute degree of slope), safe (10° shallower than infants' borderline slopes), borderline slope, risky (10° steeper than infants' borderline slopes), and 50° (absolute degree of slope). Error bars represent standard errors.

displayed positive–neutral expressions regardless of whether they walked down slopes (97.2% of walk trials), slid down (97.9% of slide trials), or avoided descent (98.3% of avoid trials). The few trials with negative facial or vocal affect occurred primarily when infants avoided (29.3% of avoid trials), rather than walked (6.0% of walk trials) or slid down (8.7% of slide trials).

Gestures. Gestures were infrequent across all levels of risk and conditions ($M = .12$, $SD = .32$). Gestures were primarily manual (98% of trials with gestures) rather than head gestures (11% of trials with gestures). Half of the manual gestures were pick-me-ups directed at the mother and points to the slope (52%). A 2 (condition) $\times$ 5 (risk level) repeated measures ANOVA for infants' gestures revealed a main effect for risk level, $F(4, 92) = 4.23$, $p < .01$ partial $\eta^2 = .16$. Trend analyses showed an increase in gestures across normalized risk levels, $F(1, 23) = 7.43$, $p < .02$.

Discussion

The main goal of this study was to examine whether infants weigh and integrate perceptual and social information when making decisions about motor action. Of particular interest was whether social information would prevail when perceptual information was inadequate and whether social or perceptual information would be more influential when the two sources of information were in conflict. On safe slopes, discouraging social information was in conflict with perceptual information and encouraging social information was concordant. On risky slopes, the opposite was true. On borderline slopes, perceptual information was most uncertain. In previous work conducted from the perception–action approach, caregivers offered only unsolicited encouragement across a range of slopes, and experienced crawling and walking infants decreased their attempts to crawl and walk on increasingly risky increments (Adolph, 1995, 1997; Adolph &

Avolio, 2000; Mondschein et al., 2000). Thus, we expected that experienced 18-month-old walkers would continue to rely on perceptual information on risky slopes regardless of mothers' message. However, if infants showed a lower attempt rate on risky slopes when mothers discouraged walking (concordant social information), we would conclude that social information was also playing a role in infants' motor decisions. That is, encouragement on risky increments (discordant social information) was likely increasing infants' attempt rates in the previous work.

Consistent with previous work from the perception–action approach, infants relied on their own appraisal of safe and risky slopes. They nearly always walked down safe slopes within their ability ($M = 90.7\%$ of trials at $4°$ and $-10°$), even when their mothers discouraged walking. And, they rarely attempted risky slopes beyond their ability, even when their mothers encouraged them to walk ($M = 11.7\%$ of trials at $+10°$ and $50°$). Thus, at safe and risky increments, attempt rates were similar in the two social message conditions, suggesting that when social and perceptual information are in conflict, perceptual information is more influential.

Selective Use of Social Information

Most striking were infants' motor decisions at the borderline slopes. At these slopes, the probability of walking successfully was most uncertain, and infants followed their mothers' advice. They attempted to walk on 74% of trials when mothers encouraged them to walk but on only 27% of trials when mothers discouraged them from walking, an extremely large effect size. These findings suggest that 18-month-olds weigh and integrate competing sources of information on a case-by-case basis. That is, infants evaluated mothers' advice about whether to walk on the basis of perceptual information for trial-to-trial changes in affordances, rather than generalizing mothers' discouragement or encouragement to all slopes within each condition. Apparently, at the borderline slopes, infants recognized that the available perceptual information was inadequate for guiding their decisions about action and simultaneously acknowledged that their mothers possessed information that was relevant to the situation. Thus, at the borderline slopes social information provided by their mothers received the greater weight. This finding extends previous work conducted from the perception–action framework, in which typically attempt rates are high at borderline slopes under conditions of encouragement (Adolph, 1995, 1997; Adolph & Avolio, 2000).

The findings also extend previous work in the area of social cognition by highlighting infants' selective use of social information. By estimating borderline slopes for individual infants and subsequently testing infants across dozens of trials, this study sheds light on the conditions under which social information is most salient. In earlier work, infants faced objects, people, or situations deemed to be novel or ambiguous in valence (e.g., Klinnert et al., 1983; Mumme & Fernald, 2003; Sorce et al., 1985). Every infant was presented with the same toys or people in the playroom, or the same apparent drop-off on the visual cliff. On the standard visual cliff, the comparison increments were extreme (a 0.06-cm drop-off and a 102-cm drop-off), allowing assessment of infants' responses under clearly safe or risky conditions, but precluding assessment of how well infants discriminate between safe and risky conditions. With Sorce et al.'s (1985) modified visual cliff with the 30-cm drop-off, infants received only one trial in one

of two social message conditions, precluding within-subject comparisons of infants' use of social information at an intermediate increment. However, what is novel or strange might vary substantially across infants, which would indicate the value of adopting a more individualized approach.

