On the origin of the understanding of time, speed, and distance interrelations

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Abstract

We examined 18- and 24-month-old infants’ sensitivity to the functional relationships between time, speed, and distance. The task included a train moving first visibly and then into a tunnel. The movement of the train was always accompanied by a train-characteristic sound signalling the travel duration. After the train concluded its travel, infants were requested to search for it in two possible locations inside the tunnel. Infants’ reaching and head turn behavior indicated that 24-month-olds were sensitive to time-speed-distance interrelations, while 18-month-olds showed no such understanding. Reducing occlusion duration (by shortening the tunnel’s length) revealed an increase in 18-month-olds’ reaching and anticipatory head turns. Results are discussed in terms of the developmental course of the understanding of time-speed-distance interrelations and the strength of infants’ representations.

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Infants are constantly confronted with objects that move in and out of sight. The understanding of such dynamic events is especially important to predict the future behavior of objects and to plan and control one’s own actions accordingly. There is now ample evidence illustrating infants’ astonishing perceptual sensitivity toward various spatiotemporal aspects of object motion (Gredebäck & von Hofsten, 2004; Spelke, Kestenbaum, Simons, & Wein, 1995; von Hofsten, Feng, & Spelke, 2000; von Hofsten, Visthon, Spelke, Feng, & Rosander, 1998; Wilcox & Schweinle, 2003). Infants were found to be sensitive to spatiotemporal continuity, inertia, and the dynamics of an object’s movement.

Infants (and adults) expect objects to move on continuous paths in time and space. That is, they expect an object to traverse the spatial path between different locations within an appropriate time frame. If this basic physical law is violated, infants (and adults) draw conclusions accordingly. For example, Spelke and colleagues presented 5-month-old infants with a rod that moved sequentially behind two screens, which were positioned at spatially separated locations. Infants’ looking behavior indicated that they regard this rod as one discrete moving object when it traversed the path between the screens. When the rod did not appear between the two screens, infants’ looking behavior suggested that they perceived two individual objects (Spelke et al., 1995). Spatiotemporal continuity is a key principle that guides object persistence and refers to a phenomenon of visual cognition, namely *spatiotemporal priority* (Scholl, 2001). This phenomenon points to the vital role of spatiotemporal information and means that infants (as adults) often judge spatiotemporal information as more important for object perception and individuation than featural information (cf. Xu & Carey, 1996).

Studies of infants’ predictive abilities showed that infants’ anticipations take the principle of inertia (objects preserve their present state of rest or consistent motion unless acted upon by forces) into account. In a study by von Hofsten and colleagues (2000) 6-month-old infants were presented with objects that moved along diagonal trajectories that intersected...
at the occluded center of the display. Once set in motion along one diagonal, the object either continued to move along the same diagonal or changed its direction at the intersection. While infants’ predictive head turns indicated that they expected the object to continue its linear movement, they also learned, albeit slowly, to expect nonlinear changes. Consequently, results imply that infants expect forces that affected the object’s motion prior to occlusion to continue during unseen parts.

Another important finding is that infants preserve the spatiotemporal properties of the occluded motion and manage to “track [the object] with their mind’s eye” (Gredebäck & von Hofsten, 2004, p. 182). More specific, Gredebäck and von Hofsten (2004) demonstrated that 6- to 12-month-old infants were able to predict where and when temporarily occluded objects reappear. Infants were presented with objects that traveled with different speeds on circular trajectories and were temporarily occluded (occlusion ranging from 0.5 to 4 s). Results suggest that infants are able to represent parameters of the object’s movement during temporal occlusion. Moreover, it was found that latency of gaze shifts was a function of occlusion duration. That is, at all ages did infants’ predictions take occlusion duration into account.

The above mentioned studies show that infants confronted with temporarily occluded objects expect continuous, inert movements, and that they preserve and use motion parameters to make correct anticipations. However, it remains an open question whether infants are sensitive toward the interrelations of the motion parameters (i.e., time, speed, distance). For example, in order to correctly infer when a temporarily occluded object will reappear, infants must have some notion about the relationship between time and distance (i.e., it will take longer to traverse a long tunnel than a short one at equal speed). Results of Gredebäck and von Hofsten (2004) suggest that infants have such an early awareness (given that latency of gaze shifts was adjusted to occlusion duration). However, to our knowledge it was never systematically investigated whether infants consider time, speed, and distance interrelations (TSD) when predicting the whereabouts of moving objects. That is, are infants
able to infer values of one dimension (e.g., distance) when given the values of the other two dimensions (e.g., time and speed)? In other words, do infants have a functional understanding of TSD interrelations in the sense that they apply rule-based reasoning? The purpose of the present study was to investigate this question and provide insights in infants’ sensitivity to the functional relationships between TSD.

