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How and when infants learn to climb stairs

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Abstract

Seven hundred and thirty-two parents reported when and how their infants learned to climb stairs. Children typically mastered stair ascent (mean age = 10.97 months) several months after crawling onset and several weeks prior to descent (mean age = 12.53 months). Most infants (94%) crawled upstairs the first time they ascended independently. Most infants (76%) turned around and backed at initial descent. Other descent strategies included scooting down sitting, walking, and sliding down face first. Children with stairs in their home were more likely to learn to ascend stairs at a younger age, devise backing as a descent strategy, and be explicitly taught to descend by their parents than children without stairs in their home. However, all infants learned to descend stairs at the same age, regardless of the presence of stairs in their home. Parents' teaching strategies and infants' access to stairs worked together to constrain development and to influence the acquisition of stair climbing milestones.
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Staircases are one of the oldest building elements in architectural history. Most cultures, both ancient and modern have some version of stairs or ladders to reach higher elevations. Ancient cultures, for example, cut steps into hillsides to expand their territories (Templer, 1992a). Stairs are also integral to modern high-rise architecture. Dense, urban cultures build multi-story buildings to create more usable space.

However, stairs pose a potential danger for newly mobile infants and toddlers. Nearly, 1 million people are treated in hospitals for falls on stairs and steps each year, and in 2002 (the most recent year for which data are available), the odds of dying from a fall on stairs were 1 in 180,188 (Centers for Disease Control and Prevention, 2002; National Safety Council, 2005). Infants are at greater risk from falling down stairs than toddlers or older children (National SAFE KIDS Campaign, 2004).

Despite the prevalence of stairs in the environment and the potential risks that they pose for newly mobile infants, the process of learning to climb up and down stairs has been largely taken for granted. Surprisingly little is known about the social and environmental factors that influence how infants learn to navigate stairs.

Previous research on stair-climbing has focused on the biomechanical differences between walking up and down stairs and walking on level ground in adult populations (e.g., Andriacchi, Andersson, Fermier, Stern, & Galante, 1980; McFadyen & Winter, 1988; Riener, Rabuffetti, & Frigo, 2002; Townsend, Lainhart, Shiavi, & Caylor, 1978). Walking

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on flat ground is biomechanically easier than stair ascent and descent. Ascent requires high energy expenditure of the muscles to pull up the body against gravity (Andriacchi et al., 1980; McFadyen & Winter, 1988). Descent requires walkers to support their weight on a bent limb, maintain their balance on one limb during a lengthened swing phase, and control forward momentum (Andriacchi et al., 1980; McFadyen & Winter, 1988). Head stability decreases during stair descent, as the heads' center of mass is displaced due to increased neck flexion (Cromwell & Wellmon, 2001). The problem of stair climbing is exacerbated in the elderly who are likely to have diminished muscular strength, flexibility, and stability (Haslam, Sloane, Hill, Brooke-Wavell, & Howarth, 2001; Kim, Kinugasa, Tanabe, & Kuno, 2002). Stair descent almost certainly poses a similar challenge for newly crawling or walking infants whose body proportions make them top-heavy (Adolph, Vereijken, & Denny, 1998; Adolph, Vereijken, & Shrout, 2003), although this premise has not yet been tested experimentally.

Previous work on children's stair climbing has been limited to establishing norms for the onset of motor milestones. Stair climbing is viewed like infants' other motor milestones—a universal skill achieved through maturation (Gesell, 1934; McCaskill & Wellman, 1938; McGraw & Breeze, 1941). For example, the Denver Developmental Screening Test includes an item for determining whether children's development is progressing normally based on whether infants can walk up steps by age 14–21 months (Frankenburg & Dodds, 1967). However, even normative data on infants' stair climbing is incomplete. Most assessments document the mean age of onset of stair ascent, but not stair descent; most studies observed when infants learned to walk up stairs, but not when they could crawl up; and most researchers credit infants with stair climbing when they can manage just a few steps, but do not take into account their ability to navigate a full flight of stairs (Bayley, 1969; Frankenburg & Dodds, 1967; Gesell, 1934; McCaskill & Wellman, 1938).

1. Current study

Although stair climbing has been considered a major milestone in the motor development literature for decades, experimenters have neglected to fully examine the circumstances surrounding how infants learn to climb stairs. An extensive literature on stair negotiation by adults, particularly the elderly, exists (see Startzell, Owens, Mulfinger, & Cavanagh, 2000, for a review), but the current study is the first comprehensive examination of stair climbing in infancy. Thus, our primary aim was to provide a rich description of basic, but previously undocumented, information: the typical ages of onset for stair ascent and descent, the onset of ascent and descent relative to other motor milestones, and the stair climbing strategies that infants use to cope with biomechanical constraints.

Our second aim was to examine potential influences on the age of onset of stair climbing. We considered parents' role in infants' learning to navigate stairs a potential social component of the learning process. Thus, we interviewed parents about their expectations of infants' stair climbing ability, their practices for teaching infants to climb stairs, and the strategies that infants devised to climb stairs with the goal of understanding how social factors might influence how infants learn to navigate stairs.