In the current study, we defined ambiguity empirically, prior to testing infants under varying social message conditions. A wide range in abilities among infants of the same chronological age is the norm in studies of motor development (Adolph & Berger, 2006). Thus, borderline slopes were individualized to each infant's walking ability, and infants received multiple trials across a range of normalized and absolute risk levels. The normalized risk levels ($\pm 10°$) were selected to assess how well infants' responses discriminate among risk levels, and the absolute $4°$ and $50°$ increments were selected to be extreme comparisons.

The results of the psychophysical procedure showed that normalization was important for assessing infants' decisions under conditions of uncertainty and competing sources of information: Borderline slopes ranged from $12°$ to $40°$, and thus what was safe or risky showed a correspondingly large range. In fact, we began the study without knowing the range of borderline slopes for 18-month-olds and had not anticipated such a wide range in abilities within experienced infant walkers. Absolute risk levels overlapped the normalized risk levels for only 2 of the infants. Had we tested infants only at $4°$ and $50°$ in the current study— analogous to work on the standard visual cliff—we would have erroneously concluded that infants do not take mothers' advice. We hedged our bets by defining $+10°$ and $-10°$ as "safe" and "risky." Future studies might determine the window around which 18-month-olds stop deferring to social information.

An individualized approach to testing infants' integration of perceptual and social information might be especially valuable when testing infants at either end of the normal distribution, because the average borderline slope for the group would be either too easy or too difficult for such infants. The present findings confirmed that infants with shallow (see Figure 4A), average (see Figure 4B), and steep borderline slopes (see Figure 4C) showed a pattern of attempt rates similar to the overall group results: They deferred to social advice at the most uncertain borderline increment.

In addition to assessing risk for individual infants, we did not specify how mothers should encourage or discourage their infants' walking. This approach contrasts with previous work in which mothers' messages were carefully controlled. Although we risked losing some experimental control over mothers' message, a goal was to observe infants' responses to social messages under less constrained conditions. We found that mothers were able to deliver encouraging and discouraging messages under open-ended instructions and that their messages were highly effective in swaying infants' decisions when perceptual information was most uncertain—at the borderline slopes.

Why Infants Take Mothers' Advice

In addition to examining infants' decisions, we also coded their facial and vocal affect, latency, touching, and position shifts. We found no evidence that negativity was associated with infants' motor decisions about whether slopes were safe for walking. They did not display negative facial or vocal affect in response to

mothers' discouraging message or at the sight of a precipice. Facial affect was uniformly positive–neutral in both social message conditions (95% of trials) and rarely negative (10% of trials). Positive–neutral vocalizations were higher in the discouraging condition and negative vocalizations were consistently low in both conditions, indicating that discouragement did not elicit negative responses. Likewise, we found no evidence that steep slopes elicited negative displays. In fact, positive–neutral vocalizations increased with increasing risk, and negative vocalizations were consistently low across risk levels. The best predictor of negative displays was avoidance. Perhaps infants became frustrated when they recognized that walking was impossible, but they could not find an alternative way to descend. Alternative strategies provided a means to achieve their goal and might explain the high levels of positive affect on trials in which infants slid down.

In terms of latency and exploration, infants hesitated longer and shifted positions more frequently in the discouraging condition across risk levels but touched slopes equally frequently in both social message conditions (see Figures 3B–3D). How might these patterns of behavior be reconciled with infants' selective deference to mothers' advice at the borderline risk level of maximum ambiguity?

The main effect for decision time is consistent with a conservative interpretation of infants' social cognition. If infants were merely socially responsive (like a pet dog responding differentially to "Come" and "Stay") without understanding the referential intent of mothers' messages, the discouraging message may have functioned to hold infants in place longer across all risk levels. However, this interpretation does not account for selective deference at borderline slopes.

