Infant Behavior & Development 47 (2017) 112–120

Contents lists available at ScienceDirect

Infant Behavior and Development

A study of reaching actions in walking infants

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ARTICLE INFO

Article history:
Received 20 September 2016
Received in revised form 20 March 2017
Accepted 28 March 2017
Available online 12 April 2017

Keywords:
Walking
Reaching
Motor development
Prehension
Developmental change

ABSTRACT

Acquiring motor skills transforms the perceptual and cognitive world of infants and expands their exploratory engagement with objects. This study investigated how reaching is integrated with walking among infant walkers ($n = 23$, 14.5–15.5 months). In a walk-to-reach paradigm, diverse object retrieval strategies were observed. All infants were willing to use their upper and lower bodies in concert, and the timing of this coordination reflected features of their environment. Infants with an older walking age (months since walking onset) retrieved items more rapidly and exploited their non-reaching hand more effectively during object retrieval than did same-age infants with a younger walking age. This suggests that the actions of the upper- and lower-body are flexibly integrated and that this integration may change across development. Mechanisms that shape sophisticated upper-body use during upright object retrieval are discussed. Infants flexibly integrate emerging motor skills in the service of object retrieval in ways not previously documented.

The acquisition of new motor skills in the first two years of life profoundly impacts the human infant. Gaining control and skill around movement of the eyes, head, trunk, arms, hands, and legs dramatically advances and shapes infants' ability to perceive and exploit features of their environment (Gibson, 1988). Motor changes are intrinsically linked to infant development across many domains. For instance, beginning to crawl transforms infants perceptually, socially, and linguistically (Campos et al., 2000). Acquiring and mastering walking also drives developmental change. New walkers differ from their same-age crawling peers in what they see of their environment (Kretch, Franchak, & Adolph, 2014). They are also socially transformed, spending more time interacting with and gesturing towards their mothers (Clearfield, 2011) and producing more social bids than crawlers (Clearfield, Osborne, & Mullen, 2008). In response, these new walkers receive different types of verbal responses from their caregivers than they did as crawlers (Karasik, Tamis-LeMonda, & Adolph, 2014). New walkers more frequently carry and share objects with their mothers (Karasik, Adolph, Tamis-LeMonda, & Zuckerman, 2012). They also demonstrate a willingness to travel long distances in order to engage with preferred objects, a behaviour less common among crawlers (Dosso & Boudreau, 2014). Beginning to walk thus constitutes a qualitative change in the way that infants engage with the world and specifically with objects. Early walking constitutes a major biomechanical change to the infant's whole body, affecting the position and movements of the head, arms, trunk, and legs (Bril & Brenière, 1993; Ledebt, 2000; Sutherland, Olshen, Cooper, & Woo, 1980; Yaguramaki & Kimura, 2002). Walking can also "free" the hands for a greater range of object exploration and manipulation. How might these newly-available arms and hands be exploited during upright locomotion, especially as infants approach stationary objects?

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http://dx.doi.org/10.1016/j.infbeh.2017.03.006
0163-6383/

Reaching has been shown to be context-dependent throughout development, so we hypothesize that this will be the case during walking as well. For instance, Savelsbergh and van der Kamp (1994) found that reaches in 12–27 week-old infants were more frequent and more mature in form when infants were upright than when they were reclined or supine. Rochat and Goubet (1995) found that the motor milestone of sitting changed the integration of sitting with leaning in young infants, and a number of papers have found that the onset of walking shapes reaching that is performed while seated (Corbetta & Bojczyk, 2002; Grzyb, Smith, & Del Pobil, 2013). There are descriptions of hand use during walking that describe how objects are carried during walking (Karasik et al., 2012; Mangalindan, Schmuckler, & Li, 2014), as well as unique, passive hand positions like the "high guard" posture (Kubo & Ulrich, 2006). However, we were aware of no research on the influence of walking on concurrently performed active prehension skills.