Finally, we documented the opportunities available to infants for ascending and descending stairs with the goal of understanding how environmental factors, such as proximity to stairs on a regular basis, might also influence how and when infants learn to navigate stairs. We asked whether infants with more opportunities to climb stairs, such as those with stairs in their homes, might learn to climb stairs earlier than infants with less access. Recent cross-cultural research on motor development suggests that access may, in fact, make a difference for the age at onset of motor milestones. For example, African and West Indian infants who do not have access to the floor because their mothers keep them supported in upright postures, often skip crawling, a motor skill considered crucial in Western cultures (Bril & Sabatier, 1986; Hopkins & Westra, 1988, 1990). Thus, we sought to clarify what constituted having stairs in infants' environments. Was daily access to stairs in the home related to an earlier onset age for learning to climb stairs or was sporadic exposure equally facilitative?

2. Method

2.1. Design and participants

Parents of 732 infants (362 boys, 370 girls) participated in a structured interview (Adolph et al., 2003) about circumstances surrounding their children's learning to use stairs. Infants were recruited from published birth announcements and purchased mailing lists in the Bloomington, IN ($n = 30$; 15 boys, 15 girls), Pittsburgh, PA ($n = 173$; 89 boys, 84 girls), and New York City metropolitan areas ($n = 529$; 258 boys, 271 girls). All infants were healthy and born at term; most were white and from middle- to upper-income families.

For 693 infants (342 boys, 351 girls), the survey was part of a battery of questions routinely asked of parents who brought their infants to the laboratory to participate in a separate study about cognitive or motor development. An additional 39 parents (20 boys, 19 girls) participated in the stair survey by telephone. Most of the data ($n = 683$) were collected retrospectively, whereby parents who brought their children to the laboratory for a one-time visit or who participated by telephone were asked to recall onset dates of their children's motor milestones. Parents consulted their personal records, such as a baby book, calendar, or diary to augment their memories and an experimenter prompted them using temporal landmarks, such as holidays, vacations, and birthdays, as reference points. After probing, if parents did not remember certain dates, these data were considered missing. For the rest of the sample ($n = 49$; 24 boys, 25 girls), data were collected prospectively, whereby parents whose children were participating in longitudinal studies kept daily records of their children's stair climbing and locomotor milestones.

Infants' ages at the time of parents' report about their skills on stairs ranged from 8.48 to 23.93 months. For retrospective reports, the average time lag between children's first stair ascent onset and first stair descent onset and when parents reported those events was 3.15 months for ascent (S.D. = 2.48 months) and 2.55 months for descent (S.D. = 2.43 months). A subset of children had no experience climbing up or down a full flight of stairs at the time of report. For prospective reports, there was no time lag between onset and report because parents were keeping ongoing records of infants' motor milestones.

2.2. Interview and procedure

The survey contained a formal series of questions about the context in which infants learn to ascend and descend stairs.

2.2.1. Motor milestones

All parents reported whether their infants could go up or down a full flight of stairs independently at the time of the interview. We defined independent stair ascent and descent as being able to manage seven or more stairs without help from another person and using any locomotor method. We used the strict criterion of climbing a full flight of stairs because crawling a few stairs takes only a few moments, like crawling up onto or down from a couch. In contrast, climbing up or down a full flight of stairs marks a real motor achievement comparable to other milestones that require ongoing, repetitive activity, such as crawling or walking.

Most parents ($n = 531$) also reported the specific dates that their children first went up a full flight of stairs independently ($n = 272$), went down a full flight of stairs independently ($n = 11$), or both ($n = 248$). We also obtained the onset dates of four additional locomotor milestones for all 531 infants with specific stair onset data and for the remaining 201 infants in the sample. The onset of belly crawling was the first day when infants could travel at least 10 feet continuously across the room with their abdomens touching the floor during part of each crawling cycle. Hands and knees crawling onset was the first day when infants could travel on hands and knees (or hands and feet) at least 10 feet continuously across a room without their abdomens touching the floor and without stopping to rest. Cruising onset was the first day when infants could walk sideways at least three feet continuously along the length of a couch or coffee table without stopping to rest. Walking onset was the first day when infants could walk independently at least 10 feet continuously across a room without pausing.

2.2.2. Experience on stairs

Parents reported whether their children experienced a serious fall on stairs. A fall was considered serious if it drew blood or required medical attention. Parents reported on housing characteristics relevant to stair experience, including whether they had stairs in their house/yard or in their apartment/building, whether the stairs were public or private, the number of stairs in their domicile, and whether the stairs were indoors or outdoors. Parents also reported the opportunities infants had to go on stairs other than in their home, such as the park or playground, friends' or relatives' homes, a vacation home, or daycare.

2.2.3. Learning to navigate stairs

Parents were asked about the locomotor methods used by their children the first time they ascended or descended a full flight of stairs. Parents also reported whether they explicitly taught their children to descend stairs or whether they discovered descent on their own. Parents who did teach their children stair descent were also asked about their teaching practices.

2.3. Data analyses

Each statistical analysis was run for as many children in the sample as possible. Data were missing from some analyses if children had not yet achieved a particular motor milestone at the time of parents' report, if parents could not remember the date a milestone was achieved, or if the data of interest were not collected as part of the original study that brought infants to the lab. This yielded a number of analyses with different sample sizes. For each analysis, we describe the criteria for inclusion and report the number of children from the larger sample meeting those criteria in the tables, figures, and accompanying text.

3. Results

3.1. Patterns of motor milestone achievement

3.1.1. Order of achievement

One way to examine the order of infants' stair climbing skills is to compare their abilities at the time of parents' reports. Fig. 1 depicts the distribution of stair-climbing skills across infants' ages at the time of their parents' report ($n = 732$). We grouped infants by month, such that infants who were at least 8.0 months of age, but younger than 9.0 months old at the time of their parents' report were grouped together, infants who were at least 9.0 months of age, but less than 10.0 months were grouped together, and so on. Younger children tended to be unable to go up or down stairs at all, or else were only able to go up. By 13 months most children could go up stairs, and about half could both ascend and descend stairs.