Conversely, selective deference at the borderline slope is consistent with a more liberal interpretation of infants' social cognition. By 18 months of age, infants might understand the referential intent of mothers' social messages (Baldwin & Moses, 1996). According to this account, infants understood that mothers were encouraging or prohibiting their actions on the slope. They deferred to their mothers selectively at the borderline slopes because they recognized the inadequacy of the perceptual information at this increment while acknowledging their mothers as a source of useful information. Although this interpretation explains infants' motor decisions, it does not neatly explain the pattern of results for infants' latency (main effects for both condition and risk), touching (main effect only for risk), and position shifts (main effects for both condition and risk).

The overall pattern of results may be best explained by considering the real-time sequence of events (Adolph, Eppler, Marin, Weise, & Clearfield, 2000). As the experimenter placed infants at the top of the slope, infants had sight of the precipice and the degree of slant. At this point, infants may already have formed an initial opinion about whether the slope was safe to walk. Indeed, in this study in the encouraging condition and in previous studies with experienced infants on slopes, infants began walking or sliding nearly immediately (e.g., Adolph, 1995, 1997; Adolph & Avolio, 2000).

Then mothers began delivering their social message from the side of the landing platform, presumably calling infants' attention toward them. In the first few seconds while the experimenter was still restraining the infants, mothers had time only to say infants' names and possibly a command: "Lily, no!" or "Lily, come here!"

(Karasik et al., in press; Tamis-LeMonda et al., 2007). The discouraging messages might initially stop infants in their tracks, without infants yet processing the reasons for mothers' warnings. This would be akin to someone suddenly shouting your name or screaming, "Stop!" Like the infants, you might stop walking without understanding why you should stop or to what the "Stop" referred.

After initially "stopping," infants would have time to shift their gaze back and forth between their mothers, who discouraged more vehemently each time infants took a step toward the brink, and the slope which beckoned in front of them, thereby gathering additional visual information about possibilities for locomotion. According to this process, infants are first alerted and then have time to figure out that mothers are referring to the slope. Identifying the referent is not trivial. Mothers might not refer to the slope explicitly (e.g., by saying, "Don't walk down that slope") or might only do so late in the trial. Once the referent is identified, infants weigh the social information against the perceptual information generated by their own looking and touching. At the borderline slopes at which success is most uncertain, mothers' message receives the most weight, leading infants to take their mothers' advice.

Thus, from a purely behavioral standpoint, the overall pattern of results would occur if mothers' discouraging message kept infants away from the brink for several seconds. Rather than remaining frozen in a standing position, infants shifted positions to search for an alternative means of descent, find a more advantageous position for viewing the slope, or find a more comfortable position to wait out the trial. In this scenario, latency and shifts would both increase in the discouraging condition without similar increases in touching, and would account for the current patterns of findings on infants' motor decisions as well. In summary, mothers can get their infants to listen to unsolicited advice, but infants only take their mothers' advice when they cannot figure it out for themselves.

References

Adolph, K. E. (1995). A psychophysical assessment of toddlers' ability to cope with slopes. *Journal of Experimental Psychology: Human Perception and Performance, 21,* 734–750.

Adolph, K. E. (1997). Learning in the development of infant locomotion. *Monographs of the Society for Research in Child Development, 62*(3, Serial No. 251).

Adolph, K. E. (2000). Specificity of learning: Why infants fall over a veritable cliff. *Psychological Science, 11,* 290–295.

Adolph, K. E. (2002). Learning to keep balance. In R. Kail (Ed.), *Advances in child development and behavior* (Vol. 30, pp. 1–30). Amsterdam: Elsevier Science.

Adolph, K. E. (2005). Learning to learn in the development of action. In J. Lockman & J. Reiser (Eds.), *Action as an organizer of learning and development: The 32nd Minnesota Symposium on Child Development* (pp. 91–122). Hillsdale, NJ: Erlbaum.

Adolph, K. E., & Avolio, A. M. (2000). Walking infants adapt locomotion to changing body dimensions. *Journal of Experimental Psychology: Human Perception and Performance, 26,* 1148–1166.

Adolph, K. E., & Berger, S. E. (2005). Physical and motor development. In M. H. Bornstein & M. E. Lamb (Eds.), *Developmental science: An advanced textbook* (5th ed., pp. 223–281). Mahwah, NJ: Erlbaum.

Adolph, K. E., & Berger, S. E. (2006). Motor development. In D. Kuhn & R. S. Siegler (Eds.), *Handbook of child psychology. Vol. 2: Cognition, perception, and language* (6th ed., pp. 161–213). New York: Wiley.

Adolph, K. E., Eppler, M. A., Marin, L., Weise, I. B., & Clearfield, M. W.

