A Cross-Linguistic Study of Locomotor Experience and Psychological Development: Walking Onset Is Linked to Advanced Receptive and Productive Vocabularies in Berkeley and Shanghai

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A Cross-Linguistic Study of Locomotor Experience and Psychological Development: Walking Onset Is Linked to Advanced Receptive and Productive Vocabularies in Berkeley and Shanghai

By

Minxuan He

A dissertation submitted in partial satisfaction of the requirements for the degree of

Doctor of Philosophy

in

Psychology

in the

Graduate Division

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Committee in charge:

Professor Joseph J. Campos, Chair
Professor David Anderson
Professor Qing Zhou
Professor Martin Banks

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Abstract

A Cross-Linguistic Study of Locomotor Experience and Psychological Development: Walking Onset Is Linked to Advanced Receptive and Productive Vocabularies in Berkeley and Shanghai

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Minxuan He

Doctor of Philosophy in Psychology

University of California, Berkeley

Professor Joseph J. Campos, Chair

Whether motoric activities hold psychological effect has been a controversial. Recently, Campos and his colleagues (Campos et al, 2000) have shown the acquisition of prone locomotion not only precedes but also causes various changes in psychological abilities, including perception, cognition, and socio-emotional development. This dissertation work deals with another major motoric achievement during infancy, upright locomotion, and whether it brings about psychological changes. It focuses on an original phenomenon that walking brings about increased receptive and productive vocabularies (Walle & Campos, 2014). If this relation reflects the consequence of an epigenetic event, then it should be present regardless of when the infant typically begins to walk, the infant’s culture, and the infant’s native language. This study sought to replicate the previously reported link between walking and language development in American infants and investigate whether this relation exists cross-nationally in typically developing Chinese infants exposed to Mandarin. Urban Chinese infants not only provide a distinct linguistic and cultural population in which to study this relation but also typically begin walking approximately 6 weeks later than American infants. Our results demonstrated that (1) walking infants in both the American and Chinese samples had greater receptive and productive vocabularies than same-aged crawling infants, (2) differences between crawling and walking infants were proportionally similar in each sample, and (3) the walking-language relation was present for both noun and non-noun vocabularies. These findings provide further support of a relation between infant walking onset and language development, independent of age. Avenues for future research of the processes involved in this relation, as well as additional populations of interest to investigate, are discussed.
Preamble

The study of human development centers on two major issues. One is the investigation of the origins of human characteristics, such as perception, cognition, emotion, personality, etc. The second is the identification and explanation of developmental transitions in the life of the person. Early developmental transitions in human infancy, such as the acquisition of new motoric skills, serve as catalysts for changes in person-environment relations. Such transformational events have been termed “epigenetic” because their acquisition creates experiences that generate new psychological skills (Gottlieb, 1983). Thus, it is not only the emergence of the skill that is of great importance, but also the functional consequences of its onset on related domains of psychological development (Campos et al., 1997). A commonly studied example is the onset of crawling (see Campos et al., 2000). The acquisition of crawling results in a variety of developmental changes: infants’ increased capacity to search for hidden objects between two locations (Kermoian & Campos, 1988); changes in the parent-child attachment relationship (Zumbahlen, 1997; Zumbahlen & Crawley, 1996); changes in the parent’s emotional behavior towards the child (Campos, Kermoian, & Zumbahlen, 1992); more advanced infant joint visual attention (Campos et al., 1997; Tao & Dong, 1997; Telzrow, Campos, Kermoian, & Bertenthal, 1999); and finally, infants’ heightened responsiveness to information in the peripheral field of view for the control of balance (Higgins, Campos, & Kermoian, 1996).

The onset of walking is another major, but less studied, developmental transition that may also have functional consequences in psychological development. Some studies have shown that the onset of walking corresponds with a reorganization of the parent-child relationship, resulting in an increase in both positive and negative exchanges. For example, caregivers of walking infants reported increased interpersonal conflicts compared to those of crawling infants of same age (Biringen, Emde, Campos, & Appelbaum, 1995). There is also increased infant object exploration and object sharing with caregivers with the onset of walking (Karasik, Tamis-LeMonda, & Adolph, 2011). Recently, the acquisition of walking has been linked with infant language development (Walle & Campos, 2014).

To date, abundant evidence from crawling studies and growing interest in walking studies may have revealed such a mechanism that learning new skills brings the changing relation between the person and the environment and thus psychological consequences with these changes. If this argument holds true, then we should observe functional changes in those capabilities that are sensitive to the changes of person-environment relations following the onset of walking.

This dissertation work concerns the strength and mechanisms of a newly discovered link between the onset of independent walking and early language development. In 2014, Walle & Campos found that parents of walking infants reported significantly larger receptive and productive vocabularies than those of crawling infants of the same age in the Bay Area, using the MacArthur Communicative Development Inventory (CDI) short checklist, a standardized
questionnaire with outstanding reliability and validity (Fenson et al., 1994). A small longitudinal study conducted by the same researchers following infants from 11 months to 14 months of age, showed the same spurt in receptive and productive vocabularies, independently of the age of walking onset, again with Bay Area infants and using the CDI long form. These two studies have led to immediate attention to the phenomenon and a series of questions about whether this link is unique to the English language and why there would be such a link if proven in any language environment. Such a finding needs confirmation using converging research operations such as cross-linguistic comparison.

In the sections to follow, we shall first review the background about the role of motoric activities on psychological development as a general issue. The idea that motoric activities affect psychological functioning has a long history and can be dated back to philosophers like Bishop Berkeley (Berkeley, 1709) when he argued that motor activity is crucial for depth perception, and by extrapolation, form perception. Subsequently, Berkeley’s ideas have been extended by many theoreticians, most notably the Swiss epistemologist Jean Piaget. Piaget (1952, 1954) argued that the origins of intelligence were in the intercoordination of sensory information with self-produced movements, including locomotion. The ideas of Berkeley, Piaget, and many others have been very controversial, but in recent years, new evidence has been mounting on the role of motoric activity in at least some aspects of psychological development. In recent years, compelling evidence from research on crawling has confirmed that crawling not only precedes many psychological abilities but also causes certain psychological changes (Campos et al., 2000).

Second, we will discuss the effect of crawling, as a major motoric milestone during infancy, on psychological development and review empirical evidences from various domains, including perception, cognition, emotion and social development. Evaluation of the research methods and findings on crawling onset is essential as the study of crawling onset bears both conceptual and methodological merit to the study of the correlates and consequences of walking onset.

Third, we will summarize the work to date about the discovery of the link between walking onset and language and set the stage for this dissertation work. It builds on the rich work on crawling and extends to walking. Though a major motoric developmental event, the effect of walking onset awaits more systematic investigation.