A second way to examine the order of achievement of stair climbing skills is to compare the onset ages for each milestone. We were able to use this method for 524 (71.6%) of the 732 infants either because we obtained onset dates for both skills ($n = 248$) or because infants could do one stair skill at the time of the interview, but could not yet do the other ($n = 276$). Infants typically learned to descend stairs after they had already learned to ascend stairs (88%), however 12% of children achieved both stair-climbing skills on the same day. Four parents (< 1%) reported that their children learned to descend a full flight of stairs before ascending a full flight. We could not determine the order of

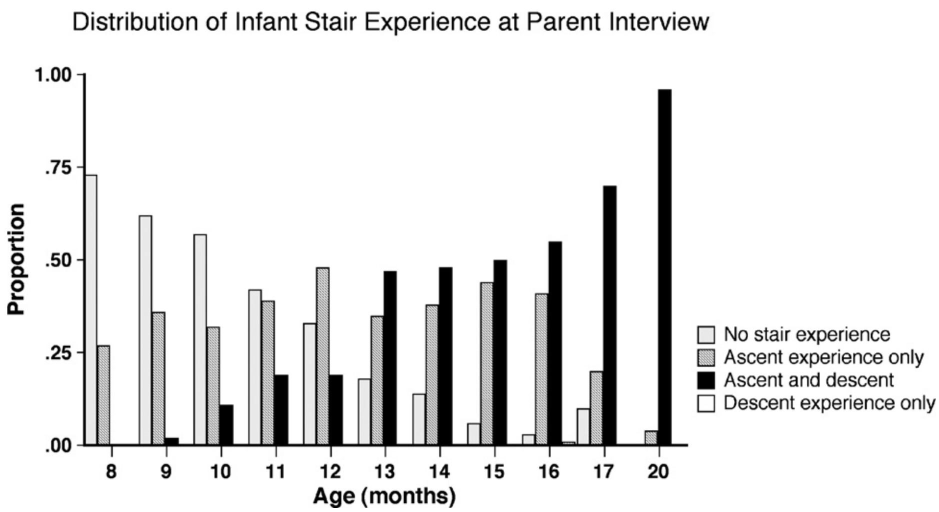

Fig. 1. Distribution of infants' skill on stairs by infants' age at the time of parents' report ($n = 732$).

Table 1
Motor milestone onsets

Motor milestone	Group average				Stairs at home			No stairs at home		
	N	Range	Mean	S.D.	*N*	Mean	S.D.	*N*	Mean	S.D.
Belly crawl	225	2.73–11.70	6.80	1.55	65	6.52	1.55	138	6.92	1.59
Hands and knees crawl	614	4.60–12.72	8.06	1.45	199	7.88	1.30	374	8.16	1.52
Cruise	421	4.34–14.14	9.32	1.49	98	9.41	1.48	288	9.39	1.48
Stair ascent	520	6.05–19.13	10.97	9.1	205	10.46	1.98	293	11.42	2.10
Walk	529	8.22–16.77	11.86	1.46	192	11.60	1.34	312	12.03	1.51
Stair descent	259	6.97–20.02	12.53	2.09	122	12.42	2.02	128	12.65	2.20

stair climbing milestone achievement for 208 (28.4%) of the 732 infants because at the time of the parent interview, infants could either do neither skill ($n = 156$) or could do both, but onset dates were unavailable ($n = 52$).

We also examined when infants achieved stair-climbing milestones relative to other locomotor milestones (crawling, cruising and walking). On average, infants learned to crawl and cruise before learning to ascend stairs independently. Walking onset followed stair ascent, but preceded independent stair descent (see Table 1, columns 2–5). There were no gender differences for onset ages for any of the motor milestones.

An examination of individual patterns of motor milestone achievement reveals a variety of developmental patterns that were masked when ages of onset were averaged across the whole sample. We were primarily interested in the locomotor milestones occurring immediately prior to or following stair ascent and descent. We had sufficient data (onset dates for four or five motor milestones) to describe the order in which milestones were achieved for 341 children. While 53 infants did match the average group pattern, we accounted for over 64% of the available sample with eight different milestone patterns (see Table 2). In total, infants achieved their motor milestones in 57 different orders, including 35 children who learned to ascend and descend stairs on the same day.

3.1.2. *Timelags between milestones*

The dataset included onset dates for hands and knees crawling and stair ascent for 465 babies. Four hundred and forty-two (95%) learned to ascend after they had started crawling. The elapsed time between the onset of hands and knees crawling and the onset of independent stair ascent ranged from .13 to 10.62 months ($M = 3.17$ months). Eight (2%) started to crawl and ascend stairs on the very same day. Parents of 15 children (3%) reported that they climbed a full flight of stairs before they reached criteria for hands and knees crawling. In some of these cases, infants had passed criterion for crawling on their bellies; presumably, the stairs provided the necessary support to allow climbing by relieving the arms from supporting so much body weight. But other infants just figured out how to climb stairs on hands and knees before they had passed criterion for crawling on hands and knees over flat ground. The time between stair ascent and crawling for these children ranged from .03 to 2.37 months ($M = .86$ months).

