12-15-2016

The Time Is at Hand: The Development of Spatial Representations of Time in Children?s Speech and Gesture

Lauren Stites

THE TIME IS AT HAND: THE DEVELOPMENT OF SPATIAL REPRESENTATIONS OF TIME IN CHILDREN'S SPEECH AND GESTURE

by

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ABSTRACT

Children achieve increasingly complex language milestones initially in gesture before they do so in speech. In this study, we asked whether gesture continues to be part of the language-learning process as children develop more abstract language skills, namely metaphors. More specifically, we focused on spatial metaphors for time and asked whether developmental changes in children's production of such metaphors in speech also became evident in gesture and what cognitive and linguistic factors contributed to the these changes. To answer these questions, we analyzed the speech and gestures produced by three groups of children (ages 3-4, 5-6, and 7-8)—all learning English as first language—as they talked about past and future events, along with adult native speakers of English. We asked how early we find evidence of developmental changes in the orientation (sagittal vs. lateral), directionality (left-to-right, right-to-left, backward, or forward) and congruency (lateral gestures with Time-RP language and sagittal gestures with Ego-RP language) of the metaphorical gestures children produced; we also examined whether comprehension of metaphors for time and literacy skills would influence the changes in children's gestures. Our findings showed developmental changes in both the orientation, directionality, and congruency of children's gestures about time. Beginning with *orientation* (sagittal vs. lateral), children increased their use of lateral gestures with age, and this increase was predicted by improvements in their literacy skills. Turning next to *directionality* (left-to-right, right-to-left, forward, backward), we found that children's metaphor comprehension and literacy skills selectively predicted the directionality of their sagittal and lateral gestures. Children who understood metaphors for time were more likely to produce sagittal gestures that placed the past behind and the future ahead; while children who showed higher levels of literacy were more likely to use lateral gestures that placed the past to the left and future to the right. Finally, for *congruency* (i.e., using gestures that correspond with spoke language), we found that older children who showed better metaphor comprehension and literacy skills were also more likely to pair lateral gestures with Time-RP language than with Ego-RP language. Overall, these results showed that children's gestures about time follow a developmental pattern that is influenced by their literacy development, and to a lesser extent, metaphor comprehension.

INDEX WORDS: Metaphorical gesture, Time metaphors, Language Development, Spatial gestures

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

in the College of Arts and Sciences

Georgia State University

2016

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December 2016

DEDICATION

This dissertation is dedicated to Robert Campbell Stites, who put up with me through undergraduate and graduate school and helped make this possible.

ACKNOWLEDGEMENTS

Thank you to Şeyda Özçalışkan, who has guided me through my graduate program with a level of grace, professionalism, expertise, and humor that was at times almost super human. Further, I would like to acknowledge the hard work and dedication of the research assistants, Tikenya Joseph, Megan Tchakarov, and Ashton Crain, without whose help this dissertation would not be possible. Finally, I would like to thank Bob and Sandy Stites, without whose support none of this would have been possible.

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1 INTRODUCTION

Gesture and speech go hand-in-hand in development, with gestures signaling oncoming changes in children's linguistic abilities (Goldin-Meadow, 2007). Children's first gestures precede their first words by several months and these early gestures predict which words will enter their vocabulary (Iverson & Goldin-Meadow, 2005). This pattern continues into children's first sentences. Children use gesture-speech combinations (e.g. point to cookie and while saying "eat") in order to express sentence-like meaning before they can express similar sentences in speech alone (e.g. say "eat cookie"; Butcher & Goldin-Meadow, 2000; Özçalışkan & Goldin-Meadow, 2005). However, language development does not stop at children's first words and sentences; children still need to learn to produce more complex speech, such as metaphors. As shown in earlier work (Özçalışkan , 2005; Özçalışkan, Gentner, Goldin-Meadow, Mylander, 2009; Stites & Özçalışkan, 2013), metaphor is an early emerging skill that changes rapidly between ages 2 and 6. However little is known about developmental changes in children's expression of metaphors in gesture and factors that contribute to these changes.

Adults frequently produce gestures while expressing metaphors in speech and such co-speech gestures convey information related to speech (e.g., McNeill, 1992; Nunez & Sweetser, 2006). As such, gesture and speech form an integrated system in the expression of metaphors. As suggested by the information-packaging hypothesis, spatio-motor thinking and input from the speaker's language simultaneously shape a speaker's gestures, allowing the speaker to convey conceptually related but unique information in the two modalities (Kita & Özyürek, 2003). There is evidence that this same pattern is found in children (Goldin-Meadow, 2014). As such, gesture might be a highly relevant communicative medium to see children's emerging abilities in metaphor expression.

Metaphor is pervasive in human communication. Even children, starting around age 2, use metaphors to express concepts in their everyday language (Billow, 1981). We think and talk about abstract concepts by structuring them metaphorically around concepts grounded in our sensorimotor experience (Boroditsky & Ramscar, 2002; Graf, 2011; Lakoff & Johnson, 1980; 1999). Sensorimotor representations stem from first person experience with the world through perception (e.g. seeing and hearing) and action (e.g., grabbing an object, moving toward and object). These tangible everyday sensorimotor experiences are then mapped onto abstract concepts, such as time, ideas, and emotions, allowing us to both structure and understand them (Barsolou, 2008; Glenburg & Kaschak, 2002). In this way, when speakers *talk* about abstract concepts, sensorimotor thinking informs the way they structure those concepts, and consequently, the way they *gesture* about them, even when not using metaphors in speech (e.g.; 'Exams are soon'+ move hand away from body to convey future in front of the speaker's body; Casasanto & Jasmin, 2012; Chui, 2011; Cienki, 2008). These gestures reflect the speaker's sensorimotor (i.e., bodily motion through space) and cultural (i.e., experience with reading and writing) experiences, as well as the conventionalized ways of structuring abstract concepts in one's language (e.g. 'past is behind, future is ahead' in English; Gentner, Imai, Boroditsky, 2002 *vs*. 'past is up, future is down' in Mandarin; Boroditsky, 2001; Scott, 1989). In this study we focus on one such abstract domain, namely spatial metaphors about time, and examine changes in children's gestures when talking about time over developmental time. We ask whether children's expression of metaphors in gesture changes with age, and if so, what factors best predict such changes that we observe in gesture.

1.1 How Adults Speak and Gesture About Time as Spatial Motion

When adults talk about abstract concepts, like time, they gesture (Casasanto & Jasmin, 2012). There is evidence that these gestures are jointly shaped by the accompanying speech (i.e., the conventionalized metaphors we use in speech; Boroditsky, 2001) and cultural artifacts, such as reading and writing direction within a culture (Casasanto & Jasmin, 2012).

1.1.1 Effect of speech on adults' gestures about time.

Adult speakers of English, along with adult speakers of many other languages (e.g., Aymara, Mandarin, Greek, Spanish, Dutch, Wolof, Japanese), predominantly rely on *space* to both conceptualize and verbally express time (e.g., Boroditsky, 2000; Boroditsky & Ramscar, 2002; Iwasaki, 2009; Moore, 2006; Núñez & Sweetser, 2006). At the same time, the way speakers use space to express time shows systematic variability both within and between languages. When adult speakers gesture about time they gesture along one of several axes, either sagittally (towards or away from the body; Figure 1A), laterally (across the body; Figure 1 B) or vertically (along a trajectory towards or away from the body i.e., moving an open palm upward or downward parallel to chest). However, these gestures are influenced by both the accompanying speech produced by the adult and the cultural artifacts (such as reading and writing direction) available in the environment of the speaker.

1A. SAGITTAL AXIS 1B. LATERAL AXIS

Figure 1 Adult English speaker producing a sagittal gesture (i.e., move open palm forward away from the body; panel A) and a lateral gesture (i.e., move finger right to left; panel B) to convey future times

The verbal metaphors for time show variability both within and across languages. Beginning with *variability within a particular language*, English speakers, as well as speakers of several other languages (e.g., Japanese, Wolof), conceptualize time in terms of spatial motion using one of two metaphor types (1) Ego-Reference-Point (Ego-RP) metaphors and (2) Time-Reference-Point (Time-RP) metaphors (Gentner, 2001; Núñez, Motz, & Teusher). *Ego-RP metaphors* use the speaker's self (i.e., ego) as an anchor and are of two types: MOVING-EGO metaphors position time as stationary, with the speaker moving towards or away from different stationary time points (Gentner, Imai, & Boroditsky, 2002; Moore, 2006). For example, in the expression, "We have gotten through the winter and are now approaching the summer", the speaker moves away from winter (past) toward the summer (future), while both winter and summer remain stationary (see Fig.1, Panel A1). Whereas, in MOVING-TIME metaphors, the speaker is stationary while time moves toward or away from the speaker. The past is always behind the speaker and the future is ahead of the speaker (Gentner, Imai, Boroditsky, 2002). For example, in the expression "The winter months are finally behind us and summer is fast approaching", winter (past) moves away from the speaker, while summer (future) moves toward the speaker (Moore, 2006; see Figure 2A). In contrast, *Time-RP metaphors* construe points in time in relation to each other and do not rely on the ego's perspective to infer the temporal sequence of events. That is, time-RP metaphors construe time as a conveyor belt with different times positioned along it (Moore, 2006). For example, in the expression, "The hot summer follows the cold winter", summer is placed in relation to winter, with winter occurring before summer without any reference to the speaker's self. (Figure 2B.)

2A. EGO-RP 2B. TIME-RP

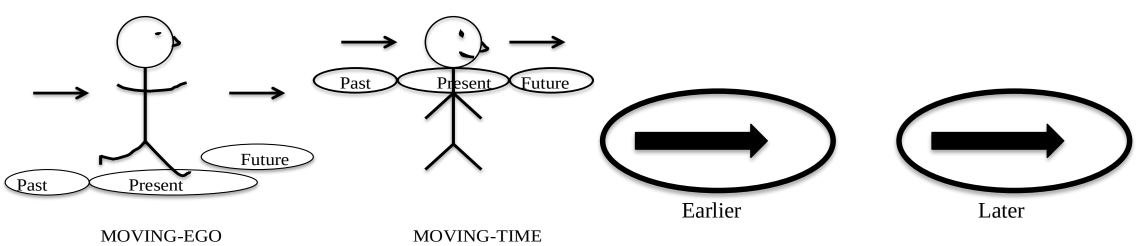

Figure 2 Schematic depiction of two dominant metaphors for time, with time as moving in relation to the self (i.e., moving ego or moving time, panel A) or time moving in relation to different time points (i.e., time reference point, panel B)

These two dominant time metaphors also become evident in adult speakers' gestures, following the patterns found in their speech. In a recent study, Casasanto and Jasmin (2012) asked adult English speakers to gesture about temporal direction, while using either *Ego-RP* metaphors ("How would you gesture about things that will happen a long time from now, far ahead in the future?") or *Time-RP* metaphors ("How would you gesture about things that will happen in your children's generation, then a generation after that?") in speech. They found that adults tended to use more sagittal gestures (i.e., axis orthogonal to the self-moving away or toward the body) when prompted with Ego-RP metaphors than when prompted with Time-RP metaphors, suggesting an effect of language (i.e. accompanying speech) on nonverbal representations of time. This pattern becomes even more pronounced when examining speakers' spontaneous gestures. In a closely related study, Casasanto & Jasmin (2012) explored the same question by examining spontaneous gestures produced by another group of English-speaking adults and also found the same close coupling between speech and gesture in the expression of time metaphors. They asked dyads of adults to read, memorize and then re-tell short stories that involved events that happened either in the past or that will happen in the future. They found that adults, when using Ego-RP metaphors (e.g., "I am coming up on the deadline"), which use the self as reference point, produced more sagittal than lateral gestures (i.e. axis moving from left-to-right or right-to-left in front of the body). Even more important, adults never used sagittal gestures when using Time-RP metaphors (e.g., "The deadline follows my vacation"); instead they relied exclusively on lateral gestures by positioning past events to the left and future events to the right in their gesture space (Casasanto & Jasmin, 2012).

The influence of verbal metaphors for time on co-speech gesture within a language also becomes evident in languages other than English. One study examined the gestures produced by Chinese-English bilingual adults (with Chinese as first language) while they explained the meanings of words about time to another adult in Chinese (Gu, Mol, Hoetjes, & Swerts, 2014). Different from English, Chinese speakers can express time by using either vertical spatial metaphors or non-spatial language (Scott, 1989). Gu and colleagues (2014) constructed word lists of Chinese words, some of which used vertical verbal metaphors to express “early” or “late” and some of which did not use spatial language to express time. Participants were significantly more likely to produce vertical gestures than lateral or sagittal gestures to convey time if they were using vertical metaphors in speech (Gu, et al., 2014), showing a tight link between speech and gesture among Chinese native speakers.

Turning next to *variability between languages*, we also observe systematic cross-linguistic differences in the axis along which adult speakers situate the spatial layout of time. For example, speakers of Mandarin Chinese use not only a horizontal axis but also a vertical axis, positioning earlier events as ‘up’ and future events as ‘down’ (e.g., “An up day”, meaning a day in the future, or “A down year” meaning a year in the past; Boroditsky, 2001, Scott, 1989). Importantly, following this distinction in the expression of time in their language, Mandarin speakers, when asked to point to the location of past and future events in 3-dimensional space, used the vertical axis more than English-speakers (Boroditsky, 2008). More specifically, Mandarin- and English-speaking participants were asked to answer the question “If I tell you that this here is TODAY, where would you put YESTERDAY?” by pointing to a spot in three dimensional space. Interestingly, English-speaking participants made much less use of the vertical axis compared to their Mandarin-speaking peers (5% vs. 45%), suggesting an effect of language-specific patterns in speech on speakers’ conceptualization of time in gesture (see Boroditsky, Furhman, McCormick, 2010 for a review of studies extending this finding to other non-linguistic tasks, but also see January & Kako, 2007 for notable exceptions). Similarly, in a recent study, when Chinese-English bilinguals were asked to explain the meanings of Chinese vertical metaphors for time in both Chinese and in English, participants used vertical axis in their gestures when defining words in Chinese, but switched to the horizontal axis when explaining the same words in English (Gu, et al., 2014).