Fourth, we will present findings of the dissertation work with infants born and raised in the Bay Area and those in Shanghai, China, which is a primarily Mandarin-speaking environment. This study examines the strength of this link by extending the study in a very different linguistic environment of Mandarin Chinese. If this link is proven, there should be something more fundamental about how walking, as a cross-nationally shared activity, affects the language learning of human infants.

In the concluding section, we will discuss a number of possible “probes” (i.e., candidate mediators) that may account for the link between walking and language and, thus, avenues for future research. There is no reasonable account of why walking affects language, but some candidate mediators are worth
investigating. Therefore, it is of particular interest to identify these probes possibly underlying such a link. We will propose a few psychological assessments that should be related to the acquisition of language, which tests may tap the mediators by which walking brings about language.

Of crucial importance to such exploration is a Baconian (i.e., *a posteriori* approach) emphasizing inductive reasoning that will allow us to accumulate data from observations and reason about the possible mediators of the phenomenon. This scientific spirit is especially compatible with the nature of dissertation work. Some of this work will lead to a solid basis and some will lead to new questions.

**Introduction**

1. The Landscape of This Dissertation

1.1 Linking Motoric Activities with Psychological Functioning

The early theories of motor development can be traced back to the 1930s and 1940s, when McGraw and Gesell suggested that motor development was a maturational process and change was a result of mainly internal and genetic factors rather than external or environmental factors, let alone gene-environmental interactions. Although influential in the early phase of understanding motor development, the maturational approach lost support because although maturation is necessary, environmental influences are also important.

The idea of motoric activities has received growing attention and interest by many theories. Piaget (1960) argued against the widely held view that “there is nothing in the mind not first in the senses,” and instead proposed that the origins of mental activity begin with the imposition of motoric activity on incoming sensations. These sensations act, according to Piaget, as correctives and guides to motor activity, but not as the origins of the child’s ideas of causality, space, forms, imagination, and symbolic thought. Gibson (1968, 1979) similarly stressed the importance of actions like locomotion for revealing meaningful information present in the visual world. Mahler, a psychoanalyst, has stated that the onset of voluntary locomotion represents the “psychological birth” of the human infant (Mahler, Pine, & Bergman, 1975). Later on, the information-processing model, stressed the importance of environmental factors, shifting the focus from genes to environment while keeping the important role of the brain and the nervous system (Haywood & Getchell, 2009). The dynamic systems approach, which gained momentum in the 1980s, provided a more flexible model of motor behaviors (Thelen, 2000). More specifically, motor development was viewed as the end product of a variety of different systems (Smith & Thelen, 2003). It identified the role of numerous subsystems cooperating together while changes in the organism take place on different timescales (Smith & Thelen, 2003).

Although the developmental trajectories for the separate areas have been extensively studied, the ways in which development in one area impact development in other areas are less well understood. However, the relations between motor development and psychological impacts has received increased attention in recent years with researchers seeking to provide insights into aspects
of human development, treatment of developmental disorders or even teaching academic skills through their motor correlates (Campos et al., 2000).

1.2 An Overview of Attempts to Link Motoric Activities with Psychological Functioning

The bias against locomotion began to change during the latter half of the twentieth century as the bidirectional models spread out (a great review can be found in (Anderson et al., 2013). These bidirectional models highlight the activity-dependent nature of structural and functional development and give experience an essential role in the developmental process.

For example, dynamical systems theory stresses the reciprocity between perception, action, and cognition, and view development as the result of a complex, contingent, and multi-determined web of interactions that emerge over time (Gibson, 1988; Thelen & Smith, 1996; Witherington, 2007, 2011). Similarly, Gottlieb’s (e.g., 1970, 1991, 2007) notion of probabilistic epigenesis has provided a strong challenge to the unidirectional model of human development by highlighting the diversity of co-actions (reciprocal interactions that can literally change the interacting elements) that occur across the genetic, structural, and functional (environmental) levels of analysis during pre- and post-natal development. Probabilistic epigenesis implies that development is a function of time-based, probabilistic relations between these different levels of analysis.

A series of research investigates a broad range of psychological development stemming from a breadth of experiences infants gain with the onset of crawling (for a review, see Campos et al., 2000; Anderson et al., 2013). Researchers propose that locomotion orchestrates this diversity of changes by making it almost inevitable that infants will encounter the experiences that contribute to specific psychological changes. The acquisition of independent locomotion is not only significant because of the breadth of psychological phenomena to which it is connected. Its enduring significance stems from the fact that once locomotion has been acquired it is available across the lifespan and so it may well be vital to the maintenance of the very psychological skills it had a role in bringing about.

1.2.1 Crawling and Its Psychological Impacts

Crawling has been shown to play a vital role in the ontogeny of many psychological phenomena, but two bear special scrutiny: visual proprioception and wariness of heights.

Visual proprioception is the optically induced sense of self-movement produced by patterns of optic flow in the environment (Gibson, 1966; 1979). Peripheral lamellar optic flow (PLOF), usually generated in the visual periphery when one moves in space, is believed to be most effective in eliciting visual proprioception (Stoffregen, 1985). Visual proprioception is crucial for “establishing and maintaining postural stability, and for navigation in the world” (Anderson et al., 2013). In an age-held-constant study of crawling, pre-crawling, and pre-crawling infants with “walker” experience, infants with either real or artificial locomotor experience showed heightened postural compensation to
peripheral optic flow (Higgins et al., 1996). Second, in a true experiment using random assignment to experimental and control conditions (Uchiyama et al., 2008), the researchers randomly assigned pre-crawling infants to a powered mobility device (PMD) in which the infants could control their own movement by pushing a joystick or a no-movement control condition. Again only pre-crawling infants in the PMD condition showed increased postural compensation and negative emotional reactions to peripheral optic flow. In sum, studies using multi-methods converged on the hypothesis that locomotor experience, in this case crawling, brings about a dramatic shift in visual proprioception. The link between crawling onset and visual proprioception was also found cross-culturally with Chinese infants who naturally started crawling 6-8 weeks later than their American counterparts (Tao & Dong, 1997).

Furthermore, Bertenthal and Campos (1990) proposed a novel explanation of why human infants are initially unconcerned about drop-offs, but after some experience with locomotion, i.e. crawling, become progressively more wary about depth-at-an-edge. The explanation involves the same phenomenon mentioned above, visual proprioception. In one experiment, Dahl et al. (2013) showed that postural responsiveness to peripheral lamellar optic flow (PLOF) in a moving room paradigm predicted whether crawling infants would descend onto the deep side of a visual cliff (a large table with a Plexiglas surface divided into a shallow side and a deep side by virtue of illuminated tiles placed immediately below the surface or four feet below the surface on the floor). Infants who showed the greatest responsiveness to PLOF were the least likely to descend onto the deep side of the cliff. In a second experiment, Dahl et al. (2013) showed that prelocomotor infants who had 15 days of training in a PMD showed significantly greater postural compensation to PLOF and significantly higher cardiac responses to being lowered toward the deep side of a visual cliff (the index of wariness was the difference between the heart rate acceleration on the deep and shallow sides of the cliff) than same-age prelocomotor infants without PMD training. Taken together, there is consistent empirical evidence that the increased sensitivity to PLOF, most effectively brought about by crawling experience, has led to the emergence of wariness of heights.