Table 2
Individual patterns of motor milestone achievement

No. of infants	% of sample	Order				
		First	Second	Third	Fourth	Fifth
58	17.0	Crawl	Cruise	Walk	Ascent	Descent
53	15.5	Crawl	Cruise	Ascent	Walk	Descent
24	7.0	Crawl	Ascent	Cruise	Walk	Descent
22	6.5	Crawl	Cruise	Ascent	Descent	Walk
18	5.3	Crawl	Ascent	Walk	Descent	
17	5.0	Cruise	Crawl	Ascent	Walk	Descent
14	4.1	Crawl	Ascent	Descent	Walk	
13	3.8	Cruise	Crawl	Walk	Ascent	Descent
219	64.2					

The dataset included information about the onset dates for both stair ascent and stair descent for 248 children. When ascent preceded descent (as in 74% of cases), the lag between skills ranged from .03 to 9.66 months ($M = 2.29$). Infants who learned to go up and down stairs on the same day (25%) went up stairs later ($M = 12.00$ months) than infants with a time lag between ascent and descent ($M = 10.41$ months for stair ascent), $t(245) = 5.12$, $p < .00$. Parents of only three children (1%) reported that they learned to descend stairs before they learned to ascend.

Although we do not know when children who had only achieved stair ascent at parent interview eventually learned to descend, we could calculate the minimum lag that would have to exist between ascent and descent. The time since the onset of stair ascent and parents' report of no descent for this group ranged from 0 to 8.97 months ($M = 2.67$ months).

3.2. Influences on onset ages of stairclimbing milestones

3.2.1. Access to stairs

Although 79% of our sample had experience on stairs, only 39% of them had stairs in their homes. Clearly infants were getting experience on stairs in places other than at home. Of the 252 infants for whom we had this information, 69.4% gained experience on stairs at their relatives' homes, 30.6% at a friend's house, 10.3% at daycare, 6.7% in a vacation home, 6.0% at the playground and 4.4% in a park.

Not all children with stairs in their homes had regular access to them. Parents reported barring infants from unsupervised access to stairs with safety gates at the top and bottom of the staircase. A comparison of the onset dates for stair ascent and descent between children with daily access ($n = 84$) and children without ($n = 67$) did not reveal any differences.

Independent samples *t*-tests revealed that infants with stairs in their home crawled, walked, and went up stairs earlier than infants without stairs in their home, all *p*-values <.03. However, the presence or absence of stairs in the home did not influence the onsets of belly crawling, cruising or stair descent (see Table 1, columns 6–11). Fig. 2A and B portray the distribution of ascent and descent onset ages for children with and without stairs in their homes and reveal developmental patterns that are not as clearly expressed when averaged across the whole group. Fig. 2A shows that 77% of infants with stairs in their home have learned to ascend by 11 months of age. In contrast, only 37% of infants without stairs have learned to ascend by 11 months of age. Fig. 2B shows a different pattern for stair descent. Regardless of the presence of stairs in the home, about half of the children had descended a full flight of stairs by 13 months.

The mean time lag between crawling onset and ascent onset for infants with stairs in the home was significantly shorter ($n = 169$; $M = 2.67$ months), than the time lag between crawling and ascent for infants without stairs in the home ($n = 275$; $M = 3.26$ months), $t(442) = 2.80$, $p < .01$. In addition, infants with stairs in the home had signifi-

Fig. 2. Proportion of infants with stairs in their home (dark bars) and without stairs in their home (light bars) who learned to ascend stairs (A) and descend stairs (B) by a given age. Infants with stairs in their homes learned to ascend stairs at an earlier age than infants without stairs in their homes. Age of onset for stair descent did not depend on stairs in the home. Data about the presence of stairs in the home were available for 444 infants.