Unlike Chinese, speakers of Aymara, a language spoken in the Andean Highlands, use the same horizontal axis as English speakers. However, different from English speakers, Aymara speakers situate the past in front of the speaker (e.g. "*front year*" meaning "last year") and the future behind the speaker (e.g., "*a behind day*" meaning "a day in the future" Núñez, & Sweetser, 2006). Importantly, speakers of Aymara gesture in ways consistent with the linguistic metaphors in their language, using a sagittal (front to back) axis, but also place future behind their back (i.e., move hand toward the body over the shoulder) and past in front of their bodies (i.e., move hand forward away from the body). Similar results have been reported in a recent study with Vietnamese speakers, who follow the Aymara pattern in speech, with future behind the speaker and past in front of the speaker. Not surprisingly, Vietnamese speakers used sagittal gestures that placed the past in front of the speaker and the future behind the speaker when describing past and future events (Sullivan & Gui, 2016). Taken together, these studies show that the predominant verbal metaphors for time in one's language (i.e., the way metaphors are verbally expressed in the accompanying speech) strongly influence the way speakers' gesture about time.

1.1.2 Effect of literacy on adults' gestures about time.

Speakers of all studied languages rely both on their bodily experience of movement through space as well as the dominant verbal metaphors for time in their language as a way to construe and express time in gesture (Boroditsky, 2000; Boroditsky & Ramscar, 2002; Iwasaki, 2009; Moore, 2006; Núñez & Sweetser, 2006, Özçalışkan, 2003, 2005). At the same time, speakers of different languages also show differences in the way they use space, based on the dominant reading and writing direction of their language; and these differences become particularly evident in the lateral gestures that speakers use to describe time. For example, speakers of different languages, even if they are not using the lateral axis in their verbal description of time (e.g., speakers do not say 'a left day' to indicate a day in the past), nonetheless may use the lateral axis in their gestures to locate past and future events. In fact, as shown in earlier work (Casasanto & Jasmin, 2012), English speakers consistently place the past to the left and the future to the right when gesturing laterally about time. Casasanto & Jasmin gave a group of native English speaking dyads brief (50-100 words) stories describing sequences of events that either had a future direction or a past direction. The dyads took turns re-telling the stories to one another. The stories were written in second person ("You went to the store"), but they were asked to tell the story as if it happened to them (e.g. "I went to the store"). They examined speakers' gestures when they were using temporal direction in language and found that speakers produced lateral gestures that moved from left-to-right 74% of the time, a direction that was consistent with the reading and writing system in English (Casasanto & Jasmin, 2012). Aside from this study, there is no other work examining directionality of lateral gestures (left-to-right *vs.* right-to-left) produced by speakers of other languages. However, there are a few studies that examined the effect of reading and writing direction on the directionality of speaker's nonverbal representation of time other than gesture.

One such study (Boroditsky, Furhman, and McCormick , 2010) examined left-to-right lateral bias in a group of monolingual English speakers. They presented adults with a picture of a famous celebrity in the middle of a computer screen. After a set amount of time, another picture of the same celebrity would appear in place of the stimulus picture, which was either a picture of their younger or older self. Adults indicated whether it was an 'earlier' or a 'later' picture by pressing a button on the keyboard. For half the participants the 'earlier' button was on the left and for the other half the 'later' button was on the left. Participants identified the correct picture significantly faster if the 'earlier' key was on the left and the 'later' key was on the right than vice versa, showing an effect of the lateral orientation that is consistent with the English writing system.

This same effect was found in blind individuals, who read braille from left-to-right. One study examined the reaction time of blind readers of Italian braille and a group of sighted participants as they categorized past or future words by pressing a button to the left or to the right of a keyboard (Bottini, Crepaldi, Casasanto, Crollen, & Collignon, 2015). Both the blind and the sighted participants were quicker to categorize past words when pressing the button on the left and future words when pressing the button on the right (Bottini, et al., 2015).

More recent work even suggested that mirror reversed reading can temporarily change the direction of this relationship. In other words, a speaker that reads from left-to-right can temporarily shift from associating past to the left and future to the right when primed by reading from right-to-left. In one study, Dutch participants, who read from left to right, were presented with stimuli that were reversed in directionality (e.g. 'pet the cat' to 'tac eht tep'; Casasanto & Bottini, 2014). These participants, after just a few minutes of exposure to the reverse writing of words (i.e., right to left), were quicker to categorize words with a past direction to the right and words with a future direction to the left (Casasanto & Bottini, 2014), suggesting that even limited exposure to a new reading and writing direction could influence speakers' placement of past and future events.

Similarly, effects of writing systems have been shown for adult speakers' conceptualization of time across cultures with distinct writing systems. One study compared Spanish-speaking adults (left-to-right orthographic system) to Hebrew-speaking adults (right-to-left orthographic system) in their spatial representation of time (Ouellet, Santiago, Israeli, & Gabay, 2010). In this study, native Hebrew and Spanish speakers put on headsets and listened to words spoken into either their left or right ear. Some of the words had a past directionality (e.g., ‘‘dijo’’: he said) or a future directionality (e.g., ‘‘dira’’: he will say’); the participants were asked to identify the temporal direction of the word that they heard. Spanish speakers were significantly faster to identify the direction of the word if a past word was spoken into their left ear and a future word was spoken into their right ear, thus showing a left-to-right bias. Hebrew speakers, on the other hand, showed the opposite pattern in their reaction times, showing a right-to-left bias consistent with the Hebrew orthography.

These findings were replicated and extended to several different languages and cultures, using a variety of nonlinguistic tasks. Chan and Bergman (2005) compared literate adult native English speakers (left-to-right orthography) to Taiwanese and Chinese adult speakers, who rely on top-to-bottom and right-to-left orthographic direction, respectively. Adults were asked to arrange a set of pictures depicting the growth of living things (e.g., seed-sapling-mature tree) in chronological order. They found that Taiwanese individuals were significantly more likely to arrange the pictures top-to-bottom than both the English-speaking and the Chinese-speaking individuals. In fact, none of the English-speaking individuals and only 15 percent of the Chinese-speaking individuals arranged the pictures in top-to-bottom orientation; instead, they predominately arranged them from left-to-right (Chan & Bergman, 2005). Similar orthography-consistent biases have been shown in picture sorting tasks for Italian (left-to-right) and Arabic (right-to-left) speakers (Maass & Russo, 2003).

In sum, adult’s nonverbal representation and expression of time, including gesture, are directly influenced by their speech, the dominant verbal metaphors for time in their language, and by their cultural experiences (e.g. repeated exposure to reading and writing direction). Specifically, speakers produce gestures consistent with the accompanying speech and the dominant time metaphors in the language when talking about time. For example, English speakers use forward sagittal gestures when talking about the future in relation to the self and lateral gestures when talking about sequences of events. Speakers place future in front of and past behind their bodies in their sagittal gestures. Similarly, speakers utilize a specific lateral directionality (e.g., left-to-right for English speakers) in their nonverbal representations of time (including their lateral gestures)—directionality that is consistent with their culture's reading and writing direction. These findings thus suggest that the metaphorical gestures produced by adults, when talking about time, are jointly shaped by their language (i.e., accompanying speech and language-specific metaphors) as well as the literacy practices of their culture (i.e., writing directionality).

1.2 How Children Speak and Gesture About Time as Spatial Motion

The ability to think about time in terms of space emerges early in development (De Hevia, Izard, Coubart, Spelke, & Streri, 2014). De Hevia and her colleagues examined whether newborn infants form an association between space and time by familiarizing a group of neonates (0-3 days) with one of four different pairs of auditory-visual stimuli, either a long line with a short tone, a long line with a long tone, a short line with a long tone, or a short line with a short tone. After a 60-second familiarization trial, infants were then shown both a long line and a short line at the same time (only one of which was novel), and they heard the opposite tone of the tone that they heard during the familiarization trial (i.e., infants who heard the long tone before now heard the short tone and infants who previously heard the short tone now heard the long tone). Infants looked significantly longer at the novel line when the new tone and the novel line were concordant (e.g., the infants that previously heard a short tone and saw a short line looked significantly longer at the novel long line when they also heard the long tone), whereas there was no difference in looking time when the change was discordant (e.g., the infants that had previously heard a short tone and seen a long line during the familiarization period and then heard a long tone and saw a short novel line looked equally at both lines). These results suggest that even a newborn infant can form an association between space (length of a line) and time (i.e., duration of sound; De Hevia, Izard, Coubart, Spelke, & Streri, 2014). Relying on a similar method, Lourenco & Longo (2010) further showed that preverbal American infants can map both distance *and* volume to time, thus displaying a pattern similar to adult speakers of both English (which uses *length* to talk about duration, e.g., "we waited a <u>long</u> time") and Greek (which uses *quantity* to talk about duration, e.g., "we waited <u>much</u> time"). Taken together, these studies suggest that children can understand the mapping between space and time at a very young age (perhaps even at birth); and this mapping starts with a broader set of distinctions, which are then gradually narrowed down over development to reflect the patterns of the language the child is exposed to.

1.2.1 Effect of speech on children's gestures about time.

Although children's association between space and time may begin in infancy (Lourenco & Longo, 2010), learning metaphors, including linguistic metaphors for time, spans over several years. Two- to 3-year-old children can express simple perceptual metaphors between objects that share common features or functions (Billow, 1981; Özçalışkan & Goldin-Meadow, 2006). Perceptual metaphors involve metaphorical comparisons of objects that are perceptually similar to one another. For example, a child might say that "a cherry lollipop is like a stop sign", because both of them are red, round, and attached to a stick (Mendelsohn, Robinson, Gardner,

&Winner, 1984). These early perceptual metaphors give way to more complex conceptual metaphors that involve mappings between two conceptual domains, such as referring to someone as “cold as ice” to indicate how unemotional that person is, somewhere between age 5 to 12 (Gardner, Winner, Bechhofer, & Wolf, 1978; Gentner, 1988; Özçalışkan, 2007; Waggoner & Palermo, 1989). In fact, there has been some debate on the onset age for complex conceptual metaphors in children’s repertoires. Some researchers argue that comprehension of conceptual metaphors is a late-emerging skill that continues to develop into late adolescent years (Gardner, Winner, Bechhofer, & Wolf, 1978; Nippold, Uhden, Schwartz, 1997), while others suggest an earlier onset time for at least some conceptual metaphors (e.g., Gentner, 1988; Özçalışkan, 2005; see Özçalışkan, 2011, 2014 for reviews). For example, in one landmark study, Waggoner and Palermo (1989) asked 5-, 7-, and 9-year-old children to interpret conceptual metaphors about emotional states embedded in short stories (The metaphor, “Betty was a bouncing bubble” embedded in a story about a visit to the fair with father), and found evidence for the comprehension of such conceptual metaphors involving emotions by age 5.

More recent work that examined conceptual metaphors that are structured by spatial motion also showed evidence of metaphor comprehension at preschool age. In one study, Özçalışkan (2005, 2007) asked three- to five-year-old children to interpret metaphorical expressions involving abstract concepts that are structured by motion (e.g., ‘idea flies from the mind’, ‘time flies by’). The results showed that four-year-old children could correctly identify (in a forced-choice task) the meaning of a conceptual metaphor embedded in a story, and five-year-old children could explain the underlying mappings for such metaphors (e.g., “idea flies by means that you forget about your idea quickly”). More recent work examining the developmental trajectory of the different types of spatial metaphors for time using a similar forced choice task

(Stites & Özçalışkan, 2013a) also showed early comprehension. In this study children were told a series of short stories, each containing either Ego-RP ("His trip to the zoo is coming up") or Time-RP ("Ice cream follows lunch") metaphors, and were then asked a forced-choice comprehension question and to explain the reasoning behind their choices. The results showed that children understood Ego-RP metaphors at age 4, a year before they understood Time-RP metaphors, at age five. In addition, children's ability to explain the meanings of the metaphors followed a similar developmental trajectory, only with a one-year lag (Stites & Özçalışkan, 2013a). One explanation given for the developmental progression from Ego-RP to Time-RP metaphors was that Ego-RP metaphors reference the self and thus might be easier for young children to understand, compared to Time-RP metaphors that are more removed from the body. Further, young children have a plethora of experience with their own bodies moving through space, again making metaphors couched in first-person experience more accessible (Stites & Özçalışkan, 2013a).

Research thus far suggests that English-speaking children show early understanding of spatial metaphors for time. They begin to understand Ego-RP metaphors at age 4 and Time-RP metaphors at age 5. However, very little is known about children's early metaphorical gestures about time. Previous research has shown that children's earliest perceptual metaphors are often expressed first in gesture-speech combinations, for example, a one-year old child might point at a stop sign and say "lollipop", thus drawing a metaphorical comparison between the two objects across modalities before making such a comparison in speech using the word "like" (e.g., "a lollipop is like a stop sign"; Özçalışkan & Goldin-Meadow, 2006; Özçalışkan et al., 2009). The close link between gesture and speech is also observed in children's earliest conceptual metaphors. In an earlier study, Özçalışkan (2007) found that children in the early stages of conceptual metaphor comprehension, around age four, when asked about motion metaphors, produce full body gestures with very limited verbal expression (e.g., say “like this” while crawling on all fours on the floor when asked how time crawls). However, at age five there is a shift in gesture space to smaller representational gestures that align with the target domain of the metaphor (e.g., moving hand away from the head to indicate ideas escaping the mind), along with a shift in the verbal expression of such metaphors (“idea escaped means that I forgot it”; Özçalışkan, 2007). This suggests that changes in gesture may accompany, or even sometimes precede, a shift in children’s understanding and expression of conceptual metaphors in speech.