Thus, using converging research operations (i.e., multiple ways of testing the same hypothesis), crawling has been confirmed not only to serve as an antecedent of a wide range of psychological consequences, but also caused these changes. For example, studies with atypically developing infants have confirmed the relation between locomotor experience and several spatial search tasks. Spina bifida is a neural tube defect that is associated with delays in locomotor and psychological development. In a longitudinal study of seven infants with spina bifida (Joseph J. Campos, Anderson, & Telzrow, 2009), these infants were tested monthly after recruitment until 2 months after the delayed onset of independent locomotion, which occurred at 8.5, 11.5, and 13.5 months-of-age in three of the infants and 10.5 months-of-age in the other four. Their performance on the two-position hiding task improved dramatically from 14% to 64% correct search following the onset of crawling. Similar improvements on
other spatial cognitive tasks such as form extraction and joint visual attention were also found with this clinical population (Rivera, 2012).

1.3 The Link between Walking and Language

Walking is another locomotor transition that results in a number of distinct advantages for infant interactions with the world. In particular, the hands become free to manipulate objects and carry them from place to place, and infant goals also become increasingly more distal, necessitating the infant keep such goals in mind while traversing ground to obtain them and possibly changing parent-infant communicative patterns. Observational research has highlighted significant changes in infant exploration and social interactions occurring following the onset of walking (Biringen, Emde, Campos, & Appelbaum, 1995; Clearfield, Osborne, & Mullen, 2008; Karasik, Tamis-LeMonda, & Adolph, 2011). Of central relevance to the current investigation is the relation of infant walking with language development. Walle and Campos (2014) found that receptive and productive vocabulary sizes were larger for walking than age-matched crawling infants, with longitudinal findings indicating that these differences were accounted for by the transition from crawling to walking, independent of age. Additionally, retrospective reports also suggest a link between motor development (i.e., sitting, walking) and later vocabulary development (Oudgenoeg-Paz, Volman, & Leseman, 2012). While on their surface these findings may seem surprising, when viewed from an epigenetic perspective that underscores the interconnectedness of dynamic systems in which “each component in the developing system is both cause and product” (p. 94, Thelen, 1995), such a complex picture may actually be quite understandable.

Some researchers have speculated that changes in the infant social ecology following the acquisition of walking may be associated with language acquisition (see Iverson, 2010). The first empirical evidence clearly demonstrating a link between infants’ transition to walking, and their language development was reported by Walle and Campos (2014). As noted earlier, in both a longitudinal and a cross-sectional study, parental report revealed that walking infants had larger receptive and productive vocabularies than crawling infants, independent of age. While it seems unlikely that the acquisition of walking directly causes an increase in infant language development, we believe that walking may act as an epigenetic event that fundamentally changes infant psychological functioning in a host of related psychological domains. As discussed previously (Walle & Campos, 2014), walking may be associated with changes in neurological development (e.g., stepping coordination may help facilitate the development of the cerebellum and hemispheric lateralization of the brain), communicative usage and understanding (e.g., infant pointing and sharing of objects with adults may increase opportunities for labeling), physical movement and behavior (e.g., increased efficiency of movement may result in greater exploration of the environment and exposure to novel objects), and social interactions (e.g., parents may alter their speech in accordance with what is perceived to be a more competent social partner). Thus, the effects of walking on
the infant may be far-reaching, and, of perhaps greater importance, likely act in concert to facilitate development in an epigenetic fashion.

The studies with infants in the Bay Area leads us to the question that if walking serves as an epigenetic event that significantly impacts language development, one would hypothesize that this relation would exist in multiple languages, in multiple cultures, and be independent of when the infant typically began to walk. Because the experimental control of infant walking onset is exceedingly difficult, and clinical delays in walking are typically associated with deficits in other areas, we sought an “experiment of nature” (Bronfenbrenner, 1977) using a population with a naturally occurring, nonclinical delay in the onset of walking. Previous research has found that normative developmental trajectories of infant motor skills vary across cultures (for a review, see (Adolph, Karasik, & Tamis-Lemonda, 2010). Given the universal nature of the acquisition of upright locomotion and language in typically developing humans, we hypothesized that the relation reported by Walle and Campos (2014) would replicate with a non-Western, non-English speaking population. One population fitting the above criteria and thus selected for the present investigation is infants from Shanghai, China exposed to Mandarin Chinese, who typically begin to walk approximately 6 weeks later than American infants. The difference in age of walking onset between American and Chinese infants provides the unique opportunity to examine the relation of walking and language development using a nonclinical population with a different normative age of locomotor onset.

It is clear that locomotor experience has been proven to be important to the 7-9 month transition in psychological functioning in the form of crawling. Yet the study of walking awaits systematic work.

1.4 Locomotor, Cultural, and Linguistic Differences in Development

Research utilizing unique populations permits the study of phenomena that may develop via distinct trajectories due to variability in developmental pressures and affordances. Such differences are clearly evident between American infants and infants growing up in urban China. While Chinese and American infants reach similar motoric and linguistic developmental milestones, the timing toward proficiency and environmental input for such skills for each population is different.

Researchers have previously found that Chinese infants tend to reach locomotor milestones later than American infants. Tao and Dong (1997) reported that urban Chinese infants on average began crawling at 9.5 months of age, roughly 6-8 weeks later than American infants. The authors reasoned that Chinese infants had less space for crawling due to smaller households and Chinese parents were reluctant to have their infants crawl on the ground because of hygienic concerns. A similar delay in the onset of infant walking has been reported, with Chinese infants typically walking at about 14 months of age (Fan & Zhou, 1983), approximately 1.5 months later than American infants. This discrepancy in the onset of walking is not believed to be the result of any biological or pathological factor, but rather may be the result of economic factors, cultural factors, and parenting practices. The difference in age of walking onset
between American and Chinese infants provides the unique opportunity to examine the relation of walking and language development using non-clinical populations with different ages of locomotor onsets. Thus, while one cannot randomly assign infants to early or late walking groups, a comparison of American and urban Chinese infants allows for a naturally occurring grouping of predictably early and late walkers. Furthermore, because the age of walking onset, be it “early” or “late,” is typical for each population, concerns about possible neurological or kinesiological differences and delays in other domains are less likely.