The understanding of TSD interrelations was investigated by researchers within the field of children’s intuitive physics (Acredolo, Adams, & Schmid, 1984; Matsuda, 2001; Piaget, 1946a, 1946b, 1975; Siegler & Richards, 1979; Wilkening, 1981). According to Piaget (1946a, 1946b, 1975), children’s knowledge of the relationships between TSD undergoes a lengthy development. In a typical Piagetian task, two toy trains traveled on parallel tracks for either different durations, or with different speeds, or over different distances. Children were requested to choose the train which goes for a longer time, with higher speed, or traveled more distance. While initially children’s judgments about time and speed were often confounded by representations of distance, children mastered these concepts quite late in their development around the age of 9 to 10 years.

Evidence that children from the age of 5 years have an intuitive knowledge about TSD interrelations was provided by studies using the method of functional measurement (Wilkening, 1981). The rationale behind functional measurement is to provide children with values of two dimensions of the TSD-triad and let them infer the value of the third dimension (Anderson & Wilkening, 1990). In one application of this method, children had to infer how far an animal would escape from a barking dog (distance) while information about the quickness of an animal (speed) and the duration of a dog’s barking (time) was varied. Wilkening found that 5-year-olds correctly integrated the given dimensions to infer values of distance, but correct inferences about time and speed awaited further development. The author concluded that children have an implicit knowledge about TSD interrelations, but that the distance concept (involving a multiplying integration rule) develops before the speed and time
concept (each of them involving a dividing integration rule). On the basis of this conclusion the author reasoned that an understanding of direct relationships of the TSD constituents precede an understanding of the inverse relationship. That is, they master the direct relationship between a) time and distance (e.g., more time is related to more distance) and b) speed and distance (e.g., more speed is related to more distance) before the inverse relationship between c) speed and time (e.g., more speed is related to less time). This conclusion was later confirmed. While 4-year-old children demonstrated an understanding of the direct relationships between TSD, they did not show an understanding of the inverse relationship until the age of 7 years (Albert, Kickmeier-Rust, & Matsuda, 2008; Matsuda, 2001).

While these studies show children’s correct inferences of travel distance when given information about the travel time and speed, there are virtually no studies investigating younger age groups. Although the above mentioned infant studies point to an early sensitivity to spatiotemporal information of an object’s motion, infants’ rule-based understanding between different dimensions and their ability to infer one from the others was to our knowledge never investigated. Therefore, the present study was intended to be a first step in closing this gap between studies of children’s intuitive physics and studies about infants’ early sensitivity toward various aspects of object movement. With the following experiments, we aimed to provide answers to the question of whether infants are sensitive to the functional relationship between TSD, and whether they infer values of one parameter when values of the other two parameters were presented.

Given previous findings suggesting that children’s understanding of direct relationships precede the understanding of the inverse relationship between TSD (Matsuda, 2001; Wilkening, 1981), we started our investigation by examining infants’ sensitivity to the direct relationship between time and distance (at constant speed). Identical to research designs used with older children (Matsuda, 2001; Wilkening, 1981), infants were presented with
information about two dimensions (speed and time) and their ability to infer the value of the third dimension (distance) was measured. We employed an action-based task which was adapted from studies investigating children’s intuitive physical understanding (Matsuda, 2001; Wilkening, 1981). In particular, a toy train moved with constant speed first visually and then into a tunnel with two openings—one that was close to the start location of the train (near tunnel) and one that was located at the end of the track (far tunnel). Movement of the train was accompanied by a sound, which was presented every time and only if the train moved. After the train reached its final location, signaled by the end of the sound, infants were asked to search for it in the two hiding locations. If infants are sensitive to the functional relationship between time and distance they are expected to search (1) in the near tunnel after hearing a sound indicating a short travel time and (2) in the far tunnel after hearing a sound indicating a long travel time. While studies using analogous action-based tasks examined infants between the ages of 2 to 3 years (Berthier, DeBlois, Poirier, Novak, & Clifton, 2000; Hood, Carey, & Prasada, 2000), we decided to examine infants aged between 1.5 to 2 years and assessed both infants’ reaching and head turn behavior. On the one hand, a multi-measurement approach offers a more detailed monitoring of the developmental progress in infants’ representations of TSD interrelations. On the other hand, it allows examining possible dissociations in infants’ reaching and looking behavior (see e.g., Hood, Cole-Davies, & Dias, 2003; Jonsson & von Hofsten, 2003).