1.2.2 Effect of literacy on children’s gestures about time.

Previous research has shown that adult speakers’ non-linguistic expressions of time, including their gestures, are influenced by the direction of reading and writing system in their culture. However, there is very little research on the possible effects of reading and writing system on children’s representations of time, particularly in gesture.

Among the few studies that focus on children’s non-verbal use of lateral axis to represent time, Tversky, Kugelmass, and Winter (1991) examined kindergarten through 5^{th} grade Arabic-, English-, and Hebrew-speaking children’s preference for temporal order in 2-dimensional space. Arabic and Hebrew have a right-to-left orthography, as opposed to the left-to-right orthography found in English. To test for directionality of children’s use of space to represent time, an experimenter placed a sticker in the middle of a blank sheet of paper and told the participant that the sticker represented ‘lunch’; the children were then asked to place other stickers to represent ‘breakfast’ and ‘dinner’ on the same sheet of paper. This procedure was repeated for different times of the day (morning, afternoon, evening) as well as for children’s food preferences (favorite food to least favorite food), and quantities of familiar object (a backpack full of books, a backpack partially full, and an empty backpack). Tversky and colleagues (1991) found that English-speaking children were significantly more likely than Arabic or Hebrew speaking children to place the stickers from left to right for temporal events only, showing no preference for the other domains (i.e., quantity). However, all the children in the study had exposure to formal literacy training, still leaving the question of effect of literacy on the organization of space-to-time mapping unanswered.

A more recent study that explored lateral biases in spatial representations of action event sequencing (Dobel, Diesendruck, and Bölte, 2007), also shows an effect of culture-specific biases, but only after exposure to writing systems and systems of temporal sequencing within a culture. Dobel, Diesendruck, and Bölte (2007) examined German (left-to-right orthography) and Hebrew speaking (right-to-left orthography) preliterate children's and adults' directional bias in spatial representation of action. The participants were read aloud a series of sentences containing noun phrases; in three of the phrases the agent came first ("The mother gives the boy a ball") and in the other three the recipient came first ("The boy gets a ball from his mother"). Participants were then asked to either draw the contents of each sentence; or they were given three transparencies and asked to arrange the transparencies to depict the contents of each sentence. The direction that the participants arranged the three referents (agent, object, recipient) was recorded. The results showed strong left-to-right directional bias in German speaking adults and the opposite effect in Hebrew speaking adults, corresponding to the direction of the written language. However, more importantly, this pattern did *not* hold true for preliterate children (Dobel, Diesendruck, and Bölte, 2007). The preliterate children did not show a preference for either left-to-right or right-to-left spatial orientation (Dobel, Diesendruck, and Bölte, 2007). This same pattern of directional bias emerging after literacy has also been shown for French (left-to-right) and Tunisian (right-to-left) children (Fagard & Dahmen, 2003).

Taken together, these studies on non-verbal representation of temporal directionality suggest that children do develop a lateral bias that maps onto the reading and writing direction in their culture, but only after they obtain formal literacy training in their early school years.

1.3 Current Study

Sensorimotor experience (i.e., bodily motion in space), culture (i.e., exposure to reading and writing direction), and language (i.e., lateral vs. sagittal spatial metaphors for time in speech) jointly shape the way adults gesture about time (Boroditsky, 2008; Casasanto & Jasmin, 2012; Núñez & Sweetser, 2006). However, little is known about how children's gestures about time change throughout development and how each of the aforementioned factors might influence this developmental change.

As shown in earlier work, acquisition of time metaphors follows a developmental trajectory from comprehension of Ego-RP metaphors at age 5 to comprehension of Time-RP metaphors at age 6 (Stites & Özçalışkan, 2013a), showing an effect of sensorimotor experience in understanding such metaphors. Research with adults has shown that adults are also more likely to use sagittal gestures when using Ego-RP language (e.g., "we approach summer") than when using Time-RP language (i.e., "summer follows winter"; Casasanto & Jasmin, 2012), suggesting an effect of language on patterns of gesture production. However, children that do not comprehend (or produce) Time-RP language may not produce lateral gestures. Therefore, children's early gestures about time may shift as they begin to comprehend and produce the two different metaphors for time, beginning with sagittal gestures at the early ages, and continuing on with lateral gestures at the later ages as they begin to use Time-RP metaphors in speech.

Further, if formal exposure to orthography-specific directionality influences representations of time in gesture (Tversky, Kugelmass, and Winter, 1991), preliterate children may differ from adults in expressing spatial metaphors for time in gesture (Dobel, Diesendruck, and Bölte, 2007). Preliterate children's gestures about time may be largely influenced by their first person sensorimotor experience with movement through space and their understanding of metaphors for time in speech. As such, children might start out with more body-anchored sagittal gestures for time before they become acquainted with the artifacts of their culture (i.e., reading and writing), after which they begin to use lateral gestures that are consistent with the reading and writing direction found in their culture.

In this study we focus on the *orientation* (sagittal *vs.* lateral), *directionality* (left-to-right *vs*. right-to-left; away from the body *vs.* towards the body), and *congruency* (sagittal gestures paired with Ego-RP language *vs.* lateral gestures paired with Time-RP language) of the metaphorical gestures 3- to 8-year-old children and adults produce across two different gesture tasks: *iconic gesture tasks* in which speakers produce spontaneous iconic gestures (i.e., gestures that characterize time's movement in space, e.g. "exams are approaching" + move open palm hand toward the body') and an *deictic gestures task* in which speakers are asked to produce deictic gestures, namely gestures that indicate metaphorical locations (e.g. "Exams are behind us" + point towards back of body to convey past times). We have two questions:

(1) How early do we see a developmental shift in the orientation, directionality and congruency of children's gestures about time?

We predict that children will begin to produce different gestures in expressing the two time metaphors (Ego-RP and Time-RP) either before or at the same time as they begin to comprehend these two metaphor types in speech. We also predict that these differences will become evident in both the *orientation* (sagittal gestures *vs*. lateral gestures), *directionality* (left-to-right *vs*. right-to-left; away from the body *vs*. towards the body) and the *congruency* (sagittal gestures paired with Ego-RP language and lateral gestures paired with Time-RP language) of the gestures that children produce.

Orientation: We predict that younger children (ages 3 to 4) will produce predominantly sagittal gestures and at higher rates than older children (ages 5 to 6 and 7 to 8), who instead will rely on both sagittal and lateral gestures in describing the metaphorical motion of time.

Directionality: For *sagittal* gestures, we predict that younger children (ages 3 to 4) will produce mostly sagittal gestures that move forward away from the body, in line with their own body's typical movement through space. Older children (ages 5 to 6 and 7 to 8) and adults, on the other hand, will produce gestures that move backward towards the body to indicate past and forward away from the body to indicate future times. For *lateral* gestures, we predict that younger children (ages 3 to 4) will *not* show a preference between left-to-right and right-to-left direction; while older children (particularly ages 7 to 8) will use the left-to-right directionality more frequently, placing past to the left and future to the right, consistent with their exposure to the directionality of the writing system in English.

Congruency: We predict that older children (ages 5 to 8) will differentiate between the two metaphor types in gesture, using sagittal gestures when using Ego-RP language ("I'm coming up on lunchtime"+ hand movement away from the front of the body) and lateral gestures when using Time-RP language ("lunch is after breakfast"+ hand movement from left to right in front of the body). In other words, we predict that older children will not only increase their overall use of lateral gestures compared to their younger peers, but also use lateral gestures more frequently when producing Time-RP metaphors in speech (i.e., gestures congruent with the accompanying speech).

(2) What factors influence developmental changes in children's gestures about time?

We will examine two key factors that are likely to contribute to changes in children's gestures about time, namely children's comprehension of different metaphors for time and their exposure to literacy[1]. We expect that each factor will have an effect on the orientation and directionality and congruency of children's gestures about time.

Orientation: We expect that children's comprehension of Time-RP metaphors and their literacy level will predict the *orientation* of their metaphorical gestures. Children that show better comprehension of Time-RP metaphors and better literacy skills will produce fewer sagittal but more lateral gestures than children who show lower comprehension of Time-RP metaphors and lower literacy skills

Directionality: We predict that children's gesture directionality will depend on the orientation (sagittal versus lateral) of the gestures. We predict that the directionality of children's **sagittal** gestures (backward towards the body/forward away from the body) will be largely influenced by children's comprehension of Ego-RP metaphors. Children who show better comprehension of Ego-RP metaphors will produce more gestures that place past behind the speaker and future in front of the speaker. The directionality of children's **lateral** gestures, on the other hand, will be shaped by children's literacy level: children with better literacy skills will produce greater number of lateral gestures that place past to the left and future to the right of the speaker.

[1] We also examined a third factor, temporal sequencing ability, as predicting changes in children's gestures about time. Children's temporal sequencing ability did not show variability by age, and was therefore excluded from the analysis.

Congruency: We expect that comprehension of the two metaphor types for time will predict the congruency of children's gestures. Children who show better comprehension of the two metaphors types will produce more gestures that are *congruent* with each metaphor type in the accompanying speech. In other words, children that comprehend both Ego-RP and Time-RP metaphors will be more likely to produce sagittal gestures when using Ego-RP language and lateral gestures when using Time-RP language than children who only comprehend Ego-RP metaphors.

2 METHODS

2.1 Participants

Sixty children participated in this study; 20 3- to 4-year-olds (M = 3;6, range = 3;2-4;9, 11 boys), 20 4- to 5-year-olds (M = 5;5, range = 5;1-6;8, 8 boys), and 20 6- to 7-year- olds (M = 7;5, range = 7;1-8;5, 8 boys), along with 20 adults (M = 20, range = 18-33, 6 males). All participants were monolingual speakers of English. The child participants were predominately Caucasian (70%), of mixed racial and ethnic heritage (17%), or African-American (13%). The adult participants were predominately African American (45%), Asian (15%), or Caucasian (10%). Most of the child participants had one or more parents with graduate or professional degrees (63%). Child participants were recruited from local preschools and elementary schools, along with a database of families located in the Psychology Department at GSU. All child participants received a small toy for their participation in the study. Adult participants were recruited from the Georgia State University Psychology Research and Testing Site and received course credit for their participation.

2.2 Procedure for data collection

All children were interviewed individually in the laboratory, at local schools, or in the participants' homes. We used two sets of tasks, one set eliciting gestures and the other assessing factors that contribute to developmental changes in patterns of gesture production (i.e., orientation, directionality, congruency).

We elicited gestures in two ways: the first involved elicitation of spontaneous iconic gestures in narrative and explanation contexts; the second involved elicitation of deictic (pointing) gestures, in which we asked children to produce pointing gestures about past and future events in a structured experimental set up. The reason to include tasks that elicit two different gesture types was because of the wide age range in our study. Deictic gestures, which are easier to produce, are more commonly used by younger children; while iconic gestures that typically convey more complex relational information, are more frequently produced at the later ages (Capone & McGregor, 2004). Examining changes in children's gesture production across both gesture types allowed us to have a more comprehensive account of the developmental trajectory associated with patterns of gesture use in conveying metaphorical concepts.

We next assessed factors that contribute to developmental changes in patterns of gesture production, using a literacy task, a metaphor comprehension task, and a temporal sequencing task. In addition, parents completed a short survey stating their race/ethnicity, education level, and languages spoken at home and a brief report on recent past and future events that their child either participated or will participate in. These two events were used in the narrative task (see Appendix A, B).

Tasks that elicited gesture were administered first, followed by tests that assessed factors contributing to changes in gesture production, so that the additional tasks did not affect children's gesture production. However, we randomized the presentation order within each set of tasks.

2.2.1 Tasks Eliciting Gesture.

Narrative task eliciting iconic gestures- The purpose of this task was to elicit gestures about past and future events within a narrative context. The experimenter conducted a short interview about future and past events with the child. The structure of the interview was based on earlier work (Fivush, Grey, Fromhoff, 1987) that examined young children's conversations about past events. We used 2 past and 2 future events. Two of these events (one about the past and one about the present) were drawn from children's own experiences, including events that they either participated in or would participate in. These events were culled from a parent questionnaire administered at the beginning of the interview (see Appendix A). The other two events (one about the past and one about the present) were the same event across all children, which included their last birthday ("Do you remember your last birthday? Can you tell me about it?") and their next birthday ("What are you doing for your next birthday? Can you tell me about it?")— each followed by a set of questions about the activities within each event (e.g., "Did you first open presents and then eat the cake"; "What kind of cake will you have?"; "What games will you play?").

Explanation task eliciting iconic gestures- The experimenter conducted a short open-ended interview with each child, aimed at eliciting gestures. The interview included six questions, three eliciting explanations about Ego-RP metaphors (questions 1-3) below) and three eliciting explanations about Time-RP metaphors (questions 4-6 below). .

1. Let's say you are at home with mommy playing. And your mommy says: "Summer is coming". What do you think she means?

2. Let's say you are playing outside and your daddy says: "We are getting closer to dinnertime". What do you think he means?
3. If I told you that following our time together, I will give you a sticker, when do you think you will get your sticker?
4. Let's say you had breakfast and you went out to play ball. And then you played with blocks. Do you think you got closer to lunchtime when you started playing with blocks? (If affirmative) How?
5. Can different times follow each other, like in a line? For example, can bedtime follow dinnertime? (If affirmative) How does it follow?
6. What would it mean if someone told you that dessert is after dinner?