Cultural differences in the perceptual and social environment may also be associated with developmental differences in the relation of walking and language development. Research indicates that Chinese individuals tend to focus on the contextual elements associated with objects, whereas individuals from Western cultures are more likely to focus on discrete object properties (e.g., Ji, Peng, & Nisbett, 2000; Masuda & Nisbett, 2001), and that the effects of these cultural differences can be found early in development (Chiu, 1972). Furthermore, research suggests that the effect of culture, over and above differences in linguistic structure, leads to such differences in Chinese and American categorization of objects (Ji, Zhang, & Nisbett, 2004). Such cultural differences may result in qualitatively different parent labeling patterns and child perception of the environment that affect early language development, particularly as the infant becomes a more active participant in the relational context following the acquisition of walking. Thus, it is possible that as walking infants become more relationally engaged with the environment, cultures emphasizing relational elements of the environment may have a more pronounced effect on linguistic development following the onset of walking.

Finally, the inclusion of Chinese infants in the present study also allows for a comparison of the effect of walking development on two very distinct languages: Mandarin Chinese and English. Research indicates clear differences in the syntactic and pragmatic features of Mandarin Chinese and English that together affect language development (Tardif, Shatz, & Naigles, 1997). For example, argument omission occurs more frequently in Mandarin Chinese than in English. Verbs in Mandarin Chinese are also less heavily inflected than those in English, which increases the phonological consistency of verbs across contexts. Additionally, observational data indicate that the noun-bias, which is commonly found in English language environments, is less pronounced in Mandarin Chinese language environments (Tardif, Gelman, & Xu, 1999). The above differences are hypothesized to account for Mandarin Chinese infants having a greater proportion of verbs in their early linguistic development (e.g., Tardif, 1996; Tardif et al., 1999) than what is commonly found in other languages, such as English or Italian (e.g., Goldfield, 1993; Shatz, 1994). It is possible that the above linguistic differences may differentially impact the relation between walking and language development, specifically with regards to semantic categories, such as nouns and non-nouns.
The above research indicates clear differences in Chinese and American infants’ locomotor development, cultural variation in relational aspects of objects in the environment, and distinct syntactic and pragmatic features specific to Mandarin Chinese and English. Most critically, the difference in typical age of walking onset between American and urban Chinese infants will allow us to explore the relation of walking and language development, independent of age, in a non-clinically delayed locomotor group. If the relation of walking and language represents an epigenetic phenomenon, then this relation should be present despite the locomotor, cultural, and linguistic differences highlighted above. Furthermore, the cultural and linguistic differences in relational emphasis and prevalence of nouns in the language learning environment encourage comparisons of the size of the effect for the two samples and whether particular types of words are differentially related to walking, specifically nouns.

2. The Present Investigation

The present study employed an age-held-constant design to compare crawling and walking infants of two distinct cultures, specifically American infants and Chinese infants. The question of primary importance was whether the relation between infant walking onset and language development would be present cross-linguistically and cross-nationally. We hypothesized that walking infants would have larger receptive and productive vocabularies than same-aged crawling infants in both the sample of American infants and the sample of Chinese infants exposed to Mandarin Chinese. We also predicted that the differences in receptive and productive language between crawling and walking infants would be proportionally similar for the American and Chinese samples. Finally, given the differences in noun and non-noun development in English and Mandarin Chinese, we sought to explore the relation of walking onset on noun and non-noun receptive and productive vocabulary. We hypothesized that the effect of walking would be present for both types of words in both samples.

Method

Participants

American infants. Forty infants (21 crawling infants, 8 female; 19 walking infants, 10 female), each 12.5 months of age, were recruited from the San Francisco Bay Area. The average American infant heard English spoken for 88% of their day and was exposed to 1.45 languages. Other languages to which infants were exposed included Spanish (n = 13), French (n = 4), Mandarin Chinese (n = 2), Arabic (n = 1), Cantonese (n = 1), Hungarian (n = 1), Italian (n = 1), Japanese (n = 1), Konkani (n = 1), Korean (n = 1), Russian (n = 1), Tagalog (n = 1), Tamil (n = 1), as well as baby sign language (n = 2). The average parent age was 34 years ($SD = 4$ years) and parent education ranged from having a high school diploma to a graduate degree, with most parents having a bachelor’s degree. The average household income was $92,000. The American sample was ethnically representative of the diverse population of the local area. The majority of infants in the American sample were only children (only child = 25; 1 sibling = 10; 2 siblings = 5).
Chinese infants. Forty-two infants (21 crawling infants, 11 female; 21 walking infants, 8 female) between 13 and 14.5 months of age recruited in Shanghai, China were included in the Chinese infant sample. This age range of walking onset was determined by the motor development norm used by local pediatricians in Shanghai. The tighter age range for the American infant sample was the result of investigators being able to draw participants from an existing database of families, whereas such a database was not available from which to recruit Chinese infants. Walking and crawling infants did not significantly differ in age (Walking infants: $M = 13.89$, $SD = 0.37$; Crawling infants: $M = 13.75$, $SD = 0.31$), $t(42) = 1.37$, $p = .18$. The average Chinese infant was exposed to primarily Mandarin and Shanghainese (or the Shanghai dialect), a dialect of Chinese commonly spoken in Shanghai (97%). Very few infants (3%) had exposure to English words through daycare centers, and the exposure never exceeded 10% of all language input. All infants were exclusively Hans, the majority ethnic group in the Chinese population. Parent education ranged from middle school to a graduate degree, with the average parent having a bachelors or bachelors equivalent degree. The average family income was ¥100,000 (approximately $14,700, based on the exchange rate when the data was collected), which is comparable in value to the income from the American sample. All infants in the Chinese sample were the only child in their family when entering the study.

Measures

Locomotor Development. Parents completed a basic locomotor development questionnaire to report on specific motoric milestones and their onsets. Specific to the present study, parents reported when their infant began crawling and walking. Crawling onset was operationalized as when the child began self-locomoting a distance of twice his or her body length. Walking onset was operationalized as the infant locomoting bipedally a distance of 10 feet without falling or needing assistance. These definitions were based on previous investigations involving infant locomotor development (see Adolph, 1997; Adolph, Vereijken, & Shrouf, 2003; Walle & Campos, 2014).

Language Development. All families completed a version of the MacArthur-Bates Communicative Development Inventory. Families in the American sample completed an online version of the MacArthur-Bates Long Form Vocabulary Checklist: Level I (CDI) (Fenson et al., 1994). This language assessment tool contains a 396-item checklist that allows parents to mark words that their child “understands” (receptive vocabulary) or “understands and says” (productive vocabulary). The overall questionnaire consists of 19 semantic categories (e.g., toys, people, games and routines). Parents were permitted to mark words that the infant understood or produced in languages other than English, including signing.