1. Experiment 1

1.1 Method

1.1.1 Participants

Twenty healthy and full-term 24-month-old infants (mean age = 24 months and 9 days, \(SD = 5\) days, 10 males) and 20 18-month-old infants (mean age = 18 months and 2 days, \(SD = 5\) days, 10 males) were
9 days, 10 males) participated in the present experiment. One additional 18-month-old infant participated in the study but was excluded from the final sample due to fussiness. Participants in this and the following experiments were recruited by telephone from a pool of families who had volunteered to take part in studies of child development. Parents filled out a consent form before taking part in our study and infants received a small gift for their participation.

1.1.2 Apparatus

The apparatus consisted of a horizontal wooden track, a toy train that moved from the left side of the track to the right, and a set of tunnels (see Figure 1). The wooden track was 1.5 cm high, 160 cm long and 6 cm wide. The track was attached to the surface of a table with the left side exceeding the table’s edge by 12 cm. The tunnels (two blue ones and one white tunnel) were made out of hard cardboard. Each blue tunnel was 15 cm high, 12 cm long and 12 cm wide. They had an opening (13 high × 8 cm long) in the front side that was covered by a red curtain. The blue tunnels were connected by a large white tunnel (15 cm high × 56 cm long × 12 cm wide). The tunnels were placed at the right end of the track. Thus, the movement of the train was visible for the first 70 cm and concealed for the last 80 cm. The first 10 cm of the track were occupied by the stationary train.

The toy train was 6.5 cm high, 10 cm long and 5 cm wide. It produced a train-characteristic sound when moving. Because it was a clockwork train, it moved by itself when it was wound up. At the beginning of each trial the train was wound up three times and placed at its starting position at the left end of the track. The wound up train was held in place by a wooden lever. Upon releasing the position lever, the train started to move with a constant speed of 25 cm/s. It moved for 3.2 s before it entered the near tunnel (short distance) and for 5.84 s before it entered the far tunnel (long distance). Thus, with given speed and travel time, the train covered a distance of 80 cm and 146 cm, respectively. To prevent that infants locate the positions of the train by simply orienting toward the sound emitted by the train, we overshadowed it by presenting an additional train-characteristic sound through two
loudspeakers placed to the left and right of the track. That is, the additional train-characteristic sound was presented centrally and for the exact amount of time the train was in motion (producing its own sound which was successfully overshadowed).

The train moved from the child’s left to its right and could be stopped by a small rigid barrier within the near or far tunnel. Foam was glued onto the barrier’s surface to absorb any impact sound. Before starting the movement of the train, the experimenter inconspicuously positioned the barrier in the near or far tunnel. When placing the barrier on the track the experimenter always reached with both hands into both tunnels, in order to give no clue as to where the train will stop.

1.1.3 Design and Procedure

The experimental session started with the infant sitting on their caregiver’s lap facing the apparatus. Parents were asked to look at the back of their infant’s head during the experiment to prevent interference. Infants were seated between the near and far tunnel, so that reaching distance to each tunnel was identical. The experimenter sat across from the infant facing the back of the apparatus.

First, a familiarization was conducted in which infants were accustomed to the train and tunnel set. During the first two trials, the toy train moved the full length of the track without being hidden by any tunnel. In these and the following trials, the train’s sound was always overshadowed by presenting the additional train-characteristic sound. After these trials, the near and far tunnel were placed at their locations on the track and the train moved again twice from left to right but was stopped between the tunnels. The reason of this familiarization was to provide infants with information about speed and sound of the train and to show its ability to move through the tunnels. Furthermore, familiarization aimed to present infants with information about the connection between the train’s movement and the movement-linked

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1 A pilot study revealed that adult participants relied on the sound emitted by the speakers to anticipate the whereabouts of the toy train. That is, adults deemed the train’s own sound as sufficiently overshadowed and confirmed that they were not able to locate the train by simply orienting toward its sound.
sound. Given that young infants have been frequently shown to connect sound and movement (Walker-Andrews & Lennon, 1985), infants of the present experiments were expected to associate movement and sound. Importantly, Srinivasan and Carey (2010) illustrated recently that 9-month-old infants were able to bind particular spatial lengths with the appropriate temporal durations, indicating a functional overlap between spatial and temporal representations.