Transcription, coding, and scoring of tasks eliciting iconic gestures: All responses were videotaped and later transcribed for speech and gesture. For *speech*, we transcribed all responses and segmented them into clauses. A clause was defined as a segment of speech that contained a unified predicate in the form of a verb, along with associated arguments (e.g., "I got a yummy popsicle."). First, we extracted all clauses that refer either to a past (e.g., "I got a yummy popsicle") or a future event (e.g., "I will get a yummy popsicle"), which served as target clauses for our analysis. All non-target clauses, in other words clauses that do not convey past or future events, were excluded from the analysis (e.g. "Balloons are fun"). We coded each target clause further as using either an Ego-RP (; e.g., "My desert time is coming up"; "My desert time is soon"), or a Time- RP language (e.g., "After lunch I will have a popsicle"; "I had lunch, then a popsicle"). The majority of the target utterances produced by children (99%) and adults (82%) were not metaphorical.

For *gesture*, we identified all gestures that accompanied each target clause and that conveyed information about time; we then coded each gesture for orientation, directionality and congruency.

For **orientation**, we coded each gesture as depicting either *sagittal* (i.e., perpendicular to speaker's body) or *lateral* (i.e., orthogonal to speaker's body) orientation. For **directionality**, we coded of each lateral gesture as either left-to-right or right-to-left, and each sagittal gesture as either backward towards the body, or forwards away from the body. For **congruency**, we coded the informational relation each gesture held to the accompanying speech as either conveying *the same language as in speech* (e.g., an Ego-RP utterance accompanied by a sagittal gesture; "exams are coming up"+ gesturing backwards towards the body or Time-RP utterance accompanied by a lateral gesture ; e.g., "exams are after the break" + gesturing left to right), or as conveying a *different language than in speech* (i.e., incongruent; an Ego-RP utterance paired with a lateral gesture; e.g.,"exams are coming up" + gesturing left to right across the body; or a Time-RP utterance paired with a sagittal gesture; e.g., "exams are after break" + a gesture forward away from the body).

Children produced very few deictic gestures in the explanation and narrative tasks (n = 5 across both tasks), and adults produced no deictic gesture during either task. However, the deictic gestures that the children did produce had an orientation (e.g., point forward from the body), directionality (e.g., point left for past), and congruency (e.g., use ego-RP language with a forward point), therefore, these gestures were coded the same way as the iconic gestures described above.

Each participant's responses were tallied for *orientation type* (sagittal vs lateral) *directionality* (sagittal gesture that move backward towards the body vs. sagittal gesture that move forward away from the body; lateral gestures that move from left to right vs. lateral gestures that move from right to left), and *congruency* (i.e., using Ego-RP language with a sagittal gesture, e.g., "exams are coming up" + move hand away from the body; or using Time-RP language with lateral gestures e.g., "exams are after vacation" + move hand towards left).

Task eliciting deictic gestures**:** This task, adapted from Boroditsky (2008), aimed to assess spatial representations of time from a first person perspective, by having the children locate themselves in relation to past and future events in 3-dimensional space. The experimenter asked the child to stand next to the experimenter; she then pointed to the child and said: "This is now; we are here in this room playing games. If this is now, (points to child again), where would bedtime be?" If the child did not point, the experimenter asked the child to point to a spot. Next, the experimenter said "You woke up and ate breakfast, if (spot child pointed to) is bedtime, where is breakfast?" Again, if the child did not point, the experimenter would prompt the child by asking the child to point to a spot. For this task, information from 14 of the 80 participants was marked as missing (ages 3-4:15/20, ages 5-6: 18/20, ages 7-8: 19 /20, Adults: 15/20). The missing data was due to the camera angle (n = 8), the participant refusing to complete the task (n = 2), or experimenter error (n = 4).

Transcription, coding, and scoring of tasks eliciting deictic gestures: We coded each deictic gesture for orientation (lateral or sagittal) and directionality (point to the left of body, point to the right of body, point in front of body, point forward away from body). We did not code for congruency, because neither the experimenter nor the child used any metaphors in speech during the task. Each participant's responses were tallied separately for the two types of gesture orientation (sagittal, lateral) and the four types of directionality (points to left, right, forward, in front of body). Because each person only have one chance to produce a gesture for the past and one chance to produce a gesture for the future, scores were tallied by the number of participant in each group that produced each type of gesture.

Reliability: Reliability was assessed by two independent coders blind to the hypotheses of the study, who recoded a randomly selected 20% of the responses in each of the two tasks. Agreement between coders was 90% ($k = .89$, $SD = .04$; $N = 59$) for detection of gestures, 88% ($k = .88$, $SD = .04$, $N = 59$) for orientation, and 88% ($k = .88$, $SD = .04$, $N = 59$) for directionality, and 82% ($k = .79$, $SD = .04$, $N = 59$) for congruency.

2.2.2 Tasks Assessing Factors Related to Changes in Gesture Patterns

Metaphor comprehension task: To measure children's comprehension of spatial metaphors for time, children completed a forced choice metaphor comprehension task. The experimenter told each child that they would hear several short stories about different people and that during each story the child would be shown pictures of the people in the story. The child was then asked to listen carefully; the child was also told that when the story is over s/he would help the puppets Elmo and Grover understand what the story was about. Before each story, the experimenter placed two pictures on the table, depicting the two characters in each story. The experimenter then read each of the short stories aloud to the child. Each story ended with the experimenter asking the puppets a question about the meaning of the metaphor used in the story. One of the puppets answered correctly and one puppet answered incorrectly. The child was then asked to help the puppets understand by choosing the puppet that gave the correct answer, and then by explaining why the answer was correct. There were eight short stories. Each story was five sentences long and comparable in syntactic complexity, with mean utterance lengths ranging between 4.6 and 5.4. Each story had two characters; both characters in the story were shown on an 11x17 inch sheet of white laminated paper. Each story contained one metaphorical expression about time. Four of the stories contained Ego-RP metaphors (2 MOVING-TIME and 2 MOVING-EGO metaphors), and four contained Time-RP metaphors. The stories were presented to the children in random order, generated by an online data randomizer (http://www.randomizer.org/). Each puppet provided the correct answer half of the time, setting chance performance (i.e., choice based on color of the puppet) at 50%. A sample story is provided in (6); metaphor is underlined; see Appendix B for all 8 stories used in the study. Children received both a total metaphor comprehension score, calculated across all eight stories (range =0-8) and a comprehension score by metaphor type (range = 0-4), separately Ego-RP and Time-RP metaphors.

(6) Sample story Ego_RP

This is Patrick. This is Patrick's Mom. Patrick's mom tells him that his trip to the zoo is coming up. Patrick gets really excited! He shouts "YEAH!"

Why is Patrick excited?

His trip to the zoo is now. (incorrect choice)

His trip to the zoo is soon. (correct choice)

Literacy Assessment Tasks: To assess children's familiarity with written language, each child completed the Letter Word Identification subtest of the Woodcock Johnson-IV (WJ-IV; Schrank, McGrew, Mather, 2014) and the Concepts About Print Assessment (see Appendix C; Clay, 2000). To complete the Letter Word Identification Task, children were seated in front of an easel with a set of letters or words written on the front. The children were either instructed to point to a letter or read aloud a set of letters or words. They continued to read the words aloud until they were unable to read six words in a row, resulting in a score ranging between of 0-76 for each child.

To complete the Concepts About Print Assessment (Clay, 2000), each child was given the book *Honey for Baby Bear* (Randell, 1994) and asked 13 questions about how to read the book (e.g., “Where would I start reading the story?”; “Where would I read after that?”). For each child, the number of correct answers was tallied (score range = 0-13).

2.3 Data Analysis

We examined the iconic gestures and deictic gestures separately for all analysis, for several reasons. First, deictic gestures appear earlier in development, as such, they may be easier for children, therefore we could see evidence of developmental changes in the congruency and directionality of children’s deictic gestures before such changes become evident in their iconic gestures. Second, past research found systematic differences in the orientation and directionality of spontaneous iconic and deictic gestures produced by adults when talking about time (Casasanto & Jasmin, 2012)— a pattern that may also be evident in children’s gesture production.

2.3.1 How early do we see a developmental shift in the orientation, directionality and congruency of children’s gestures about time?

2.3.1.1 Analysis of Developmental Changes in Iconic Gestures

We examined differences in iconic gesture production within and across narrative and explanation tasks with one-way ANOVAs, with age group (3-4, 5-6, 6-7, and adults) as between-subjects factor, and found considerable group variability in gesture production both within each task—particularly the narrative task ($F(1,79) = 2.79$, $p = .04$)—and across the two tasks ($F(1,79) = 2.72$, $p = .05$; see Table 1). To control for the variability in gesture production, we therefore, converted all raw numbers into proportions, transformed them using arcsine, and used arcsine transformed scores in our analysis.

Table 1 Mean iconic gesture production by age

Mean (SD)	3-4	5-6	7-8	Adults
Narrative task	3.77 (2.25)	5.74 (3.90)	6.05 (3.96)	8.09 (7.65)
Explanation task	1.50 (2.00)	2.42 (1.60)	3.31 (2.21)	2.43 (2.45)
Narrative and explanation tasks	4.25 (3.55)	5.50 (5.65)	6.20 (7.40)	10.10 (9.38)

In contrast to marked changes in frequency of gesture production over time, we found no reliable differences between narrative and explanation tasks in the relative distribution of either sagittal ($F(1,79) = 2.11$, $p = .15$) or lateral gestures ($F(1,79) = .8$, $p = .38$) (see Table 2). We therefore collapsed responses across narrative and explanation tasks for the rest of the analysis.

Table 2 Mean and standard deviations of gestures by group and task, along with p values of the difference of each type of gesture across both tasks

	Mean (SD)	Narrative	Explanation	*P*
3-4	Sagittal	43.55 (45.77)	57.25 (46.15)	.14
	Lateral	26.45 (39.43)	34.25 (44.88)	.13
5-6	Sagittal	30.15 (40.27)	46.25 (38.47)	.35
	Lateral	25.80 (36.96)	38.80 (34.93)	.17
7-8	Sagittal	21.85 (37.71)	21.96 (37.71)	.06
	Lateral	48.10 (47.44)	50.00 (48.05)	.99
Adult	Sagittal	19.00 (27.31)	20.25 (33.62)	.06
	Lateral	76.05 (32.34)	50.00 (45.42)	.06
All Ages	Lateral	32.68 (41.71)	32.68 (41.71)	.15
	Sagittal	39.24 (44.25)	39.25 (44.26)	.39

Orientation:

To test our prediction that older children (ages 7 to 8) would produce more lateral gestures than younger children (ages 3 to 6), we tested differences in the production of sagittal vs. lateral gestures with a mixed two-way ANOVA, with age group as between and orientation type (sagittal, lateral) as within subject factors.

Directionality:

Lateral gestures: To test our prediction that older children (ages 5 to 8) would use more gestures that move from left-to-right—following the reading and writing direction in English—than younger children (ages 3 to 4), we examined the proportion of lateral gestures from left to right with a one-way ANOVA, with child age as the between subjects factor.

Sagittal gestures: To test our prediction that younger children (ages 3 to 4) will use more sagittal gestures that move forward away from body than older children (ages 5 to 8), we examined the proportion of sagittal gestures that move forward with a one-way ANOVA with age as the between subjects factor.

Congruency: To test our prediction that older children (ages 5 to 8) would produce more gestures congruent with speech, namely that they will use more lateral gestures when using Time-RP metaphors and more sagittal gestures when using Ego-RP metaphors in speech than younger children (ages 3 to 4; figure 3), we ran one-way repeated measures ANOVA on all speech-congruent gestures, separately for lateral and sagittal gestures, with age as the between subjects factor.

A. B.

Figure 3. A congruent Ego-RP, where a xx-year-old child moves palm forward away from body while saying, "It is time to go back far" (panel A) and a congruent Time-RP gesture, where a xx-year-old child moves attached palms left to right while saying "Dinner then bed" (panel B).

2.3.1.2 Analysis of Developmental Change in Children's Deictic Gestures

Orientation: To test our prediction that younger children (ages 3-6) will rely more on sagittal gestures and older children (ages 7-8) and adults will rely more on lateral gestures in describing the metaphorical motion of time, we used fisher's exact test, with planned post hoc comparisons using chi-square analysis.[2] For the Fisher's exact test, we first entered age group in the rows (3 to 4, 5 to 6, 7 to 8, and adults) and gesture orientation in the columns (lateral versus sagittal), resulting in a 4x2 matrix. We further tested whether the two younger age groups would rely more on sagittal gestures than the two older age groups (ages 7 to 8 and adults). To do so, we combined the two younger groups and the two older groups (3 to 4 and 5 to 6 versus 7 to 8

[2] We chose the Fisher exact test instead of a parametric measure (e.g., ANOVA) due to the dichotomous and nominal nature of our data.

and adults); we then entered age in the rows and gesture orientation (lateral versus sagittal) in the columns in a 2x2 chi-square analysis.

Directionality: *Sagittal gestures*: To test our prediction that younger children (ages 3 to 4 and 5 to 6) will differ from older participants (7 to 8 and adults) in the directionality of their sagittal gestures, wherein the younger children (ages 3 to 4 and 5 to 6) will use more sagittal gestures that move forward away from the body for both past ("point to breakfast time") and future ("point to dinner time") times and the older participants (ages 7 to 8, along with the adult participants; figure 4 panel B) will use more sagittal gestures that move forward away from the body for future times and backward towards the body for past times, we used a 2x4 fisher's exact test with planned post hoc chi-square comparisons. We entered age group in the rows and directionality in the columns of the 2x4 fisher's exact test. Next we collapsed the two younger age groups (3 to 4 and 5 to 6) and the two older age groups (7 to 8 and adults) to test whether the two younger groups differed significantly from the two older groups. We then entered younger group and older group in the rows and gesture directionality (forward versus backward) in the columns of a 2x2 chi-square analysis.