Families in the Chinese sample completed the Mandarin version of the MacArthur-Bates Long Form Vocabulary Checklist: Level I (Tardif, Fletcher, Zhang, Liang, & Zuo, 2008), or Putonghua CDI (PCDI). The PCDI contains a 411-item checklist that allows parents to mark words that their child
“understands” or “understands and says.” The overall questionnaire consists of 20 semantic categories and parents were permitted to mark words that infant understood or produced in Mandarin or dialects spoken at home, including Shanghainese.

Internal validity and test-retest reliability have been established for the English CDI by Fenson et al. (1994) and for the PCDI by Tardif et al. (2008).

**Results**

**American Sample**

American crawling and walking infants’ receptive and productive vocabulary scores are presented in Figure 1. The American walking infants had significantly larger receptive vocabularies ($M = 135.32$, $SE = 14.45$) than did crawling infants ($M = 84.76$, $SE = 11.88$), $t(40) = 2.73$, $p = .01$, $d = 0.86$, 95% CI [-88.144 to -12.96]. The American walking infants also had larger productive vocabularies ($M = 28.58$, $SE = 4.64$) than did crawling infants ($M = 11.76$, $SE = 2.16$), $t(40) = 3.39$, $p = .003$, $d = 1.17$, 95% CI [-27.34, -6.30]. These findings replicate differences between locomotor groups in American infant samples reported by Walle & Campos (2014).

Because walking infants had significantly more self-produced locomotion (SPL) experience (months since crawling onset) ($M = 4.92$, $SE = 0.32$) than crawling infants ($M = 3.50$, $SE = 0.34$), $t(37) = 2.99$, $p = .005$, $d = 1.01$, 95% CI [-2.38, -0.45]¹, regression analyses including walking status (crawling vs. walking) and total SPL were run to determine the independent effects of each variable on infant language development. For receptive vocabulary, the effect of total SPL was not significant, $\beta = .23$, $t(37) = 1.38$, $p = .18$, whereas a marginal effect remained for walking status, $\beta = .33$, $t(42) = 1.97$, $p = 0.058$.² For productive vocabulary, the effect of total SPL was not significant, $\beta = .22$, $t(37) = 1.36$, $p = .18$, but the effect of walking status remained significant, $\beta = .39$, $t(37) = 2.42$, $p = .021$.

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¹ Three parents in the American sample failed to report infant age of crawling onset.
² It is worth noting that the loss of power resulting from 3 participants not having total SPL scores and the inclusion of a covariate likely accounts for this relation becoming marginal.
Figure 1. Mean number of words understood and produced by American crawling infants and walking infants using the CDI vocabulary checklist. Error bars represent +/- 1 standard error.

**Chinese Sample**

Similar to their American counterparts, Chinese walking infants displayed larger receptive and productive vocabularies than Chinese crawling infants (see Figure 2). Receptive language was significantly larger for walking infants ($M = 241.28$, $SE = 16.23$) than crawling infants ($M = 186.90$, $SE = 15.25$), $t(42) = 2.44$, $p = .019$, $d = 0.77$, 95% CI [-99.48, -9.28]. Productive language was also significantly larger for walking ($M = 21.67$, $SE = 2.78$) than crawling infants ($M = 7.90$, $SE = 1.30$), $t(42) = 4.49$, $p < .000$, $d = 1.42$, 95% CI [-20.04, -7.48]. An analysis of covariance was conducted to rule out the possibility of an age effect for the Chinese sample because of the larger age range. Results showed that the effect of locomotor status remained significant when age was partialled out for both receptive, $F(1,39) = 3.98$, $p = .05$, and productive, $F(1,39) = 17.10$, $p < 0.00$, language.

As with the American sample, Chinese walking infants also had more self-produced locomotion (SPL) experience (months since crawling onset) ($M = 4.98$, $SE = 0.18$) than crawling infants ($M = 4.39$, $SE = 0.24$), though this effect was
only marginal, $t(42) = 1.93, p = .06, d = 0.60, 95\% \text{ CI } [-1.20, 0.03]$. Thus, regression analyses including walking status (crawling vs. walking) and total SPL were run to determine the independent effects of each variable on infant language development. For receptive vocabulary, the effect of total SPL was not significant, $\beta = .10, t(42) = 0.62, p = .54$, whereas a significant effect remained for walking status, $\beta = .33, t(42) = 2.13, p = 0.04$. For productive vocabulary, the effect of total SPL was not significant, $\beta = -.08, t(42) = -0.58, p = .57$, but the effect of walking status remained significant, $\beta = .60, t(42) = 4.43, p < .000$.

*Figure 2.* Mean number of words understood and produced by Chinese crawling infants and walking infants using the PCDI vocabulary checklist. Error bars represent +/- 1 standard error.
Differences Between Reports of American vs. Chinese Infant Language

Having established the presence of language differences between crawling and walking infants in both the American and Chinese samples, a subsequent set of analyses were conducted to determine whether these differences were of similar magnitude between the two cultures. As noted above, the English and Mandarin CDIs contain a different number of total items in their respective vocabulary checklists. Furthermore, because the Chinese infants were older due to the delay in walking onset, their language scores were larger on average compared with the American infants. Thus, a test of proportions was carried out to examine whether the language differences between crawling and walking infants were comparable for the American and Chinese infant samples. Differences between proportions of the language samples were calculated as follows:

$$\frac{\text{Mean US Crawling Infant Vocabulary}}{\text{Mean US Walking Infant Vocabulary}} - \frac{\text{Mean Chinese Crawling Infant Vocabulary}}{\text{Mean Chinese Walking Infant Vocabulary}} = \text{Proportional Difference}$$

Proportional differences in receptive vocabulary for crawling and walking infants did not significantly differ between American and Chinese infants (difference between proportions = 0.12), $z = 1.18, p = 0.24$. Similarly, the differences in productive vocabulary were also statistically similar in the American and Chinese samples (difference between proportions = 0.003), $z = 0.03, p = 0.98$. These findings indicate that the differences in crawling and walking infants’ language development were statistically similar between the American and Chinese samples.

Noun and Non-Noun Vocabularies

A final set of analyses was conducted for each sample to explore if differences in language development were specific to nouns.\(^3\) Scores on the CDI were separated into two categories: the noun categories identified by Fenson et al. (1994) and non-noun categories.

**American Sample.** American walking infants ($M = 92.58, SE = 10.81$) had significantly larger receptive vocabularies for nouns than did crawling infants ($M = 55.10, SE = 8.09$), $t(40) = 2.81, p = 0.008, d = 0.88, 95\% \text{ CI } [-64.50, -10.47]$. Interestingly, this difference was also found for non-noun vocabularies, with walking infants ($M = 42.74, SE = 3.91$) understanding more non-noun words than crawling infants ($M = 29.67, SE = 3.93$), $t(40) = 2.35, p = .02, d = 0.76, 95\% \text{ CI } [-24.33, -1.81]$. A similar pattern of findings was present for productive vocabulary size. American walking infants produced more nouns ($M = 21.63, SE = 3.47$) than crawling infants ($M = 8.29, SE = 1.59$), $t(40) = 3.50, p = .002, d = 1.14, 95\% \text{ CI } [-21.20, -5.49]$, and also produced more non-nouns ($M = 6.95, SE = 1.33$) than

\(^3\) The present sample sizes do not permit exploring locomotor differences for each semantic category because the correction factor would severely minimize the power of the analyses.
crawling infants ($M = 3.48, SE = 0.69$), $t(40) = 2.32$, $p = .028$, $d = 0.74$, 95% CI [-6.53, -0.41].