After familiarization, the large white tunnel was presented and positioned between the two blue ones. The train was hidden in one of the blue tunnels and shown to the infant. Infants were encouraged to reach and retrieve the train. This procedure was repeated until the infant reached at least once into each tunnel. Half of the infants were first exposed to the near and then to the far tunnel and half of the infants were exposed to the reversed order. All infants successfully searched for the train in both tunnels during these warm-up trials.

Immediately after familiarization and warm-up reaching, the test trial was presented, in which the train moved either to the near tunnel (short distance) or to the far tunnel (long distance). Half of the infants were presented with a short distance test trial and the other half with a long distance test trial. At the beginning of the test trial, the experimenter pointed to the train, which rested at the beginning of the track, in order to direct infant’s attention toward it. Immediately after the infant looked at the train, the position lever was removed to set the train into motion. During the train’s movement the experimenter looked down at the table to avoid inadvertently cueing the infant. After the train stopped at its final location in the tunnel (either near or far tunnel), the experimenter looked at the infant and asked “Where is the train?” and requested the infant to search. As soon as the infant retrieved the train, the trial was finished. If the infant did not react within the first 10 s, the question was repeated and the experimenter tapped three times on both tunnels simultaneously.

Moreover, infants were classified as performing an anticipatory head turn when the infant turned his/her head toward the correct tunnel (i.e., the near or far tunnel) while the train
was hidden in the tunnels. Infants’ reaching and head turn behavior was coded off-line from video tape. Ten randomly chosen participants within each age group were coded by another naïve experimenter to calculate interobserver reliability. Cohen’s kappa was 1.0 for reaching, and 1.0 for head turn behavior.

1.2 Results and Discussion

The reaching and head turn behavior of the 24- and 18-month-old infants is depicted in Figure 2. While 24-month-olds reached significantly more often to the correct location of the train (75%, Binomial, \( p < .05 \)), the 18-month-olds’ reaching behavior was at random (50%, Binomial, \( p = 1.0 \)). However, directly comparing the reaching behavior of the two age groups revealed no significant differences (\( p = .191 \), two-tailed Fisher’s exact test). In both age groups, gender, order of the warm-up, and, most notably, the particular test event (short vs. long distance test) did not influence infants’ reaching behavior (\( p > .05 \) in all cases). In addition, 80% of the 24-month-olds performed an anticipatory head turn to the correct location (Binomial, \( p < .05 \)) while only 55% of the 18-month-olds showed this behavior (Binomial, \( p = .82 \)). Again, comparing the anticipatory head turn behavior in the two age groups revealed no reliable difference (\( p = .176 \), two-tailed Fisher’s exact test).

Given that 24-month-olds’ correct reaching behavior and anticipatory head turns both differed from chance, our findings indicate that infants of this age group were sensitive to the direct relation between the duration of the object’s movement (indicated by the sound) and the travel distance. Infants’ correct anticipations support previous findings in that infants are sensitive to continuity and inertia (Spelke et al., 1995; von Hofsten et al., 2000). Beyond that, they seem to infer the correct displacement location after being presented with different values of the time dimension. In contrast, 18-month-olds’ reaching and head turn behavior was random. Although their performance did not reliably differ from that of the 24-month-
olds, they failed to anticipate and reach to the correct final location of the train, indicating that they were not sensitive to the direct relation between time and distance.

What might be the source of the observed age differences? It is conceivable that the occlusion duration was taxing for the younger age group’s representational system. In fact, recent research suggests a negative effect of occlusion duration on infants’ anticipatory reaching behavior. For example, in a task in which infants had to reach for temporarily occluded objects moving with varying speeds, van Wermeskerken, van der Kamp, te Velde, Valero-Garcia, Hoozemans, and Savelsbergh (2011) found that increasing occlusion duration led to a decrease in infants’ correct reaching performance. Various cognitive accounts attempt to explain why occlusion duration may affect infants’ performance. The graded-representations account posits that infants’ representations are not all-or-none entities but graded in nature (Munakata, McClelland, Johnson, & Siegler, 1997; Spelke & von Hofsten, 2001). That is, knowledge representations are not just present or absent, but graded in strength and become gradually more precise over development. In light of this view, a decrease in occlusion duration might increase 18-month-old infants’ performance, considering this age group’s representations are not yet strong enough to deal with longer occlusion durations.