Lateral gestures: To test our prediction that older (ages 5 to 8), but not younger children (ages 3 to 4) will show a preference between a left-to-right (past is to the left and future is to the right) versus right-to-left (past is to the right and future is to the left) direction (figure 4 panel A); we used a 2x4 fisher's exact test with chi-square planned comparisons, following the same steps outlined above for sagittal gestures.

A. B.

“point to breakfast” “point to dinner” “point to breakfast” “point to dinner”

Figure 4 Left-to-right lateral gesture (panel A) wherein the participant is indicating the past is to the left and the future is to the right, and forward and backward sagittal gestures (panel B) which the participant is indication the past in behind and the future is ahead

2.3.2 What factors contribute to developmental change in children’s gestures about time?

We first assessed developmental changes in the two factors (metaphor comprehension, literacy) that we expected to contribute to changes in children’s gestures about time**.** For **metaphor comprehension,** we computed differences in comprehension separately for each metaphor type (Ego-RP and Time-RP) and across the two metaphor types, using one-way ANOVAS, with age as a between subjects factor. For **literacy level**, we computed differences in performance, using one-way ANOVAs, with school age as a between subjects factor, separately for the Woodcock Johnson-IV (WJ-IV) Letter Word Identification and Concepts About Print literacy tasks.

2.3.2.1 Factors that Influence Developmental Change in Children’s Iconic Gestures

Orientation: To test our prediction that children’s comprehension of Time-RP metaphors and their performance on the literacy tasks would influence the *orientation* of their gestures—with children who comprehend Time-RP metaphors and who have higher literacy levels producing more lateral gestures—we ran a linear regression with chronological age (i.e., the participant's age in years and months) as a control variable entered in the first step. Next, we entered comprehension of Time-RP metaphors and the two measures of literacy (WJ-IV and concepts about print task) as predictors in the second step of the regression, with lateral gestures as the dependent variable,

Directionality: *Sagittal gestures*: To test the prediction that children who comprehend Ego-RP metaphors and have lower literacy levels will produce more **sagittal** gestures that move forward away from the body, we ran a linear regression with chronological age in the first step as a control variable. Next, we entered Ego-RP metaphor comprehension in the second step of the regression as a predictor, with forward sagittal gestures as the dependent variable.

Lateral gestures: To test the prediction that children with better literacy would produce more left-to-right lateral gestures congruent with the writing direction of their culture, we ran a linear regression, with chronological age entered in the first step as a control variable. Next we entered children's scores on the Concepts About Print task and their scores on the WJ-IV Letter Word Identification task in the second step of the regression equation as predictors, with children's left-to right lateral gestures as the dependent variable.

Congruency: *Sagittal gestures*: To test the prediction that children's *congruency* will be influenced by children's understanding of the different metaphor types in speech, with children that show comprehension of the two metaphor types producing more gestures that are *congruent* with speech type (Ego-RP metaphors with sagittal gesture), we ran a linear regression. We entered chronological age in the first step of the regression as a control variable and comprehension of Ego-RP metaphors in the second step of the regression as a predictor, with congruent sagittal gestures serving as the dependent variable. *Lateral gestures*. To test the prediction that children that show comprehension of Time-RP metaphors with produce more lateral gestures that are congruent with speech type (lateral gestures with Time-RP language), we ran a linear regression with chronological age entered into the first step of the regression as a control variable; then we entered comprehension of Time-RP metaphors in the second step of the regression as a predictor, with congruent lateral gestures serving as the dependent variable.

2.3.2.2 Factors that Influence Developmental Change in Children's Deictic Gestures

Orientation: To test the prediction that children who comprehend Time-RP metaphors and who have higher literacy levels would be significantly more likely to produce lateral deictic gestures, we used a binary logistic regression equation. Chronological age was entered first as a control variable and scores on the Concepts of Print, WJ-IV, and comprehension of Time-RP and Ego-RP metaphors were entered in the next block of the equation as predictors. Dummy coded directionality scores (0 or 1) served as the dependent variable.

Directionality: To test the hypothesis that children who have higher scores on the literacy tasks and metaphor comprehension would be more likely to produce more sagittal gestures that move forward away from the body for future times and backward towards the body for past times (past is behind and future is ahead) or left-to-right (past is to the left and future is to the right) lateral gestures, we used binary logistic regression to determine the factors that predict the directionality of deictic gestures. We entered age in the first block as a control variable and literacy and metaphor comprehension in the second block as predictors, with gesture directionality as the dependent variable.

We further predicted that literacy and metaphor comprehension would predict lateral and sagittal gestures in different ways. Specifically, we hypothesized that metaphor comprehension, particularly comprehension of Ego-RP metaphors would influence children's production of sagittal gesture that move forward away from the body for future times and backward towards the body for past times (past is behind and future is ahead) and that literacy would influence children's left-to-right lateral gestures (past is to the left and future is to the right). To test these hypothesis we first ran a binary logistic regression, with age entered into the first block of the regression as a control variable, then Ego-RP metaphor as a predictor, with directionality of sagittal gestures serving as the dependent variable. Next, we ran a second binary logistic regression with age entered in the first block of the regression as a control variable and WJ-IV scores entered in the second block as a predictor, with lateral gesture directionality serving as the dependent variable.

3 RESULTS

3.1 Developmental Changes In the Expression Of Spatial Metaphors For Time In Gesture

Iconic gesture production did not show sex differences for either the amount ($F(1,79) = .03$, $p = .9$), orientation (sagittal; $F(1,79) = .33$, $p = .57$; lateral; $F(1,79) = .008$, $p = .93$), directionality ($F(1,79) = .36$, $p = .55$), or congruency ($F(1,79) = .19$, $p = .67$). Similarly, deictic gesture production did not vary by child's sex for either orientation ($\chi^2 = 2$, $p = .19$) or directionality ($\chi^2 = 3.7$, $p = .08$). We therefore, collapsed all scores across male and female participants.

3.1.1 Iconic Gestures About Time

3.1.1.1 Orientation of Gestures.

We found a significant effect of age in the production of both lateral ($F(3,79) = 9.5$, $p < .001$) and sagittal ($F(3,79) = 9.32$, $p < .001$) gestures about time, in line with our predictions.

Children steadily increased their production of **lateral gestures,** from a mean proportion of .34 (SD = .37) lateral gestures at ages 3-4 to a mean proportion of .78 lateral gestures at ages 7-8 (SD = .37) (Tukey, *p* = .01)—a reliable increase that continued onto adulthood (Tukey, $p <$ .001). In contrast, and as expected, children steadily decreased their production of **sagittal gestures**, with significant differences between ages 3-4 (M = .65, SD = .37) and 7-8 (M = .25, SD = .36, *p* = .003). Adults did not differ from 7-8 year-old children (Tukey, *p* = .90), however, suggesting that children began to approximate adult-like patterns in their use of sagittal gestures around age 8 (Figure 5).

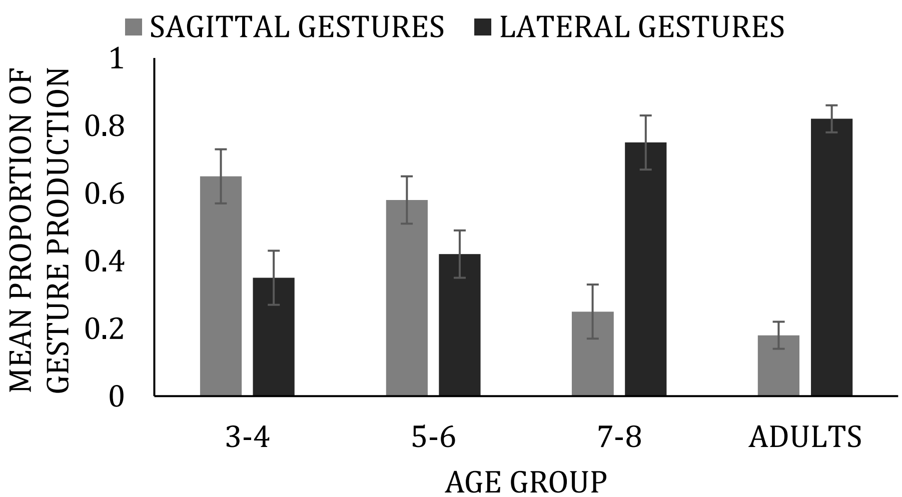

Figure 5 Mean proportion of sagittal (grey bars) and lateral (black bars) gestures produced in the narrative and explanation tasks by age group

3.1.1.2 Directionality of Gestures.

As predicted, the production of lateral gestures with left to right directionality ($F(3,79) = 3.52$, $p = .03$) showed an effect of age, with reliable increases between ages between the two younger groups (3-4 and 5-6) and 7-8, and between ages 7-8 and adults. (Tukey, *p's* < .05, Figure 6).

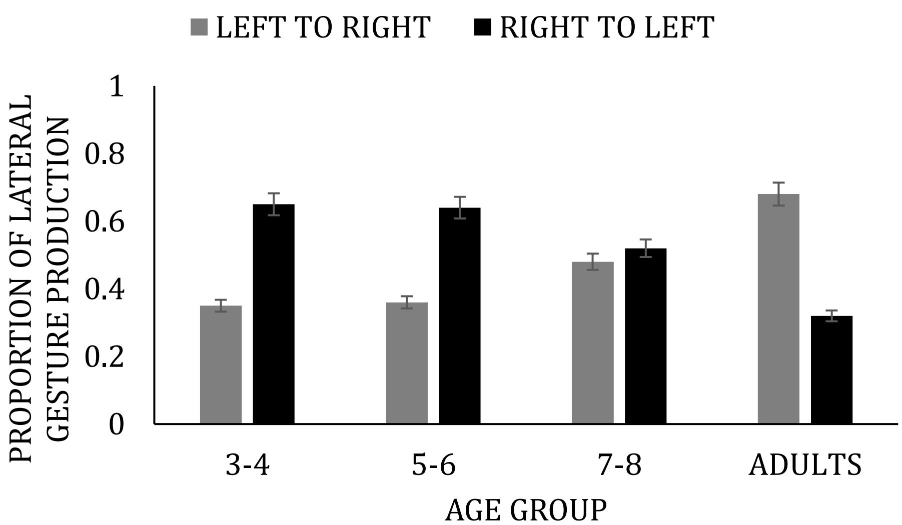

Figure 6. Mean proportion of lateral gestures with left-to-right (grey bars) or right-to-left (black bars) directionality by age group

Also in line with our predictions, we found a significant effect of age in the production of sagittal gestures with forward away from body directionality ($F(3,79) = 11.54$, $p < .001$). As can be seen in Figure 7, both 3- to 4- and 5- to 6-year-old children produced significantly fewer sagittal gestures with forward away from the body directionality than 7- to 8-year-olds the adults (Tukey, p's $< .01$), while the latter two groups did not differ from each other ($p = .90$).

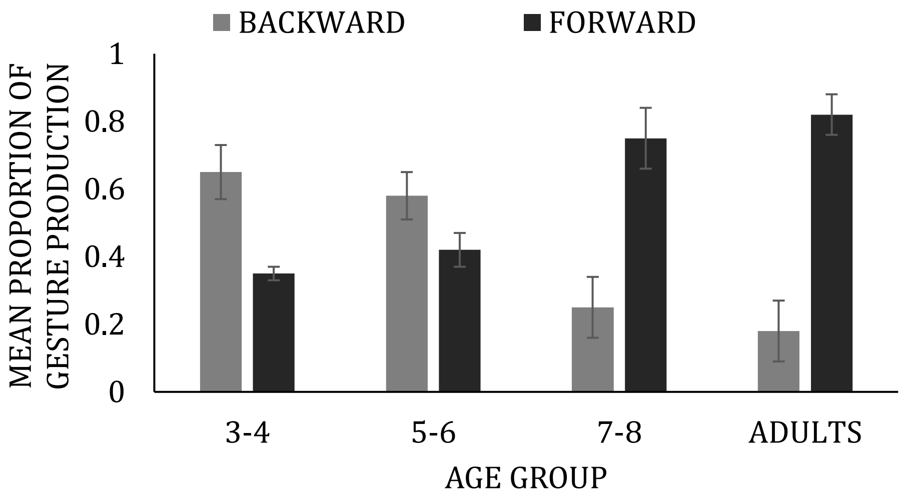

Figure 7 Mean proportion of sagittal gestures with forward away from the body (grey bars) and backward toward the body (black bars) directionality

3.1.1.3 Congruency of Gestures.

We found a significant difference in the production of congruent gestures (i.e., sagittal gestures paired with Ego-RP metaphors and lateral gestures paired with Time-RP metaphors) both for gestures with sagittal orientation ($F(3,79) = 5.22$, $p = .02$) and for gestures with lateral orientation ($F(3,79) = 11.21$, $p = .001$).

Beginning with **lateral gestures**, we found that the majority of the lateral gestures that adults produced were significantly more likely to accompany Time-RP metaphors in speech (*Tukey* = .003, figure 8). In contrast, children in all age groups (3-4, 5-6, 7-8) were equally likely to accompany Time-RP and Ego-RP metaphors with lateral gestures.