**Chinese Sample.** Chinese walking infants ($M = 127.24, SE = 8.78$) also had significantly larger receptive vocabularies for nouns than did crawling infants ($M = 90.00, SE = 7.53$), $t(42) = 2.33$, $p = .03$, $d = 0.74$, 95% CI [-44.93, -3.17]. Productive vocabulary showed a similar pattern of findings. Chinese walking infants produced more nouns ($M = 7.38, SE = 1.31$) than crawling infants ($M = 3.57, SE = 0.56$), $t(42) = 2.38$, $p = .01$, $d = 0.75$, 95% CI [-6.72, -0.89], and also produced more non-nouns ($M = 14.29, SE = 1.78$) than did crawling infants ($M = 4.33, SE = 0.99$), $t(42) = 4.89$, $p < .000$, $d = 1.55$, 95% CI [-14.10, -5.80].

**A Comparison across Semantic Categories with Chinese Sample**

The Mandarin CDI-Long consists of a total of 411 words in 20 semantic categories. We were interested in the patterns of language development by taking a closer look at each category (see Table 1 below). We found walking infants understood and produced more words across the board. Among a total of 20 categories, walking infants displayed significantly larger receptive vocabularies in 11 of them and 2 with marginal significance compared to crawling infants. Walking infants also produced more words in these 6 out of 20 categories. The finding with infants in urban area of China further strengthened the link between walking and language development, especially because of the ecological delay in the onset of walking. In addition, walking infants had larger vocabularies in all 20 semantic categories than crawling infants of the same age, indicating an overall better performance in receptive and productive language. More interestingly, the changes in such categories as “people” and “action words” echoed previous literature on the development of related aspects psychological development. For example, joint visual attention shows a shift around 12 months of age such that the infant can follow a gaze directed at objects somewhat behind the infant (George Butterworth & Jarrett, 1991). The greater facility of the walking infant to pivot to look behind himself/herself may account for the understanding of the referent of pointing gestures to objects behind the child, and hence to the labeling of objects in such a position. Another aspect relevant to action involves infants’ ability to follow the pointing gesture of the mother to its referent begins somewhat earlier than does walking, but develops more robustly around the end of first year. Therefore, the question of whether walkers do better than crawlers in following the mother’s point to its referent may reflect an improved spatial “geometry” (Butterworth, 1992). These changes may also take place when infants are able to look at the mother and to point to an object that is not the focus of the mother’s attention (Conrad, 1995). However, it is still too early to conclude same changes may be found in other linguistic systems such as English.
<table>
<thead>
<tr>
<th>Semantic Categories (listed in the order of Mandarin CDI-Long)</th>
<th>Number of words in each category</th>
<th>Mean difference in Words Understood (walking infants – crawling infants)</th>
<th>Mean difference in Words Produced (walking infants – crawling infants)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sound effects and animal sounds</td>
<td>11</td>
<td>1.06</td>
<td>2.07**</td>
</tr>
<tr>
<td>People</td>
<td>26</td>
<td>3.63**</td>
<td>3.38**</td>
</tr>
<tr>
<td>Games and Routines</td>
<td>22</td>
<td>4.08**</td>
<td>2.74**</td>
</tr>
<tr>
<td>Action words</td>
<td>78</td>
<td>13.10**</td>
<td>5.97**</td>
</tr>
<tr>
<td>Food and Drink</td>
<td>29</td>
<td>4.86**</td>
<td>2.87**</td>
</tr>
<tr>
<td>Body parts</td>
<td>18</td>
<td>2.08†</td>
<td>1.86†</td>
</tr>
<tr>
<td>Animal words (real or toy)</td>
<td>33</td>
<td>3.41</td>
<td>2.00†</td>
</tr>
<tr>
<td>Descriptive words</td>
<td>44</td>
<td>7.11**</td>
<td>2.35†</td>
</tr>
<tr>
<td>Small household items</td>
<td>35</td>
<td>6.76**</td>
<td>1.19</td>
</tr>
<tr>
<td>Toys</td>
<td>8</td>
<td>1.49**</td>
<td>0.30</td>
</tr>
<tr>
<td>Clothing</td>
<td>15</td>
<td>2.57**</td>
<td>0.93†</td>
</tr>
<tr>
<td>Furniture and rooms</td>
<td>19</td>
<td>3.91**</td>
<td>0.53</td>
</tr>
<tr>
<td>Outside things</td>
<td>22</td>
<td>3.70**</td>
<td>1.06†</td>
</tr>
<tr>
<td>Vehicles (real or toy)</td>
<td>9</td>
<td>0.80</td>
<td>0.39</td>
</tr>
<tr>
<td>Prepositions and locations</td>
<td>11</td>
<td>1.25</td>
<td>0.27</td>
</tr>
<tr>
<td>Numbers</td>
<td>6</td>
<td>0.34</td>
<td>0.56*</td>
</tr>
<tr>
<td>Question words</td>
<td>6</td>
<td>0.52</td>
<td>0.05</td>
</tr>
<tr>
<td>Pronouns</td>
<td>7</td>
<td>1.66**</td>
<td>0.23</td>
</tr>
<tr>
<td>Quantifiers</td>
<td>6</td>
<td>0.25</td>
<td>0.14</td>
</tr>
<tr>
<td>Words about time</td>
<td>6</td>
<td>0.17</td>
<td>0.14</td>
</tr>
<tr>
<td>Total</td>
<td>411</td>
<td>+62.29 *</td>
<td>+12.83 *</td>
</tr>
</tbody>
</table>

Note: † p < .10, *p < .05, **p < .01, ***p < .0
Future research may include a comparison group from rural area of China where infants are likely to start walking at an earlier age for economic reason but at a similar age as infants in the Bay Area.

**Discussion**

The present investigation replicated and extended previous research indicating a link between the acquisition of infant walking and language development. Our results in the American infant sample replicated the findings of Walle and Campos (2014), demonstrating that walking infants have significantly larger receptive and productive vocabularies than same-aged crawling infants. The present study also extended this link cross-nationally and cross-linguistically with a sample of infants from Shanghai, China. The walking Chinese infants had significantly larger receptive and productive vocabularies than same-aged crawling infants. This finding emerged despite Chinese infants acquiring walking approximately 6 weeks later than the American infants. Replication of this finding in a non-clinically delayed walking group supports the view of walking as an epigenetic event that is associated with language development independent of when this locomotor transition occurs or in what linguistic or cultural context. Furthermore, the relation of language with walking was present even after controlling for infants’ total SPL experience. This further supports the conclusion that a qualitative shift occurs with the acquisition of walking.