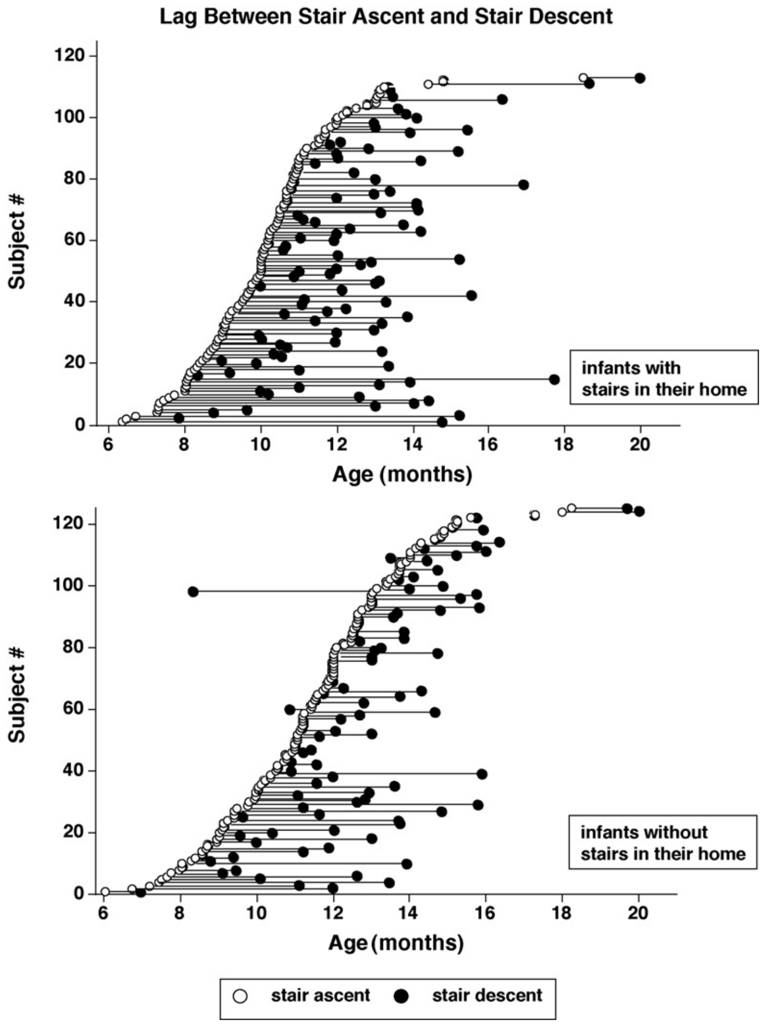

Fig. 3. Lag between stair ascent (open circles) and stair descent (closed circles) for each infant. Almost all infants learned to ascend stairs before they learned to descend stairs, regardless of the presence of stairs in the home. Note the displacement of onset dates to the right for infants without stairs in their home (bottom) indicating a delay in stair ascent, as compared to the onset dates of infants with stairs in their home (top). Data about the presence of stairs in the home and onset dates for ascent and descent were available for 239 infants.

cantly longer lags ($n = 113$; $M = 2.21$ months) between the onset of stair ascent and descent than children without stairs in the home ($n = 126$; $M = 1.17$ months), $t(237) = 4.34$, $p < .01$ (see Fig. 3). Of the children for whom we knew onset dates for stair ascent and, descent, and whether they had stairs in their home, 74% learned to ascend a full flight of stairs before they learned to descend, 25% achieved both stair-climbing milestones on the same day, and 1% learned to descend first. A chi-square test (excluding the three children who descended prior to ascending) revealed that infants who learned to ascend and descend stairs on the same day were less likely to have stairs in their home than infants who had a lag between the two stair climbing skills, $\chi^2(1) = 12.32$ $p < .01$ (Table 3, columns 2 and 3).

The presence of stairs in the home was also related to infants' locomotor status when they learned to ascend stairs. Whereas 52% of infants without stairs in their home were already walking by the time they first went up a full flight of stairs, only 40% of infants with stairs in their home were walking when they first went up a full flight of stairs, $t(444) = 2.50$, $p < .02$. There was no difference in locomotor status for stair descent. 82% of infants with stairs in their home were walking by the time they first went down a full flight of stairs, compared to 86% of infants without stairs in their home.

Table 3
Effect of infants' home stair status on stair climbing behavior

Stairs at home	Time between ascent and descent		Descent strategy			
	Positive lag	No lag	Backing	Sitting	Walking	Face first
Yes	96	17	129	19	8	
No	80	43	106	21	20	6

3.2.2. Teaching strategies

Parents' role was not limited to "gate-keeper" of the staircase. Although nearly every infant learned to ascend stairs on their own – some parents anecdotally reported leaving their infant alone for a few minutes and returning to find them at the top of the stairs – 58% of parents made a concerted effort to teach their infant to descend stairs safely. Parents' teaching methods included moving infants' limbs on the stairs to show them how to get down (76%), telling them to turn around at the top of the stairs and back down (32%), getting on stairs themselves to model stair descent for their children (49%), and giving verbal instructions, such as "turn around" or encouragement such as "good girl" (85%). Note that these numbers do not add to 100% because parents reported using more than one of these teaching strategies.

A chi-square analysis on the relationship between the presence of stairs in the home and whether parents taught their children to descend stairs revealed a significant relationship, $\chi^2(1) = 20.77$, $p < .01$. Infants with stairs in their homes were more likely to be taught to descend stairs than infants without stairs in their homes (see Table 4, columns 2 and 3). A *t*-test revealed no significant difference for the age at onset of stair descent between infants who were taught ($M = 12.37$ months; $n = 128$) and infants who figured out descent for themselves ($M = 12.77$; $n = 92$).

For 626 infants, we had information about whether they had had a serious fall down stairs that required medical attention. Parents safe-guarded their children well—only 2.7% reported having to seek medical attention for their infant due to a fall down stairs. Only one parent reported that her child avoided going on stairs after having been injured from a fall. We found no differences in the age at which infants first ascended or descended stairs based on whether they had ever fallen on stairs.

3.3. Strategies for ascent and descent

For 527 infants, we had information about the primary locomotor strategy that they used when they first ascended a staircase independently, and for 316 infants, we had information about their primary locomotor strategy that they first used for descent. Nearly every infant (94%) first ascended stairs by crawling up on hands and knees or hands and feet. The rest of the infants first ascended by walking, and two-thirds of these infants managed upright ascent by using a banister for support. Descent showed a wider range in strategies. Of the 316 for whom we had strategy data, 76% turned around and crawled or slid down backward down feet first, 9% walked while holding a banister, 13% scooted down in a sitting position, and 2% crawled or slid down face first in a prone position.