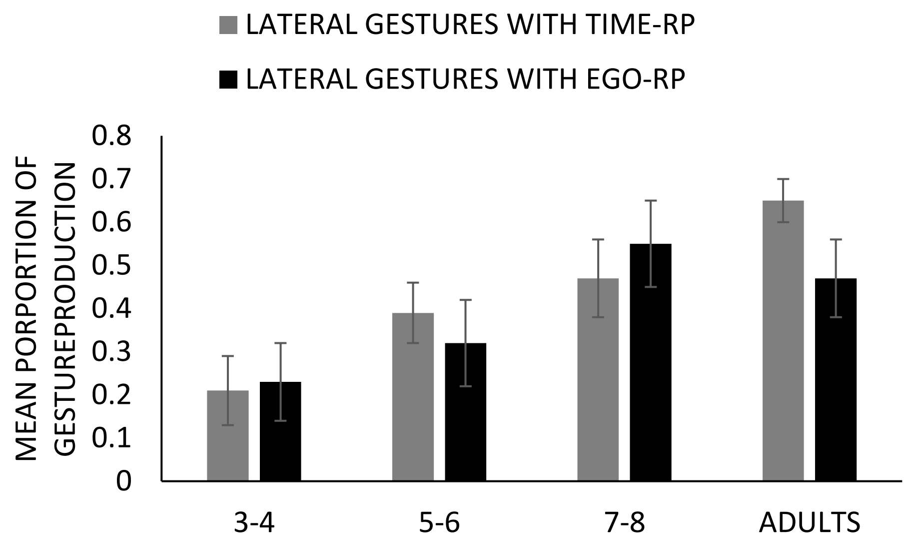

Figure 8 Proportion of lateral gestures that were incongruent (grey bars) and congruent (black bars) by age group

Turning next to **sagittal gestures**, we found that the – 3- to 4-year- old children (*Tukey, p* = .06) and the 5- to 6-year-old children (*Tukey*, *p* = .92) were equally likely to pair sagittal gestures with Time-RP as for Ego-RP metaphors in speech. However, 7- to 8-year-old children (*Tukey*, *p* = .01) and the adults (*Tukey*, *p* < .001) were significantly more likely to differentiate between the two metaphor types in their gestures. In other words, 7- to 8-year-old children and adults were more likely to accompany Ego-RP metaphors in speech with sagittal gestures compared to Time-RP metaphors. (see Figure 9).

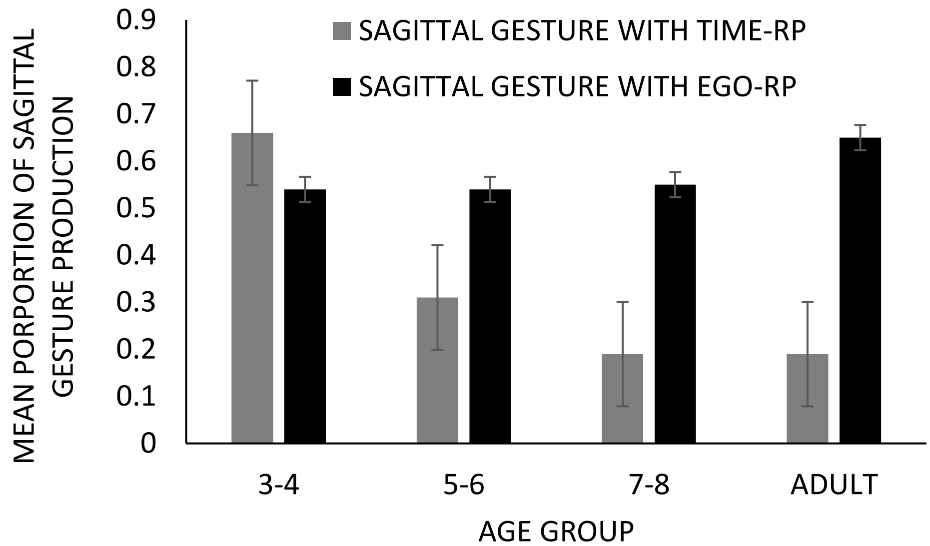

Figure 9 Proportion of sagittal gestures that were incongruent (grey bars) and congruent (black bars) by age group

3.1.2 Deictic Gestures About Time

3.1.2.1 Orientation of Gestures.

As predicted, we found significant increase in the production of lateral gestures over time ($F(3,79) = 9.53$, $p < .001$), even though overall production of sagittal gestures was higher than lateral gestures across ages (fisher's exact, $p = .03$ The number of participants that used lateral gestures also increased significantly with age group ($\chi^2 = 9.25$, $p = .02$), with none of the 3- to 4-year-olds but 42% of 7- to 8-year-olds producing lateral gestures (see figure 9).

While we found no differences between ages 3-4 and 5-6 ($\chi^2 = 2.75$, $p = .23$) or between ages 7- to -8 and adults ($\chi^2 = .13$, $p = .5$), there was a significant difference in the orientation of the gestures younger (ages 3-6) children produced, compared to older children and adults ($\chi^2 = 10.59$, $p = .002$—, showing a pattern akin to the one observed for iconic gestures in the number of subjects that produced lateral gestures as opposed to sagittal.

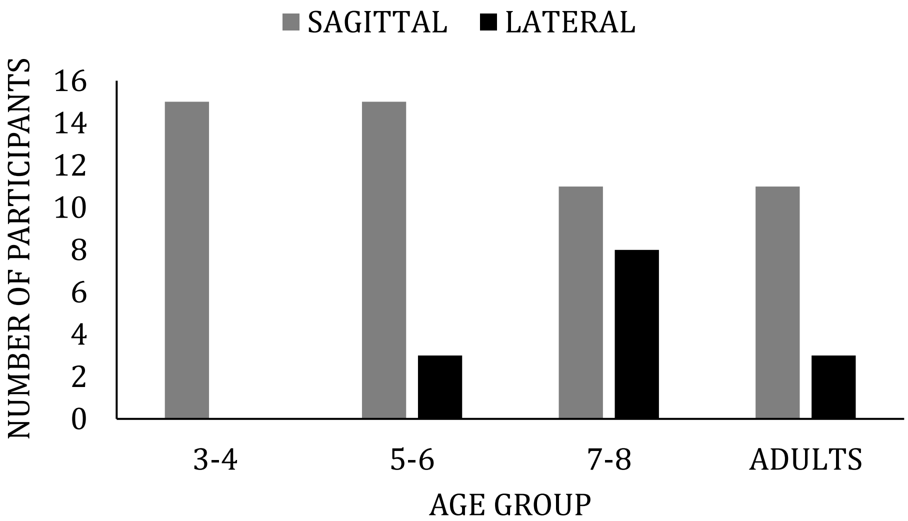

Figure 10 Number of participants that produced sagittal deictic gestures (grey bars) and lateral deictic gestures (black bars) by age group. (max number of participants=20)

3.1.2.2 Directionality of Gestures.

In line with our predictions, we found a significant difference between the groups (χ^2 = 13.14, p = .004) in terms of directionality of deictic gestures. Only one of the 3-4 year old children used with left-to-right or past behind and future ahead directionality, while most of the adults (9 out of 10) used gestures with left-to-right or back-to-front directionality..

Again, we used planned comparisons to further examine the developmental differences in the participants' gestures. We found that no differences between the 3-4-year-olds and the 5-6 (χ^2 = 3.48, p = .1) and the 7-8-year-olds and the adults (χ^2 = .14, p = .99). Therefore we combined the two younger groups (3- to -4 and 5- to -6) and the two older groups (7- to -8 and adults).

Interestingly, in the deictic gestures, the number of gestures with left-to-right or back-to-front directionality produced by the 3-4 year old children and the 5-6 year old children did differ significantly from the number of gestures with left-to-right or back-to-front directionality produced by the 7-8 year old children and the adults ($\chi^2 = 5.81$, $p = .01$). In other words, when producing deictic gestures, the older two groups (7-8 year olds and adults) were more likely to indicate that the past is to the left or behind them and the future is to the right or in front of them; showing a different pattern than the iconic gestures (figure 11).

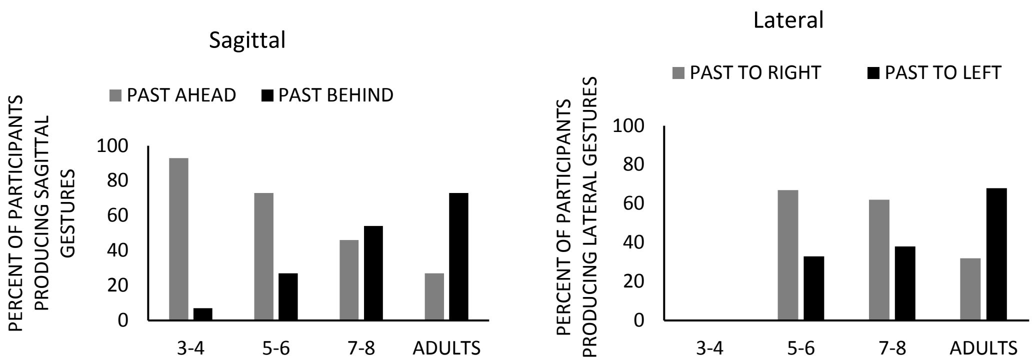

Figure 11 Sagittal gestures (panel A) that indicate the past is ahead (grey bars) or past is behind (black bars). Lateral deictic gestures that indicate the past is to the right (grey bars) or the past is behind (black bars)

We predicted that the 3-4 year old children would use more gestures with ‘forward away from body’ directionality for both past and future events. As predicted, we found that the 3-4 year old group were significantly more likely than any of the other groups to produce forward points for both the past and the future ($\chi^2 = 26.47$, $p < .001$; Figure 12).

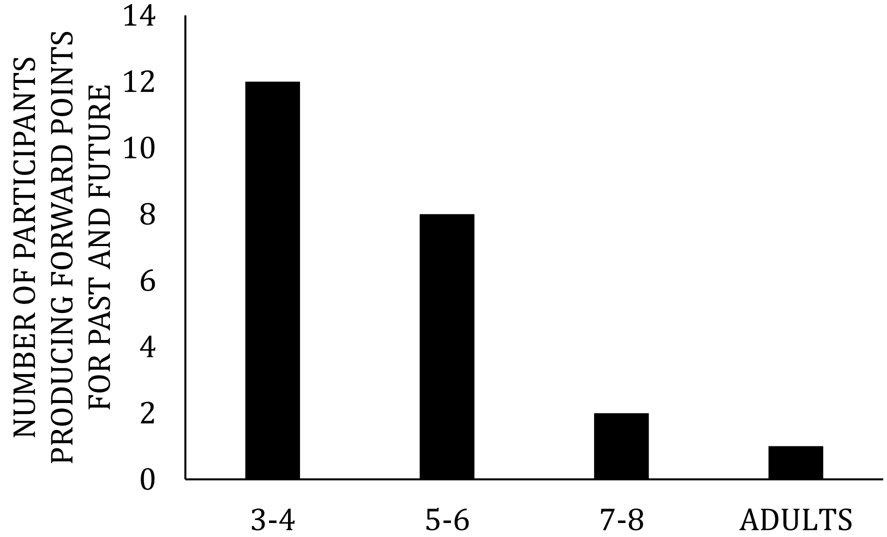

Figure 12 Number of participants that produced forward away from body points for both past and future events

3.1.3 Summary

Our findings showed developmental changes in the orientation, directionality, and congruency of the iconic and orientation and directionality of the deictic gestures children produced when talking about time. The gestures 3- to 4-year-olds produced relied primarily on the sagittal orientation with forward directionality independent of the type of metaphor conveyed in speech (Time-RP vs Ego-RP). In contrast 7- to 8- year-old children (and adults) increased their production of lateral gestures with left-to-right directionality, typically accompanied by Time-RP metaphors in speech. Older children (7- to 8- year-olds) and adults also produced some sagittal gestures, but typically accompanied those with Ego-RP metaphors in speech.

3.2 Factors that contribute to developmental change in children's gestures about time

We first examined developmental changes in the factors that contribute to changes in children's production of gestures about time, namely metaphor comprehension and literacy.

Beginning with *metaphor comprehension*, we found that comprehension of metaphors increased with age ($F(3,79) = 16.3$, $p < .001$, Table 2), with significant differences between 3- to 4-year-olds and children in the other two groups (5- to 6- years and 7- to 8- year olds) . (Tukey, *p's* < .01). However, the 7- to 8- year old children's score did not differ significantly from the adults (Tukey, $p = .61$). We also found an effect of age in comprehension of the two types of metaphors: namely Ego-RP metaphors ($F(3,79) = 5.02$, $p = .003$) and Time-RP metaphors ($F(3,79) = 7.68$, $p < .001$, Table 2). Three- to 4-year-old children scored significantly lower than the two older groups of children and the adults (Tukey, *ps* < .05).

Table 3 Means and standard deviations of performance on metaphor task

Mean (SD)	3-4	5-6	7-8	Adults
Metaphor Comprehension	4.20 (1.74)	5.80 (1.51)	6.60 (1.35)	7.15 (0.99)
Ego-RP Comprehension	2.45 (1.15)	3.40 (0.75)	3.10 (1.25)	3.60 (0.75)
Time-RP Comprehension	1.75 (1.16)	2.40 (1.00)	2.30 (1.08)	3.25 (0.99)

Turning next to literacy, we also found a significant effect of age on both the concepts about print task ($F(3,79) = 280.47$, $p < .001$, Table 2) and the WJ-IV Letter Word Identification task ($F(3,79) = 50.02$, $p < .001$, Table 4), with all groups differing significantly from each other (Tukey, *p's* < .001).

Mean (SD)	3-4	5-6	7-8	Adults
WJ-IV Raw scores	10.00 (5.51)	26.60 (8.54)	52.10 (8.64)	67.65 (3.28)
WJ-IV Standard Score	109.90 (12.13)	121.10 (11.04)	120.80 (9.53)	97.90 (5.75)

Concepts About Print	7.55 (2.76)	11.95 (1.36)	12.95 (0.22)	13.00 (0.00)

Table 4 Means and standard deviations of Woodcock Johnson-IV and Concepts About Print task

3.2.1 Factors that Contribute to Changes in Iconic Gestures about time

3.2.1.1 Orientation of Gestures

Here, we expected that children's comprehension of time metaphors in speech, particularly the different metaphor types (Ego-RP vs. Time-RP) and their familiarity with literacy would influence the orientation of the metaphorical gestures that they produce. Specifically, we expected children's comprehension of Time-RP metaphors and their literacy level to influence the *orientation* of their gestures, with children who comprehend Time-RP metaphors and have higher literacy levels producing more lateral gestures and children who only comprehend Ego-RP metaphors and who are lower in literacy producing more sagittal gestures.