Proportional analyses indicated that although the Chinese infants were older, and therefore had larger vocabularies than the American infants, the differences between crawling and walking infants’ receptive and productive vocabularies were comparable to those of the American sample. This suggests that the functional relation between walking and language is proportionally similar for early and later walkers. Our results also suggest that the distinct linguistic features specific to Mandarin Chinese and English did not affect the link between infant walking and language development. Specifically, the effect of walking appeared to affect nouns and non-nouns in both the American and Chinese samples, despite the greater proportion of non-nouns understood and produced by Mandarin Chinese infants.

Taken together, this set of findings supports the view that the acquisition of walking is an epigenetic event that is related to infant language development, independent of age, across multiple languages and cultures.

**General Discussion**

While the present findings support the link between walking acquisition and language development, there remain a number of unanswered questions for future research.

First and foremost, although the presence of a relation between walking and language in the Chinese sample lends support that this phenomenon may be wide reaching in human development, it by no means provides evidence that this is a universal finding. Future research may wish to examine infants from rural
areas of China, who, based on anecdotal reports from Chinese pediatricians, typically begin walking at similar ages as American infants, possibly because of increased physical space for movement and differences in caregiving practices in urban settings. Additionally, research is required with other cultures and languages to further investigate the link between walking and language. For instance, the Gussi tribe of Kenya could be one such population that would offer a host of interesting comparative analyses. Gussi caregivers are more likely to hold infants, particularly on their backs, after the onset of walking than is observed in other cultures (LeVine, 1994). This would allow for a natural control of infant exploratory behavior and daily locomotor experience. Additionally, the Gussi do not typically conversationally engage infants in the first 2 years of life (LeVine et al., 1994; Richman, Miller, & LeVine, 1992). This would help isolate the effect of locomotion while controlling for possible changes in infant social interactions with the caregiver following the onset of walking. Interestingly, the frequency of Gussi speech to infants increases from 9-10 to 14-15 months of age (though it is still roughly half of what is observed in American families). It is possible that this shift in vocalizations coincides with the onset of Gussi infants beginning to walk, though to date no one has documented at what age Gussi infants acquire upright locomotion. Another population of interest would be infants who sign (both with and without hearing impairments). It would be fascinating to examine the possible role of hands-free locomotion in facilitating these infants’ communicative abilities.

Second, the CDI and PCDI rely on parents’ self-report of their child’s language abilities. It is possible that parents of walking infants may attribute greater language to their infants because of differences in their perception of the infant (e.g., walking infants may be judged as more intentional or more competent). Naturalistic observation of mother-child interactions and direct testing of word comprehension and production would provide converging research to assess infant language development before and after the onset of walking. Additionally, although the proportional differences between crawling and walking infants were similar between the present samples, it is entirely possible that the process of language learning for each sample is unique. Thus, the same outcome may have been reached through different, culturally specific, processes.

Third, the lack of statistical power prevented the current study from comparing specific CDI and PCDI semantic categories. Although the effect of walking on language was present for both noun and non-noun categories, and anecdotally we can report that this pattern appears similar across semantic categories, research is necessary to more thoroughly explore such differences. Additionally, it is worth noting that comparisons of the ratios of nouns to non-noun vocabulary sizes indicate distinct patterns between American and Chinese infants. As expected based on previous research, American infants exhibited a greater ratio of nouns to non-nouns for receptive (walkers = 92.58:42.74; crawlers = 55.10:29.27) and productive (walkers = 21.63:6.95; crawlers = 8.29:3.48) vocabulary. However, Chinese infants’ receptive vocabularies indicated a more even ratio of noun to non-nouns (Receptive Vocabulary: walkers = 127.24:114.05; crawlers = 96.90:90.00) and a greater ratio of noun to
non-nouns for productive vocabulary (Productive Vocabulary: walkers = 7.38:14.29; crawlers = 3.57:4.33). Thus, the present data demonstrate the expected noun to non-noun patterns for English and Mandarin Chinese, respectively, reported in previous research (e.g., Tardif et al., 1999). However, the effect of walking appears to be related to both nouns and non-nouns alike.

Fourth, we strongly encourage a follow-up longitudinal study including Chinese infants from both urban and rural areas. As discussed earlier in this paper, the discrepancy in the timing of walking onset in the Bay Area and Shanghai is likely the result of non-biological factors, as all children in the present study were typically developing. Unlike infants in Shanghai, infants in rural China likely have more access to space for exploration. These infants would serve as an excellent reference group: although they are being raised in linguistic and cultural setting of mainland China, their walking onset would be expected to be more similar to American infants. It is also possible that the binary classification of infant locomotion used in the present study and in Walle and Campos (2014) may have missed important differences in infant walking skill. Learning to walk is a slow process (see Adolph et al., 2003) and the longitudinal findings by Walle and Campos (2014) indicate distinct, non-linear developmental trajectories for receptive and productive language. Additional research is needed to explore how differences in motoric skill and proficiency may affect language development.

Finally, although these findings highlight and support our view that an epigenetic event is likely taking place, they only begin to scratch the surface of elucidating the underlying mechanisms affected by this locomotor transition. Language learning is a multifaceted developmental process. The acquisition of walking is likely to have significant psychological consequences in a number of areas, some of which likely relate to language development (see Walle & Campos, 2014). For example, infants’ responding to attentional cues of referents outside their visual perspective has been found to develop in the second year of life (Butterworth & Cochran, 1980; Butterworth & Jarrett, 1991; Deák, Flom, & Pick, 2000). It is possible that walking infants’ increased ability to pivot and look behind them may improve infants’ understanding of the self in relation to objects in space. The development of this ability could increase infants’ understanding of the referent of pointing gestures to objects outside the infant’s visual field, and hence to the labeling of objects in such a position. Another aspect relevant to the affordances of walking is gesture, an important tool for infant language learning (e.g., Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). Walking infants demonstrate greater gesturing than crawling infants (Clearfield et al., 2008; Karasik et al., 2011), and more mobile bids for attention, which in turn elicit differential maternal responses (Karasik, Tamis-LeMonda, & Adolph, 2014). Thus, walking infants may help create richer and more infant-driven language learning contexts. It is also possible that infants’ increased first-hand experience with gesturing helps facilitate appreciation of the communicative intent of others’ gestures (see Sommerville, Woodward, & Needham, 2005). Research is sorely needed to explore how changes in various psychological domains may mediate the relation between walking and language development.
Taken together, the present research more clearly indicates the “what” (i.e., infant walking acquisition is related to language development), but considerable additional research is needed to investigate the “why.” This lingering question remains daunting in its openness. However, we are optimistic that careful and creative research will help reveal the interrelated factors of this complex relationship.

