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Infant visual attention and step responsiveness to optic flow during treadmill stepping

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ABSTRACT

This study examined infant treadmill stepping in two groups of pre-locomotor infants in response to terrestrial optic flow. The optic flow was provided via the treadmill belt for flow translation that was directionally consistent with the forward stepping of the infants. Twelve 2–5-month-old and twelve 7–10-month-old infants participated. Visual attention (duration and direction) and step responsiveness (frequency and step types) were coded from digital video, and visuomotor coupling was examined by temporally juxtaposing the visual attention and step data. Longer durations of visual attention to the patterned belt with increased step frequencies during periods of visual attention were observed, suggesting that the visuotactile calibration afforded by the patterned treadmill belt, increased visuomotor coupling and enhanced the frequency and complexity of stepping in prelocomotor infants. The findings are discussed with regard to sensorimotor experiences that enhance treadmill stepping in infants and that may have application to clinical populations.

1. Introduction

The capacity for perception–action coupling in newborns has been demonstrated for visual control of posture (Jouen, Lepecq, Gepenne, & Bertenthal, 2001), and more recently with regard to optic flow and air stepping (Barbu-Roth et al., 2009). Beyond the neonatal period, very young infants also respond to optic flow with directional consistency of the head and trunk, well in advance of an ability to sit independently. The proposal that visual perception is not a rate limiter in the emergence of postural control (Bertenthal, Rose, & Bai, 1997), leaves open the question of whether this is true as well for emergent locomotion. Indeed, it may be. Air stepping in 3-day-old infants can be facilitated with terrestrial optic flow that translates toward the infant (Barbu-Roth et al., 2009). In particular, visual–motor coupling occurred only when optic flow specified self-motion (Barbu-Roth et al., 2009), and it occurred in the absence of tactile information that is known to also facilitate stepping across infancy (Thelen & Ulrich, 1991). Whereas visual control of posture continues to integrate with other sensory information and improves with motor experience and the age of the infant (Bertenthal & Bai, 1989; Bertenthal et al., 1997; Lejeune et al., 2006; Savelsbergh, Caljouw, van Hof, & van der Kamp, 2007; Uchiyama et al., 2008), it is unknown whether a similar trajectory occurs with stepping.

To begin to address this, we examined infant stepping on a support surface in the presence of optic flow. This approach provided an opportunity to examine visuotactile integration in the organization of this early capacity for complex

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sensorimotor function. Two groups of infants were studied, a younger group, 2–5 months of age who were pre-sitters, and an older group, 7–10 months of age who were pre-locomotors (sitting but not walking). The developmental shift to more consistent alternating stepping in infants occurs at about 3–5 months when the infant can more actively control posture and extend into the treadmill surface (Thelen & Ulrich, 1991). The expected differences in the stability of stepping responsiveness at the two age levels of infants in this study allowed for the examination of potential shifts in the stability of stepping in the younger group as a function of visuotactile integration. We hypothesized that both groups of infants would respond to the presence of optic flow with increased stepping, and that the younger group of infants would show an increase in the complexity of their steps (increased alternating stepping) while visually attending to the patterned belt.

2. Methods

2.1. Participants

Twenty-eight infants were recruited for this study, 14 in both a younger and older age group. Two infants in the young group and two infants in the older group were excluded from the analyses due to crying with eyes closed for more than 20 s during any 30-s trial. Ultimately, data from a total of 24 infants were analyzed for this study, twelve 2–5-month-old infants (mean age 3.3 months) and twelve 7–10-month-old infants (mean age 8.62 months). Infant characteristics are summarized in Table 1. Overall, the infants in this study were 76% Caucasian, 16% Hispanic, and 8% South East Asian, all from parents with or currently obtaining at least a college education. Birth orders of the infants within their families included 71% first, 25% second, and 4% third. The older group of infants included two sets of male twins, who were first children in their respective families.

All infants were recruited through a university community. To assure that each infant met the inclusion criteria, the parent(s) provided written informed consent prior to their infant's participation in the study, and a developmental history and family demographic interview was conducted prior to initiating the treadmill trials. Inclusion criteria included full term birth, no known congenital, acquired or developmental conditions, no visual or orthopedic conditions, and motor skills ranging from vertical head control to pre-sit development for the younger group, and from sitting to pre-gait development for the older age group. This study was approved by the Internal Review Board of the University of Wisconsin-Milwaukee, and this research was conducted in accordance with APA ethical standards in the treatment of human subjects.

2.2. Procedure

This study used a custom designed infant treadmill (67.5 cm × 44 cm × 29 cm; Carlin's Creations) to create a moving terrain known to facilitate the emergence of stepping in non-ambulatory infants (Thelen & Ulrich, 1991). The treadmill belt measured 62 cm × 31 cm, and three visual belt conditions were utilized. Terrestrial optic flow was created using a 7.5 cm black and white checked patterned treadmill belt, which was contrasted to two solid belts (black and white). Belt speed was 0.16 m/s across all belt conditions (Thelen & Ulrich, 1991), and terrestrial optic flow as a function of translation of a patterned belt, was coupled to the speed of the stimulus for stepping, though not temporally coupled to the infant's stepping response. The order of belt condition was randomly assigned across trials, for a total of three trials per condition (checked, black, and white). Data were collected across three, 30-s trials per condition (9 trials total). Pilot testing was conducted to confirm that this trial duration and overall number of trials would capture the required data while also minimizing the likelihood of fatigue-related crying or eye-closure in the youngest infants.

All infants were tested at the time of day that the parent identified as optimal relative to infant mood, wake-alert periods, and feeding schedules. Testing took place in a laboratory setting, and all infants were awake and alert at the start of the

Table 1
Infant characteristics by group (*SD* in parentheses).

	Group	
	Younger (n = 12)	Older (n = 12)
Sample gender	3 f, 9 m	4f, 9 m
Birth order		
First child	8	9
Second child	3	3
Third or higher	1	0
Mean age (months)	3.3 (1.01)	8.62 (1.13)
Mean body wt (kg)	5.99 (0.63)	8.51 (0.93)
Mean body length (cm)	61.81 (3.29)	70.23 (2.23)
Mean Ponderal Index	29.05(0.65)	29.03 (0.64)
Gross Motor Score		
BSID-III, scaled score	10 (2.61)	11.36 (2.69)

Note: Ponderal Index calculated as $PI = 1000 \times ((weight_{kg})^{1/3}/height_{cm})$, where 20–25 is considered "average" for infants (WHO, 1995). BSID-III refers to the Bayley Scales of Infant Development, 3rd edition (Bayley, 2006), with a mean of 10 ($SD = \pm 3$).