Similarly, the cognitive-load account proposes that infants’ limited processing capacities are negatively influenced by increases in the overall cognitive load of a task (e.g., by additional motor demands) (Berthier et al., 2001, Boudreau & Bushnell, 2000; Keen, Carrico, Sylvia, & Berthier, 2003). Thus again, infants should profit from a decrease in occlusion duration because it decreases the cognitive load of the task.

Taking these considerations into account, we decided to reduce occlusion duration by shortening the tunnel’s length within the next experiment. We expected this manipulation to lead to more correct search and head turn behavior in 18-month-old infants.

2. Experiment 2
2.1 Method

2.1.1 Participants

Twenty healthy and full-term infants at the age of 18 months participated in this experiment (mean age = 18 months and 6 days, \(SD = 9\) days; 10 males).

2.1.2 Apparatus

The apparatus was identical to the one in Experiment 1 except for the following change. The white tunnel between the two blue ones was reduced in length from 56 cm (Experiment 1) to 30 cm. The size of the blue tunnels was the same as in Experiment 1. Thus, the tunnels (two blue and one white tunnel) covered now 54 cm of the track. To keep the visible part of the train’s movement identical to Experiment 1, the tunnels were placed again 70 cm from the train’s starting point, resulting in a total track length of 134 cm. Thus, while travel time and distance to reach the near tunnel were identical to Experiment 1, these movement parameters changed to 4.8 s and 120 cm to reach the far tunnel in Experiment 2.

2.1.3 Procedure

Procedure and coding were analogous to Experiment 1. Ten randomly chosen participants were coded by another naïve experimenter to calculate interobserver reliability. Cohen’s kappa was 1.0 for reaching, and 1.0 for head turn behavior.

2.2 Results and Discussion

Eighteen-month-old infants reached significantly correct to the final location of the train (85%, Binomial, \(p < .01\)). Moreover, infants’ reaches in the present experiment were significantly more often correct than reaches of the 18-month-olds in Experiment 1 (\(p < .05\), two-tailed Fisher’s exact test). Gender, order of the warm-up reaching and the particular test event (short vs. long distance test) did not significantly influence infants’ reaching behavior (\(p > .05\) in all cases). In addition, 95% of the 18-month-olds performed an anticipatory head turn.
to the correct location (Binomial, \( p < .001 \)), which constitutes a significant difference to the hear-turn behavior of the 18-month-olds in Experiment 1 (\( p < .01 \), two-tailed Fisher’s exact test).

Reducing the occlusion duration led to a reliable increase in both 18-month-olds’ anticipatory head turns and their reaching behavior. As the 24-month-olds in Experiment 1, the 18-month-olds in Experiment 2 correctly anticipated and reached toward the final location of the train. Thus, if the task is tailored to meet younger infants’ cognitive capacities (i.e., shorter occlusion durations), a sensitivity to the direct relationship between time and distance is already observed by an age of 18 months. Like older infants, they are then able to infer values of one dimension (distance) after being presented with values of the others (time and speed). The positive influence of reducing occlusion duration is consistent with recent findings (van Wermeskerken et al., 2011) and provides supportive evidence for the graded-representations and the cognitive load account (Berthier et al., 2001; Keen et al., 2003; Munakata et al., 1997; Spelke & von Hofsten, 2001).

3. General Discussion

The aim of the present study was to provide initial insights into the origin and developmental course of a sensitivity toward TSD interrelations. We were able to demonstrate that at the age of 24 months, infants made correct inferences about the travel distance of a moving object. That is, they were able to infer values of one dimension (distance) from the others (speed and time) and thus, seem to have a rule-based sensitivity about the direct relation between time and distance. Given infants’ correct inferences in the present experiments, we can presume that they perceived the movement as continuous and inert and were aware of the constant speed of the object. Most importantly, infants inferred (1) a short travel distance when hearing a sound indicating a short travel time and (2) a long travel distance when hearing a sound indicating a long travel time. In contrast, 18-month-olds
demonstrated this understanding neither in their reaching behavior nor in their anticipatory head turns when tested with the same long tunnel as the 24-month-olds (Experiment 1). Under conditions when occlusion duration was reduced (Experiment 2), 18-month-olds’ anticipatory head turns and their reaching behavior increased in correctness, indicating that even at this age, infants are sensitive to the direct relation between time and distance.