3.3.1. Effects of age and locomotor status on stairclimbing strategies

Several factors had an effect on infants' first descent strategies. For example, infants' age at the onset of stair descent predicted whether their first descent strategy involved approaching the stair in a prone position or in an upright position. A point biserial correlation between infants' age at the onset of stair descent and the type of descent strategy the first time they went down stairs was significant, $r_{pb}(254) = .25$, $p < .01$. Younger infants were more likely to use a strategy

Table 4
Factors related to parents' teaching practices

Taught to descend	Stairs at home		Descent strategy			
	Yes	No	Backing	Sitting	Walking	Face first
Yes	106	67	139	22	8	1
No	44	83	70	16	13	3

Table 5
Stair descent strategy of crawling and walking infants

Descent strategy	Locomotor status	
	Crawler	Walker
Backing	96	100
Sitting	9	26

where they approached the stairs on all fours. The very youngest infants used the inefficient strategy of trying to crawl or slide down face first ($M = 10.97$ months; $n = 4$), whereas infants who figured out how to turn around and back down the stairs on hands and knees were over a month older ($M = 12.20$ months; $n = 193$). In contrast, the older infants chose strategies that were compatible with approaching the staircase on foot, such as scooting down on their bottoms ($M = 13.55$ months; $n = 34$) or walking down holding the banister ($M = 14.12$ months; $n = 23$).

For 231 of the infants for whom we had data on their first descent strategy, we also had data on their locomotor status at the time of first descent. A chi-square analysis revealed a significant relationship between the strategy that babies used for first stair descent and their locomotor status, $\chi^2(1) = 6.48$, $p < .02$. Crawlers were unlikely to scoot down the stairs in a sitting position (see Table 5).

For 143 infants, we could examine the descent strategies for walking infants, who presumably had a choice in how to approach stair ascent and descent—on foot or by switching to hands and knees. For ascent, most walking infants (87%) still chose to crawl up stairs the first time they went up. As for stair descent, walking experience influenced infants' strategy choice. A point biserial correlation between infants' walking experience at stair descent (lag between walking and stair descent onsets) and descent strategy the first time they went down stairs was significant, $r_{pb}(143) = .27$, $p < .01$. Walkers with less experience were more likely to crawl down face first ($M = .89$ months walking experience; $n = 1$) or back down ($M = 1.82$ months walking experience; $n = 96$), whereas infants with more walking experience were more likely to walk down ($M = 2.30$ months; $n = 21$) or scoot down on their bottoms ($M = 3.23$ months; $n = 25$).

3.3.2. Effects of social and opportunistic factors on stairclimbing strategies

For various subsets of infants, the dataset included additional information that allowed us to examine the effects of several factors on infants' descent strategies. For example, for 272 infants, we could examine the effects of parents' teaching on infants descent strategies. A chi-square test revealed a significant relationship between the strategy that infants used for first stair descent and whether they were taught how to descend a flight of stairs, $\chi^2(3) = 9.51$, $p < .03$. Infants backed down stairs twice as often when they were taught than when they figured out how to descend for themselves. In contrast, infants walked down stairs more than 60% more often when they figured out how to get down a full flight of stairs by themselves (see Table 4, columns 4–7).

For 309 infants, we had sufficient data to examine the effect of stairs in the home on descent strategies. Infants usually backed down stairs, but those who walked down were unlikely to have stairs in their home, $\chi^2(3) = 12.60$, $p < .01$ (see Table 3, columns 4–7).

3.4. Regional differences

Because the data presented in this paper were compiled from several studies conducted in different cities around the United States, it was possible that a large proportion of children living in urban areas (New York City) would live in high-rise apartment buildings with elevators, whereas a large proportion of suburban (Bloomington, Pittsburgh) children would live in multi-level houses with staircases. Thus, there may have been regional differences relevant to infants' access to stairs based on the availability of stairs in the home.

To investigate this possibility, we used information about physical housing characteristics from the 2000 United States Census to run a cluster analysis on the 145 different zip codes where families in our sample lived (707 children contributed data about their zip codes). The analysis identified subgroups of zip codes that demonstrated distinctly different patterns of housing characteristics based on the number of units in the structure (single family homes to greater than 50 units) and the number of rooms in the unit (1 to >7). Our criteria for analyses were the proportions of families in each individual zip code who lived in a building with over 20 units.

Table 6
The relation between stair presence and housing types in urban and suburban areas

Stairs at home	Urban (New York City)			Suburban (Pittsburgh and Bloomington)		
	Sprawling	Mixed	Dense	Sprawling	Mixed	Dense
Yes	12	20	94	121	16	1
No		27	349	17	4	

Table 7
Effect of housing type on mean age (months) of stair ascent and descent

Housing type	Age of onset	
	Ascent	Descent
Sprawling	10.20 (n = 121; S.D. = 1.90)	12.02 (n = 65; S.D. = 1.79)
Mixed	10.51 (n = 58; S.D. = 2.08)	12.27 (n = 35; S.D. = 1.79)
Dense	11.34 (n = 322; S.D. = 2.07)	12.77 (n = 148; S.D. = 2.27)

Examination of the dendrogram and comparison of mean proportions of housing types yielded three discrete clusters of housing patterns into which the 145 zip codes could fall:

- *Sprawling* (on average, only 5.45% of people in a zip code lived in a building with over 20 units; the proportion of people with >20 unit dwellings per zip code ranged from 0 to 26.30%).
- *Mixed* (30.61% lived in dwellings with over 20 units; range: 11.10–53.30%).
- *Dense* (78.46% lived in dwellings with over 20 units; range: 58.40–99.60%).

Kruskal–Wallis tests revealed significant differences in the proportion of infants who had stairs in their home for the three housing patterns and for the two area types (urban versus suburban), $\chi^2(1) = 212.09$, $p < .01$ and $\chi^2(1) = 189.61$, $p < .01$, respectively. The most common patterns were sprawling housing with stairs in suburban areas and dense housing without stairs in urban areas (see Table 6).