(2000). Exploration in the service of prospective control. *Infant Behavior and Development, 23,* 441–460.

Adolph, K. E., Tamis-LeMonda, C. S., Ishak, S., Karasik, L. B., & Lobo, S. A. (2007). *Experience is posture specific for descending slopes.* Manuscript submitted for publication.

Baldwin, D. A., & Moses, L. J. (1996). The ontogeny of social information gathering. *Child Development, 67,* 1915–1939.

Bertenthal, B. I., & Clifton, R. K. (1998). Perception and action. In D. Kuhn & R. S. Siegler (Eds.), *Handbook of child psychology. Vol. 2: Cognition, perception, and language* (5th ed., pp. 51–102). New York: Wiley.

Bradshaw, K. D. L., Goldsmith, H. H., & Campos, J. J. (1987). Attachment, temperament, and social referencing: Interrelationships among three domains of infant affective behavior. *Infant Behavior and Development, 10,* 223–231.

Corkum, V., & Moore, C. (1998). The origins of joint visual attention in infants. *Developmental Psychology, 34,* 28–38.

Feinman, S., Roberts, D., Hsieh, K., Sawyer, D., & Swanson, D. (1992). A critical review of social referencing in infancy. In S. Feinman (Ed.), *Social referencing and the social construction of reality in infancy* (pp. 15–54). New York: Plenum Press.

Karasik, L. B., Tamis-LeMonda, C. S., Adolph, K. E., & Dimitropoulou, K. A. (in press). How mothers encourage and discourage infants' motor actions. *Infancy.*

Kingsnorth, S., & Schmuckler, M. A. (2000). Walking skill versus walking experience as a predictor of barrier crossing in toddlers. *Infant Behavior and Development, 23,* 331–350.

Klinnert, M. D., Campos, J. J., Sorce, J. F., Emde, R. N., & Svedja, M. (1983). Emotions as behavior regulators: Social referencing in infancy. In R. Plutchik & H. Kellerman (Eds.), *Emotion: Theory, research, and experience* (Vol. 2, pp. 57–86). New York: Academic Press.

Mondschein, E. R., Adolph, K. E., & Tamis-LeMonda, C. S. (2000). Gender bias in mothers' expectations about infant crawling. *Journal of Experimental Child Psychology, 77,* 304–316.

Moore, C., & Corkum, V. (1994). Social understanding at the end of the first year of life. *Developmental Review, 14,* 349–372.

Moses, L. J., Baldwin, D. A., Rosicky, J. G., & Tidball, G. (2001). Evidence for referential understanding in the emotions domain at twelve and eighteen months. *Child Development, 72,* 718–735.

Mumme, D. L., & Fernald, A. (2003). The infant as onlooker: Learning from emotional reactions observed in a television scenario. *Child Development, 74,* 221–237.

Saarni, C., Campos, J. J., Camras, L. A., & Witherington, D. (2006). Emotional development: Action, communication, and understanding. In N. Einsenberg (Ed.), *Handbook of child psychology* (Vol. 3, pp. 226–299). New York: Wiley.

Sanderson, P. M., Scott, J. J. P., Johnston, T., Mainzer, J., Wantanbe, L. M., & James, J. M. (1994). MacSHAPA and the enterprise of exploratory sequential data analysis (ESDA). *International Journal of Human-Computer Studies, 41,* 633–681.

Sorce, J. F., Emde, R. N., Campos, J. J., & Klinnert, M. D. (1985). Maternal emotional signaling: Its effects on the visual cliff behavior of 1-year-olds. *Developmental Psychology, 21,* 195–200.

Sroufe, A. (1977). Wariness of strangers and the study of infant development. *Child Development, 48,* 731–746.

Tamis-LeMonda, C. S., & Adolph, K. E. (2005). Social cognition in infant motor action. In B. Homer & C. S. Tamis-LeMonda (Eds.), *The development of social cognition and communication* (pp. 145–164). Mahwah, NJ: Erlbaum.

Tamis-LeMonda, C. S., Adolph, K. E., Dimitropoulou, K. A., & Zack, E. A. (2007). "No! Don't! Stop!" Mothers' words for impending danger. *Parenting: Science and Practice, 7,* 1–25.

Vaish, A., & Striano, T. (2004). Is visual reference necessary? Contributions of facial versus vocal cues in 12-month-olds' social referencing behavior. *Developmental Science, 7,* 261–269.