We found no effect of comprehension of Time-RP metaphors, (β = .04, $t(79)$ = 1.06, p = .3) or performance on the Concepts About Print Task (β = .01, $t(79)$ = .69, p = .4) on children's production of lateral gestures. However, we found that performance on the WJ-IV, which measures literacy, significantly predicted children's use of lateral gestures (β = .5, $t(79)$ = 2.73, p = .008, R^2 = .25, Figure 10), even after controlling for the participant's chronological age.

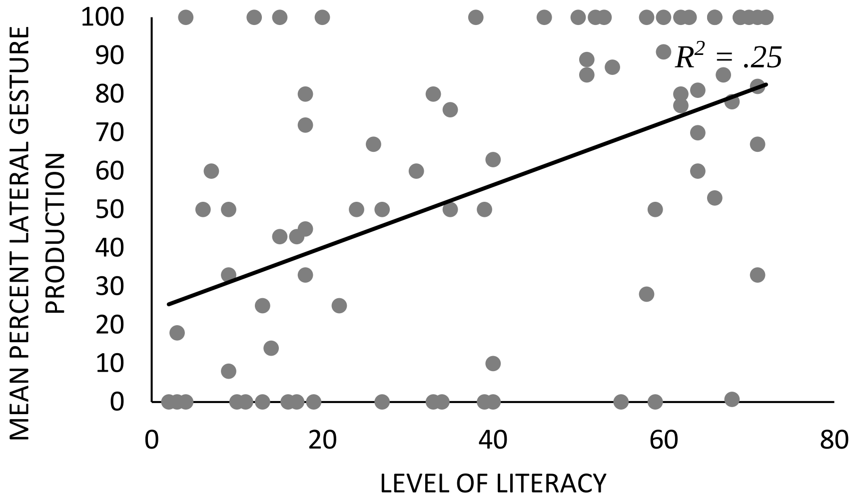

Figure 13 Correlational plot for the mean percent of lateral gestures children produced and the mean literacy scores assessed by Woodcock Johnson Letter Word ID subtest

3.2.1.2 Directionality of gestures.

Turning next to the directionality of children's iconic gestures (left-to-right lateral gestures and forward away from body and backward toward body sagittal gestures), we predicted that children's literacy level would significantly predict their use of left-to-right lateral gestures; we also predicted that their understanding of Ego-RP metaphors would predict sagittal gestures that move backward towards the body for the past and forward away from the body for the future.

Starting with **sagittal gestures**, we did not find any evidence that Ego-RP metaphor comprehension predicts the use of forward away from the body for the past and backward away from the body for the future (past is behind and future is ahead; β = .17, t(79) = .002, p = .9; figure 14).

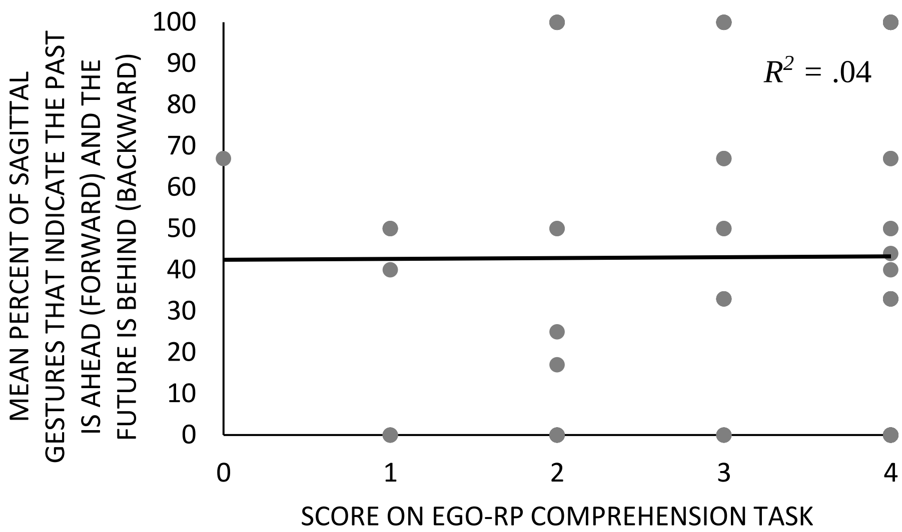

Figure 14 Correlational plot for the mean percent of sagittal gestures children produced and that indicate the past in behind and the future is ahead and performance on the Ego-RP metaphor comprehensions task

Turning next to **lateral gestures**, we found no evidence that scores on the concepts about print task (β = .02, $t(78)$ = .1, p = .9) predicted children's production of lateral gestures. However, we found that, even after controlling for chronological age, scores on the WJ-IV Letter Word Identification task significantly predicted the participant's use of left-to-right lateral gestures (past to the left and future to the right; β = .35, $t(78)$ = 2.22, p = .03, R^2 = .13, Figure 15), suggesting that experience with reading direction influences the use of left to right gestures.

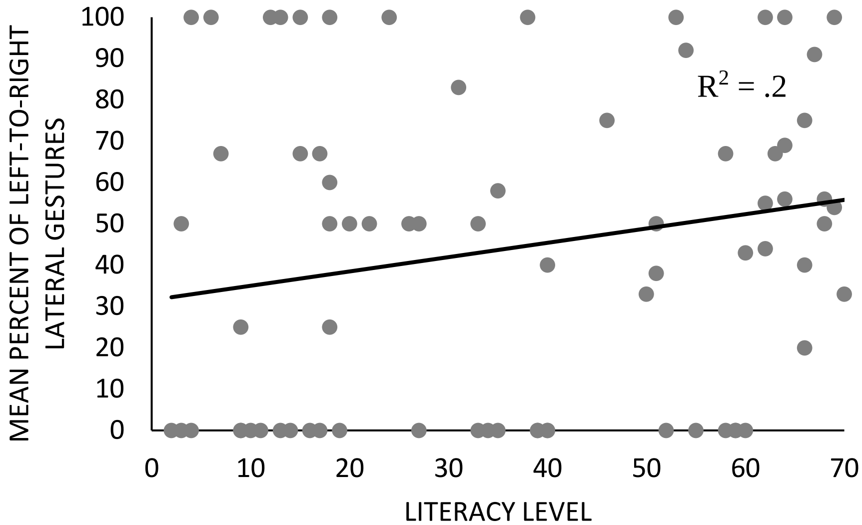

Figure 15 Correlational plot for the mean percent of left to right lateral gestures children produced and the mean literacy scores assessed by Woodcock Johnson Letter Word ID subtest

3.2.1.3 Congruency of Gestures.

We predicted that children who comprehended two types of metaphors for time would be more likely to produce gestures that are congruent with the two types of metaphors in speech (i.e., sagittal gesture paired with Ego-RP metaphors in speech and lateral gestures paired with Time-RP metaphors in speech). Our analysis provided no support for this prediction: comprehension of Ego-RP metaphors did not predict congruency of sagittal gestures that children produced (β = .14, t(78) = 1.27, p = .1), and comprehension of Time-RP metaphors did not predict congruency of lateral gestures (β = .13, t(78) = 1.14, p = .27).

3.2.2 **Factors that contribute to changes in Deictic *Gestures About Time***

3.2.2.1 Orientation of Gestures.

We predicted that children's comprehension of Time-RP metaphors and their literacy level would influence the *orientation* of their gestures. That is, children who comprehend Time-

RP metaphors and have higher literacy levels would produce more lateral gestures, and children who only comprehend Ego-RP metaphors would produce more sagittal gestures**.**

Our analysis showed that neither the scores on the Concepts About Print task (β = .64, p = .08), comprehension of Ego-RP metaphors (β = .08, p = .07), nor comprehension of Time-RP metaphors (β = .14, p = .85) predicted the orientation of children's deictic gestures. However, scores on the WJ-IV significantly predicted the orientation of children's gestures: children with higher scores on the WJ-IV produced significantly more lateral gestures, compared to children with lower scores on the same test (β = .07, p = .01; figure 15)

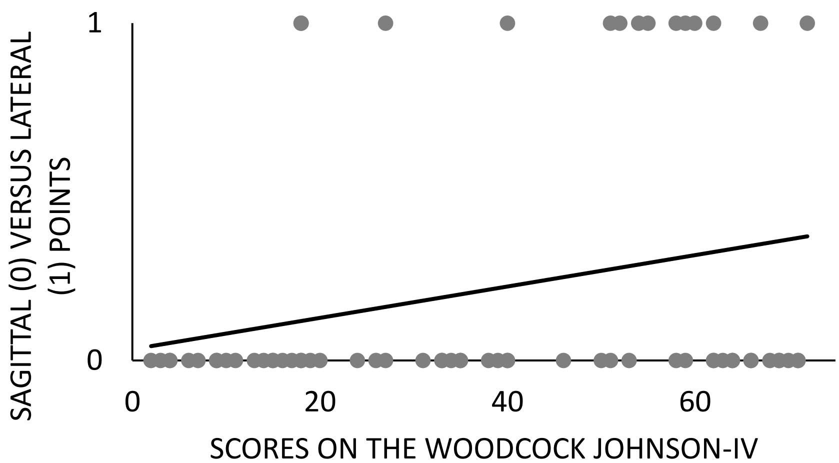

Figure 16 Scatterplot of sagittal (0) versus lateral (1) points and scores on the Woodcock Johnson-IV letter word ID task

3.2.2.2 Directionality of Gestures

We hypothesized that children's comprehension of metaphors for time would predict their use of backward toward the body and forward away from the body sagittal gestures that indicate that the past is behind and the future is ahead and their literacy would predict the use of left-to-right lateral gestures that indicate the past is to the left and the future is to the right.

Here we found that metaphor comprehension significantly predicts the directionality of children's gestures. Children with higher scores on the metaphor comprehension task were significantly more likely to produce backward toward the body sagittal gestures for the past and forward away from the body sagittal gestures for the future, and left-to-right lateral gestures that indicate the past is to the left and the future is to the right (β = .6, p = .01). However, neither the WJ-IV scores (β = .01, p = .7) nor performance on the concepts about print task were significant predictors (β = .2, p = .34) of directionality.

To further explore this relationship we examined sagittal gestures and lateral gestures separately. Turning first to **sagittal gestures** we found that comprehension of Ego-RP metaphor (β = 2.5, p = .02), but not literacy (β = .03, p = .4), significantly predicted production of backward toward the body sagittal deictic gestures for the past and forward away from the body deictic gestures for the future. In other words, children that comprehend Ego-RP metaphors were significantly more likely to indicate that the past in behind and the future is ahead.

Next we examined **lateral deictic gestures**, and found no evidence that comprehension of Time-RP metaphors influenced left-to-right lateral deictic gestures (β = .16, p = .85). However, we found that literacy significantly predicted left-to-right lateral gestures (β = 3.7, p = .006). In other words, participants who scored higher on the WJ-IV were more likely to produce lateral deictic gestures that moved from left-to-right.

3.2.3 Summary

In summary, we found that children's literacy level predicted—as assessed by the Woodcock Johnson Letter Word ID subtest-- the orientation and directionality of their gestures about time, both for iconic and deictic gestures. Children with higher levels of literacy were more likely to produce lateral gestures that moved from left-to-right, similar to the reading and writing direction in English. We also found that children's understanding of Ego-RP metaphors predicted the directionality of children's sagittal gestures, but only for deictic gestures. Specially, children who understood Ego-RP metaphors were more like to produce forward away from the body and backward toward the body sagittal gestures that placed the past behind and the future ahead, while those that did not understand Ego-RP metaphors produced sagittal gestures that placed both the past and the future in front of them.

4 DISCUSSION

In this study, we focused on children's metaphorical gestures for time across early school years (ages 3 to 8). We asked how early we see a developmental shift in the orientation, directionality, and congruency of the gestures children produced and whether comprehension of metaphors in speech and literacy skills influence the developmental changes that we observed. We found that children showed developmental changes in the orientation, directionality and congruency of their gestures over time; we also found literacy skills to be a strong predictor of these developmental changes... Children began by gesturing about time sagittally, placing both the past and the future ahead. However, over time, they began to place the past behind and the future ahead in their gestures. This became especially evident in their deictic gestures, wherein children who showed better comprehension of metaphors for time in speech were also more likely to place the past behind and the future ahead of their bodies in their deictic gestures. In addition, as the children gained further experience with literacy, their gestures became more lateral, showing a directionality from left-to-right, also consistent with the directionality of reading-writing in English. Older children and adults also began to show greater congruency in their gestures about time, pairing Ego-RP metaphors in speech with sagittal gestures for time and pairing Time-RP metaphors in speech with lateral gestures. Overall, our findings suggest that children's gestures about time show marked developmental changes beginning around age 6, changes that are also strongly connected their literacy level, and to a lesser extent, their comprehension of metaphors for time.

4.1.1 Changes in the orientation of gestures

Children increased their use of lateral gestures and decreased their use of sagittal gestures with increasing age—a pattern that was true for both iconic and deictic gestures. One explanation for this pattern is that 3-4 year old children are preliterate and do not yet comprehend metaphors about time; therefore, their gestures are most closely related to their bodily movement through space- in other words moving their own bodies forward through 3-dimensional space. As such, their gestures about time are largely sagittal. In fact, younger children are significantly more likely to point forward to indicate both the past and the future—the direction of movement with which they have most experience, further lending evidence to the theory that one's sensorimotor movement through space informs one's gestures. (Hostetter & Alibali, 2008). In other words, gestures stem from spatial representations, namely from motor simulation of body's movement through space (Hostetter & Hopkins, 2002; Hostetter & Alibali, 2007); and young children that do not yet understand the convention "past is ahead and future is behind" gesture in a way that is consistent with their most common spatial experience, that is their body's forward movement through space.