Because access to stairs influences the age at which infants learn to climb and because where infants live may influence their access to stairs, we tested for regional differences that may have indirectly determined the age at onset of stair climbing skills in infancy. One-way ANOVAs revealed significant differences for the effect of housing type on the age of onset for stair ascent and stair descent, $F(2, 498) = 15.46$, $p < .01$ and $F(2, 245) = 3.22$, $p < .05$, respectively (see Table 7).

4. Discussion

This study examined when and how infants learn to ascend and descend stairs. In addition to collecting data about infants' ages when they first acquired stair climbing and other locomotor skills, we asked parents to report on social (teaching, monitoring) and environmental (stairs in the home, regular access to stairs) factors that may have influenced the acquisition of stair climbing. We also asked parents to report their children's first stair climbing strategies and we examined the effects of infants' age, social factors and environmental opportunities on infants' first descent strategies.

Children typically mastered ascent several months after crawling onset and several weeks prior to descent. The presence of stairs in the home was related to the age of onset for stair ascent, the strategies infants used for descent, and whether parents taught infants to descend stairs. Age of onset for descent did not depend on whether infants had stairs in their home.

4.1. Environmental constraints on stair climbing

Access to stairs influenced the age of onset for stair climbing. Ironically, New York City has the highest density of stairs in the country, but the use of stairs in high-rise buildings is limited to emergencies. Instead, families ride to the upper floors of their buildings in elevators. In walk-up apartment buildings without elevators, parents reported restricting their infants from stairs before they could walk up and down independently because the public stairwells were unsanitary. As a result, infants with stairs in their homes learned to ascend stairs earlier than infants who lived in homes without stairs. Furthermore, regional differences in housing types created a "suburban advantage" where infants living in suburban neighborhoods with sprawling housing learned to climb up and down stairs at younger ages than infants living in urban areas.

Stair access is not the sole urban–suburban disparity contributing to the difference in onset ages for stair climbing skills because when the presence of stairs in the home is the sole criterion, it does not predict a difference in age of onset for stair descent. Thus, other factors associated with living in suburban homes must affect stair climbing. One possibility is that different housing types lead to different locomotor experiences which in turn affect how infants approach novel situations such as stairs. Indeed, infants living in large suburban homes have qualitatively different crawling experiences than infants living in small urban apartments. Although infants travel approximately the same distances regardless of urban/suburban housing, they accumulate crawling experience differently. Infants in large homes take advantage of more open floor space by taking long, less frequent crawling trips. In contrast, infants in smaller apartments with less open floor space make shorter, more frequent crawling excursions (Chan, Lu, Marin, & Adolph, 1999).

Opportunity influences the achievement of motor milestones in other contexts, as well. For example, in some African and West Indian cultures, parents do not provide infants with access to the floor. Without spending time in prone positions, most infants skip crawling and proceed straight to walking (Bril & Sabatier, 1986; Hopkins & Westra, 1988, 1990). In the current study, the large range of onset ages for stair climbing and the vast individual differences in when stair climbing was learned relative to other motor milestones emphasize the importance that opportunity plays in motor milestone achievement. Like learning to crawl, learning to climb stairs also requires a specific combination of factors, including independent mobility and a somewhat artificial, particularly shaped structure. Given the opportunity, some infants in our sample climbed a full flight of stairs at 6 months. At the other extreme, some infants in our sample had no access to the requisite environment and they did not have their first experience on stairs until 18–20 months of age. Infants without stairs in their homes capitalized on their rare opportunities to go on stairs when those opportunities arrived. One consequence of living in a home without stairs was the frequent acquisition of both stair ascent and stair descent on the same day or after only a very short delay.

4.2. Social structuring of stair climbing

What factors might account for the time lags between crawling and stair ascent and between stair ascent and descent? For crawling infants, neither stair climbing skill should be motorically challenging. Crawling up stairs relieves infants from supporting as much body weight on their arms as required in crawling on flat ground. However, only eight infants learned to crawl and to climb stairs on the same day. Descending stairs by crawling or sliding backward feet first should be less motorically challenging than crawling on flat ground because balance requirements are minimal with infants' bellies plastered to the stairs. Furthermore, it was rare in our sample for infants to learn to go up and down stairs on the same day. Once infants got to the top of the stairs, why did they simply not back down immediately? Did they climb to the top and then get stuck up there?

One possible explanation is that our criteria for onset of stair ascent and descent were strict: we required infants to climb a full flight of seven stairs. Possibly infants began crawling up and down single-stair changes in elevation or played on the bottom few steps of a staircase (Ulrich & Thelen, 1990) coincident with the onset of crawling. Access to stairs cannot be the sole explanation because the presence of stairs in the home did not affect the age of onset for descent. We offer an alternative explanation for the time lags between locomotor milestones that has a more social flavor. As in previous work, our interviews highlighted the important role of parents in monitoring their children's safety on stairs (Gärling & Gärling, 1995; Gärling & Gärling, 1988; Valsiner & Mackie, 1985). Possibly, social control provided by parents contributes to the time lag between stair ascent and descent. Once infants figured out how to go up stairs, parents may pluck them off the landing to keep them safe before infants explore possibilities for coming down. Infants with stairs in their homes may have been prevented from going down them by their parents for several weeks after they had learned to go up.