Research investigating children’s intuitive physics (Matsuda, 2001; Wilkening, 1981) demonstrated that children at the earliest of 4 years had an intuitive knowledge about the direct relations between TSD. We extend this finding by suggesting that earliest signs of this understanding are found at the age of 18 months. Our non-verbal action-based task was an adaptation of the one used by Matsuda (2001) and Wilkening (1981) with older verbal children. It has been repeatedly shown that with a sensitive task, even young infants evidence abilities that are thought to be accomplishments of older children.

Our findings are in accordance with several results from previous studies. First, infants in our study were able to predict the travel distance of a moving object, which agrees with infants’ predictive behavior in other studies (Jonsson & von Hofsten, 2003; van der Meer, van der Weel, & Lee, 1994). Second, infants in our experiments were also sensitive to several physical laws like continuity and inertia that govern objects in motion (Spelke et al., 1995; von Hofsten et al., 2000; von Hofsten et al., 1998). Third, our results point to a strong effect of occlusion duration on infants’ cognitive processes and their subsequent behavior. This is evident in 18-month-olds’ enhanced performances during shorter (Experiment 2) compared to longer occlusion durations (Experiment 1). Given that the experimental set-ups and designs of both experiments were completely identical except of the different occlusion periods, it is highly unlikely that infants’ enhanced performance during Experiment 2 was due to other factors than occlusion duration. During shorter occlusion durations (Experiment 2), infants reached and anticipated more correctly than expected by chance which was not the case for same-aged infants tested with longer occlusion durations. This finding of enhanced
performance is in accordance with recent empirical evidence (van Wermeskerken et al., 2011) and supports assumptions of the graded-representations and the cognitive load account (Berthier et al., 2001; Keen et al, 2003; Munakata et al., 1997). That is, infants’ representations of the moving object became less precise with increased occlusion duration (according to the graded-representations account) or the overall cognitive load of the task increased with longer occlusion durations (according to the cognitive load account). However, while the occlusion duration of Experiment 2 supported 18-month-olds’ correct reaches and anticipations, the occlusion duration of Experiment 1 (which was 1.04 s longer) seemed to exceed their representational capacity, resulting in degraded behavior (e.g., less correct reaches and anticipatory head turns).

Twenty-four-month-olds’ correct inferences during longer occlusion durations (Experiment 1) show that infants’ ability to tolerate occlusion durations enhances with increased age. One possible explanation is that the precision of object representations improves with increased age (e.g., see Munakata et al., 1997; Spelke & von Hofsten, 2001). As infants get older, the rate of accuracy loss in representations decreases. In turn, this decline results in a higher tolerance for long occlusion durations and thus, longer sustainment of the representations. With regards to our findings and task specifics, we can conclude that infants’ sensitivity to the direct relationship between time and distance was dependent on factors (like occlusion duration) that in general influence cognitive processes. Consequently, we agree with Munakata and colleagues (1997) in that reaching and looking performances “[are] a function of the state of development of both task-specific mechanisms and representational systems” (p. 690).

Ultimately, our findings provide further insights into the development of physical reasoning, and in particular add to our understanding of the early development of the functional relationships between TSD. In addition, the use of the present action-based task was found to be a valuable method in closing the gap between looking-time studies carried
out with young infants and verbal tasks conducted with older children. Our data imply that 18-month-old infants are aware of the “more is more” relation between time and distance dimensions and correctly infer values of the distance dimension from values of the time and speed dimensions. Importantly, these correct inferences are dependent on the representational strength of the infant’s cognitive system. However, in order to corroborate our findings, future studies may investigate infants’ sensitivity to time-speed-distance interrelations by using varying speeds and more locations than in our task. Future studies should also address whether infants younger than 18 months show a sensitivity to the direct relations between TSD and whether infants’ sensitivities toward both direct relations within TSD interrelations (between time and distance as well as speed and distance) are similar in their developmental trajectory.
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References


Figure Captions

*Figure 1.* View of the apparatus with the toy train resting at the left side of the track.

*Figure 2.* Percent correct responses for 24-month-old and 18-month-old infants tested in Experiment 1 and 2.
Figure 1.
Figure 2.