Infants' daily lives present a plethora of opportunities for the dynamic integration of walking and reaching; these concurrently performed skills proved easy to elicit in the laboratory, suggesting their central importance in propelling early development. Our core thesis was to study the integrated performance between two critical—and simultaneously developing—emerging motor systems: walking and reaching. Thus the study set out to describe the flexibility of infant walkers' whole-body approaches to object retrieval when reaching upright.

We used a novel "Walk-and-Reach" task to elicit reaches from upright infants. Infants determined for themselves whether to reach while standing or while walking, as well as the posture from which to perform the reach, and the configuration of all four limbs. This work therefore provides a unique approach to understanding the ways in which developing walking performance might flexibly interact with the use of the upper body.

1. Methods

Families who had previously expressed interest in developmental research were contacted from a database shared between three developmental laboratories within the university. During a phone screening, caregivers were asked whether their infant was born full-term and was able to take five consecutive unsupported steps. Twenty-eight 15-month-old infants (14.5–15.5 months) meeting these criteria participated in the task. During a warm-up period, caregivers provided informed consent and filled out a short questionnaire about the infant's recent motor milestones. The ethnic background of these infants was Caucasian ($n = 13$), Multiethnic ($n = 8$), East Asian ($n = 4$), Latin American ($n = 1$), and undisclosed ($n = 2$). Of this sample, five infants were excluded due to state issues ($n = 4$) and medical conditions affecting motor development ($n = 1$). Time since walking onset in months (which we will refer to as walking age) ranged from 1.4 to 7.4 months (3.3 ± 1.6, $M \pm SD$) in the final sample of 23 infants. Walking onset was defined for parents as any unsupported steps.

We developed a Walk-and-Reach corridor with 18 object positions varying across height (16, 35, and 54 cm), distance from the start position (56, 82, and 108 cm), and corridor side (left and right); see Fig. 1, A1. On each trial, a target (a colorful 3.3 cm square wooden block) was placed at one of the eighteen positions and infants were encouraged to retrieve it and place it in a hard plastic container held by an experimenter at the far end of the corridor. Dropping the object in the container produced auditory feedback that infants seemed to find rewarding. There were two blocks, with each block including nine trials. Within a block, all targets were presented on the same side of the infant (left or right). Block order was randomized, and order of the nine object locations within each block was also randomized. Thus, there were eighteen trials in total, comprised of one trial for each object location. Infant behaviour on each trial was recorded by three cameras: two placed at approximately four feet in height at each end of the corridor to capture full body actions, and one placed to the side of the corridor at approximately five feet in height (illustrated in Fig. 1, A1) to capture fine details of hand movements.

At the beginning of each trial, infants began with their guardian seated on the floor. An experimenter blocked visual access to the corridor using a curtain while the target was secured in position, mounted to the wall with Velcro. Then, the experimenter said to the infant, "One, two, three, go!" and removed the curtain, revealing the target. Another experimenter was seated at the far end of the corridor holding a container, and encouraged the infant to retrieve the target and deposit it in the container to produce a collision sound. Once the infant successfully deposited the object in the container, they were rewarded with cheers and encouraged to return to the guardian to perform the next trial. Infants found the task quite engaging, performing a mean of 17.5 trials out of a possible 18.

Infant movements were coded using frame-by-frame analysis of the video recording and Observer software (Noldus). Coding was initiated the moment the curtain was removed, the guardian no longer had contact with the infant, and the infant had fixated the target object. Coding was performed as follows:

1. Hand height during walking prior to the reach initiation was coded for each hand as Above Shoulder, Trunk, or Below Waist.
2. Hand swing during walking prior to the reach initiation was coded as Alternating or Non-Alternating.
3. Time was coded at a frame level from trial onset to object retrieval (when the object was detached from the wall). For each frame, body movement was coded as either standing or walking and each hand was coded as not reaching, reaching, or contacting the object.
4. Action of the secondary (non-retrieving) hand was categorized for each trial based on hand position at the moment of object retrieval (for successful retrievals) or object release (for non-successful retrievals) as: No Contact, Wall Contact,