**Future Directions**

As mentioned earlier in the discussion section, early language development, especially comprehension, is likely to be overestimated by parents using the questionnaire method. A more sensitive and objective laboratory assessment of infant language comprehension is crucial to validate parental report obtained from the CDI questionnaire. The assessment will utilize the intermodal preferential looking paradigm (IPLP). This paradigm capitalizes on infants’ natural tendency to look toward images or events that correspond with auditory information and has been used successfully to assess infants’ early language understanding (Thomas, Campos, Shucard, Ramsay, & Shucard, 1981; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Golinkoff, Ma, Song, & Hirsh-Pasek, 2013).

In order to confirm the link between walking and talking, there are two key steps for the set-up of this paradigm. First, we need to develop a sensitive and objective assessment to test an infant’s understanding of a word. Humans have a tendency to look toward a figure that matches a word that is being said by another, and infants from 11 to 13 months of age similarly have been shown to do so (Thomas et al., 1980). Infants should look at a display of four objects, one in each of four corners in a rectangular display, which is the referent of the word that is uttered. This should be independent of gender, locomotor status or even language comprehension scores in the CDI. Second, we should select words that follow a certain distribution, such as walking infants are more likely to comprehend than crawling infants. Since IPLP can only be applied to verbs and events until 17 months or later (Friedman & Stevenson, 1975), our current set-up mainly focuses on infants’ understanding of object names.

The two questionnaire studies presented in this dissertation work would serve as our word bank for future study. We will select words that are mostly likely to be known after the onset of walking and pair them with words that are likely known to both locomotor groups and words unlikely known by either walkers or crawlers.

We will then look for colorful and vibrant images online based on the words. These images are very generic and made to be the same size so to prevent confounding variables. The images will be put into power point slides. Each side contains 4 images (one in each corner), including 1 high frequency (mostly likely known by walkers), 1 medium frequency (by both walkers and crawlers) and 1 unknown word (by either group). Since we are assessing the infant’s understanding of the target word, the location of the target word will be counterbalanced on a randomized order. There are a total of 16 slides.
The dissertation work initiates a foray into the psychological consequences of walking, and studies children in China who are delayed in walking purely for ecological and cultural reasons, part of a broad intellectual movement pointing to the importance of motoric activities on psychological functions. The findings provided cross-national and cross-linguistic evidence to the investigation of the relation between walking and language comprehension and production.

Obviously, walking per se cannot produce receptive and productive changes in language. Walking must recruit some major changes in the child’s and the mother-child relationship that MEDIATES the walking-language shift. The identification of potential mediators of this linkage is thus a key objective of the future research. We propose a longitudinal study of some 40 infants who will be brought in monthly from 11 months to 15 months of age into the laboratory. During these monthly visits, the infant will be tested by research assistants who will not know the locomotor status of the infant, i.e., walking or crawling, on the following assessments, each of which should show some direct relation to language acquisition. (NOTE: The order of description of the paradigms does not necessarily match the order of testing of the infants.)

Is there a difference in the language environment of walker vs. crawling infants?

One paradigm will assess differences in the language environment that may pace walking infants' relatively greater advances in language. This sociolinguistic approach has already been studied in the area of emotional communication (Biringen et al., 1995). In this study, we will directly assess the number of words the parent directs toward the child, and the number of words the child uses. In addition, because walking greatly increases the distances and the relative position of the child to environmental objects, we are going to center on the use of language that taps spatial relations (especially in light of the powerful role of early locomotion on spatial cognitive skills, (see Campos et al., 2000). We will study all words bearing on spatial relations, including not only nouns and verbs, but also prepositions such as in front of, behind, under, over, to the left (right), and so on. Although our CDI data does not show clear differentiation between walking and crawling infants in spatial language, it is possible that the CDI, as a self-report instrument, may have missed words of this spatial cognitive quality. The study of the communicative environment of mother and child will also obtain direct evidence of differences in receptive and productive language among the children in the study, and thus not depend exclusively on the CDI, a maternal-report instrument.

Are communicative gestures involving spatial relations differentially effective in the two groups of infants?

The second category of mother-infant interactions that we propose to "probe" involves joint visual attention. There are numerous changes that take place in the infant’s ability to understand (and, in some cases, produce) attentional cues that have linguistic implications. Joint visual attention refers a skill to relate different visual fields one to the other with eyes or fingers in one
field and target of visual attention in another visual field. Joint visual attention shows a shift around 12 months of age (the prototypical age of onset of walking) such that the infant can follow a gaze directed at objects somewhat behind the infant (Butterworth & Jarrett, 1991). The greater facility of the walking infant to pivot to look behind himself/herself may account for the understanding of the referent of pointing gestures to objects behind the child, and hence to the labeling of objects in such a position.

**The potential importance of imitation in the two groups of infants**

Because the relation between words and their referent is specific to each language family, the infant must use imitation of the caregiver’s speech to acquire both receptive and productive language. To create a joint language, the child must therefore imitate the use of the word to refer to the proper referent of the word. The English-learning child must imitate the word “milk” to refer to the white, sweet drink in a cup. The Spanish-learning child must imitate “leche” and the French-learning child “lait” to become accurate in his/her production of the word. In addition, the imitation must be of the deferred variety for the child to be cued to use the word if he or she sees the substance in view, or to recall it from memory if the child is bidding for the substance when it is not visible or present. Thus, deferred imitation skill thus must be involved in language acquisition.

**Coda**

In conclusion, this dissertation work provided converging evidence on the same unexpected and difficult-to-explain conclusion that something related to the onset of walking facilitates the acquisition of both the receptive and the productive aspects of language. The findings were infants in Shanghai performed similarly to infants in Berkeley. The correspondence of findings in Shanghai, China raised two issues. Number one is how walking is related to speech. Is it entirely maturational process that affects two distinct psychological domains - motoric and speech? Or is it more intimate link between the two domains? To disentangle this issue poses formidable challenges. The fact that infants in China acquire walking at a later age than do infants in Berkeley may be one way to disentangle the factor of age from motoric abilities. The second issue has to do with the possibility that walking serves as catalyst, like crawling, for a wide array of psychological development, including those discussed in the dissertation, and others that are not. It will require a large study using batteries of various psychological assessments and a longitudinal design to assess what proxies might prove to be mediators and which prove not to be mediators at all. To this end, this dissertation work discussed various ways to initiate the investigation of potential determinants or antecedents of this difference. This represents the next step in a thorough investigation of the discovery reported in the dissertation. To date, the research on possible mediators is in progress both in Berkeley and Shanghai.


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