In addition to placing restrictions on what children experience, parents guide their children in potentially dangerous situations by teaching them how to protect themselves, particularly after they are independently mobile (Gärling &

Gärling, 1988). Stairs are a prevalent, potentially dangerous (but alluring) obstacle for infants. Many parents in our sample taught their infants safe methods for stair descent, particularly backing down feet first. However, infants who were taught a descent method did not learn to go down stairs any earlier than infants who discovered stair descent on their own. This suggests that parents were sensitive to when their infants were ready to learn stair descent and did not try to teach them earlier. Furthermore, infants' low rate of falls on stairs provides further evidence that parents' strategies were successful and that they judged their children's abilities appropriately.

4.3. Strategies for stair ascent and descent

Many biomechanical studies of stair climbing have emphasized the physical difficulty in walking up and down stairs as compared to walking on level ground. For example, stair climbing requires a wider range of knee motion and generates larger forces on muscles in the knees than level walking does (Andriacchi et al., 1980; McFadyen & Winter, 1988; Townsend et al., 1978). During descent these greater muscle and joint demands are necessary for providing stability to the body while it is simultaneously lowered and moved forward. During ascent, the muscles in the hips, knees, and ankles have to convert more chemical energy into potential energy than walking on level ground requires to lift the body up and forward (Riener et al., 2002). Despite these physical demands, stairs did not pose an insurmountable obstacle for the infants in our survey. Infants who could not yet walk on flat ground or who were not big or strong enough to go up and down staircases coped by using adaptive climbing strategies, such as clambering up on hands and feet and crawling down backwards with their bellies to the stairs.

Although stairs typically are not built to infant-friendly proportions (Templer, 1992b), crawling infants may actually have a stair climbing advantage over adults because being close to the ground on four limbs provides more stability than being upright on two feet. Elderly stair-climbers often cite poor balance control or limited muscle strength as contributing to their own instability on stairs (Haslam et al., 2001). To reduce their risk of falling on stairs the elderly tend to avoid them as much as possible—even to the extreme of moving into new homes without stairs (Haslam et al., 2001). Most walking infants, who may have faced similar biomechanical limitations as the elderly, dealt with the difficulty of ascent and descent by switching to a crawling posture.

4.4. Speculation about the cognitive demands of stair climbing

A final possibility for the time lag between ascent and descent and for the descent strategies infants employed concerns infants' cognitive abilities. Although not measured directly in this study, other research suggests that infants' descent strategies may be related to their cognitive abilities (Adolph, 1997). Most parents teach their children to back down stairs because backing is the safest position for descent. However, it is also the most cognitively difficult descent strategy. Backing requires infants to make a detour at the top of the stairs, give up visual guidance of the goal, and to crawl backwards on hands and knees or hands and feet. Coordinating these pieces into a complete backing strategy is more difficult than doing them separately (Wechsler & Adolph, 1995). If infants preferred or were taught to descend stairs by climbing down backwards, they would need the cognitive skills to make a locomotor detour away from their goal which typically is not acquired until late in the first year (Lockman, 1984; Lockman & Adams, 2001). Indeed, infants in our sample who typically crawled down stairs backwards, rather than crawling on flat ground forward, first did so just after 12 months of age. The cognitive difficulty of backing may explain why some parents of younger infants anecdotally reported trying to teach backing as a descent strategy, but then giving up because it was too complicated for their children to understand.

When infants chose a descent strategy other than backing, their locomotor posture contributed to their choice. Rather than making the effort to turn around or switch from hands and knees to sitting, crawlers who did not back down continued down the stairs face first. Rather than making the effort to switch postures and directions, walkers who approached the staircase on foot, but did not back down, went down in a sitting position or walked down holding the banister. Indeed, novice walkers often find it difficult to switch from walking to crawling, even when their performance on a locomotor task may be hindered by sticking with their preferred posture (Berger, 2005). Those infants who did not adopt the safe strategy of backing down stairs may have been simply unable to perform a complex motor behavior while simultaneously navigating a set of stairs (Berger, 2004). Thus, access to stairs alone is insufficient for learning stair descent and parents wait to teach their children descent strategies because stair descent often requires coming up with new locomotor means to achieve a goal.

5. Conclusion

Parents and developmental psychologists have typically considered motor development in normative terms, as if all that is required for skill acquisition is the physical wherewithal to manage the movements. Stair climbing serves as a vivid illustration of how multiple, interacting factors influence the acquisition of developmental milestones. Stair climbing does indeed require physical ability, but it also requires the opportunity to be in a specific environment, along with environmental and social supports. The effect of having stairs in the home on the age at which infants first learn stair ascent emphasizes the role that opportunity plays in locomotor development. In contrast, the lack of effect of stairs in the home on the age at which infants first learn stair descent emphasizes the role that social opportunity and cognitive ability play in locomotor development. Parents can facilitate infants' experiences with stairs by teaching them climbing strategies and restrict infants' experiences on stairs by preventing them from climbing altogether.

As a first attempt to address the circumstances surrounding how infants learn to climb stairs, this study lays the groundwork for a new set of research questions. To assess more directly the role of cognitive abilities in learning to descend stairs, future research should examine the types of cognitive tasks that children can perform successfully at the same age that they are mastering stair descent. Future endeavors may also want to consider how parents decide when their children are ready to go on stairs. Finally, what is infants' experience on stairs before they negotiate a full flight? Observational studies can document the possible experiences that precede infants' eventual mastery of stair climbing.

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