Although lateral gesture use increased with age for both iconic and deictic gestures, we did see some difference in gesture orientation between the two gesture types. Here, although most of the iconic gestures about time produced by adults and older children (ages 5- to- 8) were lateral, the majority of deictic gestures produced by all age groups were sagittal. This is similar to findings by Casasanto and Jasmin (2012), which showed that when adults were not told to gesture but instead produced spontaneous gestures, the majority of the gestures about time that they produced were laterally orientated. However, when *explicitly told to gesture* about time, such as we did in the current study in the deictic gesture task, adults produced more sagittal gestures (Casasanto & Jasmin, 2012). It is possible that asking participants to gesture activates a spatial schema that is consistent with the ways that we talk about time in English ("Summer is behind us and winter is ahead"), in which the body is used as an anchor with past behind and the future ahead. However, when gesturing spontaneously speakers use a schema rooted in their habitual experience with reading and writing direction in their native language, in which the body is an anchor with the past to the left and the future to the right. This would explain why we observed greater use of lateral gestures in literate participants.

Another possibility is that English speakers use a different schema to express metaphorical motion events when they are gesturing silently (i.e., without speech as in our deictic gesture task) than when those gestures accompany speech. Recent research has shown that adult speakers of English and Turkish gesture in non-language specific ways when gesturing about motion events silently, without any accompanying speech (Özçalışkan, Lucero, & Goldin-Meadow, 2016). However, interestingly in our study, the deictic gestures produced without speech relied more on the conventions of the English language than iconic gestures that are produced with speech. That said, it is possible that 'past is behind and future is ahead' might be a universal packaging of metaphorical motion through space, possibly because it is connected to our own body's movement through space instead of cultural artifacts, such as reading and writing. However, the silent deictic gestures produced by young children who did not yet understand metaphors for time placed both the past and the future ahead. However, once they understood metaphors for time in English, their deictic gestures began to take on a specific directionality (past behind and future ahead), suggesting that deictic gestures produced without speech might be driven by patterns in the language. This is supported by previous research showing that speakers of other languages, when using deictic points to express time, also used deictic gestures that were in line with the types of spatial time metaphors used in their own language (Boroditsky, 2008).

4.1.2 Directionality of Gestures

Children increase their use of gestures indicating the past is behind or to the left and the future is ahead or to the right with increasing age when producing both iconic and deictic gestures. Again, we observed that younger children that did not yet understand metaphors for time and are preliterate did not use a specific directionality when gesturing about time; instead, preliterate children placed both the past and the future ahead of themselves. This is consistent with previous research showing that young children do not have a specific temporal directionality (Tversky et al, 1991). In the Tversky et al. (1991) study, preliterate children were asked to place a series of transparencies in order. The preliterate children placed the transparencies in random order and not in a way that was consistent with conventions of metaphorical language for time or literacy. In other words, preliterate children that do not yet understand metaphors for time do not consistently place the past behind or to the left, and the future ahead or to the right.

Here we see a close coupling between iconic and deictic gestures. In both tasks younger children were less likely to indicate that the past is behind or to the left and the future is ahead or to the right. We posited that a change in directionality may be seen earlier in deictic gestures than in iconic gestures, because these types of gestures are easier for young children and are seen earlier in development, however, that was not the case. One possibility is that the children focused only on the part of the question in which we asked them to point. We asked children to point to “breakfast time” and to point to “dinner time”, therefore they may have just understood the direction to “point” and pointed in front of them. However, because children followed the same pattern when *not* asked to gesture, it seems unlikely that their propensity to gesture forward for past and future was an artifact of the instructions in the deictic gesture task. Another possibility is that young children have trouble comprehending the difference between a time in the past and a time in the future, therefore, they point at the same spot for both time points. Again this seems unlikely because we know that children as young as two are capable of talking about past events (Fivush, et. al., 1987). A more likely possibility is that children’s gestures are informed by other factors, such as a burgeoning understanding of metaphors for time and their experience with literacy, which we will discuss in more detail below.

4.1.3 Congruency of Gestures

We found that, although older children and adults were more likely to use lateral gestures when producing spontaneous iconic gestures, when they did use sagittal gestures, they were more likely to accompany them with Ego-RP metaphors than Time-RP metaphors in speech. This is consistent with previous findings that showed that adult speakers of English used sagittal gestures when using Ego-RP language and lateral gestures when using Time-RP language (Casasanto & Jasmin, 2012). This is likely because Ego-RP language references the self (e.g.,“Exams are approaching [me]”), as do sagittal gestures (e.g., “+ open palm gesture towards self to indicate time moving toward speaker). In contrast, Time-RP language puts two (or more) time points in relation to one another and is not from the viewpoint of the self (e.g. “Exams are after Thanksgiving”); lateral gestures also do not reference the self, but place time points in front of the body (“open palm gesture from left to right to indicate a future time).

4.2 Factors that contribute to developmental change in children's gestures about time: comprehension of metaphors

Children's metaphor comprehension did *not* predict changes in the orientation and directionality of their iconic gestures, a pattern that was reversed for deictic gestures. Children who did not understand Ego-RP metaphors in speech were more likely to produce sagittal gestures that moved forward to convey both past and future events. In contrast, children who understood Ego-RP metaphors in speech, ('I'm glad summer is behind us so we can look forward to the spring') were more likely to produce sagittal gestures that placed the past ahead of and future behind the speaker. In other words, children that comprehended metaphors for time in English used language-specific patterns when producing sagittal deictic gestures about time.

Further, in the current study we found that young children, who did not comprehend spatial metaphors for time, produced sagittal iconic gestures equally when using Ego-RP language as they did when using Time-RP language, whereas adults and 7- to 8- year olds were more likely to produce sagittal gestures when using Ego-RP language, also hinting at an effect of metaphor comprehension on the congruency of children's gestures about time. Past research on adults has found that adults use different gestures when they use Ego-RP vs Time-RP metaphors in their speech. Specifically, adults use sagittal gestures most often with Ego-RP metaphors, which references the self (Casasanto & Jasmin, 2012). In this study, we took this finding one step further by showing how early we find effect of metaphor comprehension on children's gestures about time.

There is evidence that spatial language and gestures about time are related (Boroditsky, 2008). In our study, we found that adults and older children prefer to use language-specific sagittal gestures, in other words sagittal gestures that placed the past behind and the future ahead, when asked to produce deictic gesture about time and that this relationship was predicted by comprehension of metaphors about time. However, when examining production of iconic gestures about time, we found a different pattern. Adults and older children prefered to use lateral gestures about time, specifically gestures that move from left-to-right, a pattern not common to the English language. For example, in English you cannot say ‘A left day’ to indicate a day in the past, yet we find a strong preference for left-to-right gestures when gesturing spontaneously, however they are more likely to use these gestures when using Time-RP language. These findings support previous research with adults (Casasanto & Jasmin, 2012; Gu, Mol, Hoetjes, & Swerts, 2014), showing the effect of metaphors produced in speech on gestures about time.

4.2.1 Effect of Literacy on Gestures about Time

Here we found that children’s gestures about time are directly influenced by their experience with literacy. Not only did younger preliterate children rely mostly on sagittal gestures to express time both in the deictic gesture task and the iconic gesture task, but older children and adults were significantly more likely to use lateral gestures than younger children in both the iconic and deictic gesture tasks. Importantly, literacy level predicted the use of lateral gestures, particularly the ones that moved from left to right. In this study, we showed, for the first time, evidence for the effect of of literacy on children’s gestures about time. However, importantly, it was not just knowledge about reading-writing directionality, as measured by the Concepts About Print task, that influenced gesture orientation or directionality; it was changes in word reading ability, which is measured by the WJ-IV, that specifically accounted for changes in children’s gestures about time.

We know from previous research that adults tend to organize time laterally in a way that is consistent with the reading and writing direction in their native language (Chan & Bergman, 2005; Maass & Russo, 2003). Further, there is evidence that adults also rely mostly on lateral gestures about time that have a specific directionality, namely moving from right-to-left (Casasanto & Jasmin, 2012). These findings suggest that the sensorimotor experience with reading and writing direction is the driving force behind the organization of adults' gestures about time.

The current findings support the theory that sensorimotor experience with native orthography informs the mental timelines of adults and older children that have a plethora of experience with the reading and writing direction in English. However, if adults and older children use primarily left-to-right gestures about time instead of language-specific back to front gestures, then that leaves the question of how adults and literate children organize their mental time line. Here we find evidence that instead of adopting an Ego-RP or Time-RP view of time that is consistent with the English language, literacy contributes to a third organization of mental timelines, called 'Moving-Attention' (Casasanto & Jasmin, 2012). Here both the speaker and time points are stationary, instead of time flowing towards or away from the speaker or moving laterally in front of the speaker. More specifically, points in time stretch in front of the speaker with past events located to the left and future events located to the right. The speaker then moves their attention to different points on the time line to express temporal information, resulting in gestures with left-to-right directionality (Casasanto & Jasmin, 2012; Figure 17). Although this is similar to the Time-RP view of time, it differs in one important aspect; instead of time moving in front of the speaker, similar to items on a conveyor belt, time is stationary and the speakers' attention shifts from one point in time to another. This mimics the conventions of reading and writing in that we move our attention from one item to the next. In the current study we found for the first time some evidence suggesting that not only do English speaking adults and older children adopt a 'Moving-Attention' mental time line when expressing past and future events spontaneously, but that this perspective is directly related to English orthography.

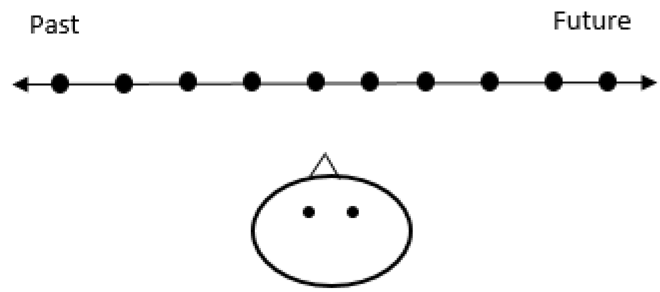

Figure 17 Adapted from Casasanto and Jasmin (2012), depiction of 'Moving-Attention' view of time

The 'moving attention' theory is also in line with prominent theories of gesture production that state that sensorimotor experience and language input together shape a speaker's gesture, allowing gesture and speech to form an integrated system in which gesture expresses related but different information from speech (McNeill, 1992). We see evidence for this in our study- where the single largest predictor of gesture orientation and directionality is the literacy skills of the gesturer.

4.3 Summary

In this study we find the first direct evidence for developmental changes in children's gestures about time. Here we find that these changes are driven by literacy, and to a lesser extent, by metaphor comprehension. Specifically we found that young children that do not comprehend spatial metaphors for time rely on their own body's movement forward in space to locate both past and future events. However, as they begin to understand metaphors for time, they begin to place the past behind and the future in front of their bodies when asked to produce deictic gestures, in line with the way they speak about time in English. Finally experience with reading and writing begins to inform children's gestures about time as they take their first steps into literacy—an influence that is evidence mostly in children's lateral gestures about time.

Overall our findings also suggest that gesture continues to reflect knowledge relevant to the language learning process as children develop increasingly complex language abilities. Previous research has shown gesture to be closely tied to the child's emerging language system for early language milestones, from *first words* (Bates, et al.,1976; Iverson & Goldin-Meadow, 2005; Özçalışkan, Adamson, & Dimitrova, 2015) and *first sentences* (Butcher & Goldin-Meadow, 2000; Özçalışkan & Goldin-Meadow, 2005) to first *similarity comparisons* (e.g., "Butterfly is like rainbow"; Özçalışkan, Goldin-Meadow, Gentner, Mylander, 2009). Our study extends this to the domain of early metaphors about time and shows that gesture continues to reflect children's burgeoning understanding of the speech patterns evident in their native language (see also Özçalışkan, 2007 for other metaphorical domains structured by space) as well as orthographical direction in their native language.

4.4 Limitations and Future Directions

The main limitation to the current study is that it was conducted only on monolingual speakers of English. Therefore, there was no comparison group of speakers that have different directionality in their spoken metaphors about time (such as the vertical metaphors found in Mandarin Chinese; Boroditsky, 2001; Scott, 1989) or different directionality in their reading and writing direction (such as Hebrew speakers; Ouellet, Santiago, Israeli, & Gabay, 2010). Future research with speakers of other languages with different levels of literacy would help further extend the findings of this study.

Although this study provides evidence that literacy and language are related to the organization of time in the minds of adults and children, further research is needed to ascertain how this relationship is built and under what context different mental time lines are maintained. Here we found a difference in the participants' gestures about time depending on whether they were explicitly asked to gesture (i.e., tasks eliciting deictic gestures) or were gesturing spontaneously (i.e., tasks eliciting iconic gestures). This suggests that asking the participants to gesture activates a different mental time line than people normally rely on when speaking about past and future events. Further research across different languages is needed to determine whether the differences that we observed in the two types of gesture tasks are driven by the explicit instruction to gesture (told to gesture vs. not told to gesture) or by the nature of the gesture itself (silent gestures produced without speech vs. co-speech gestures produced with speech)

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APPENDICES

Appendix A

Activity Questionnaire

We would like to get to know more about the activities that your child does. Please answer the questions as best you can.

A. Does your child attend school? Yes No
   If yes what grade is your child in?

   Preschool Pre-K Kindergarten 1st grade 2nd grade 3rd grade

B. Does your child attend any after school care or daycare? Yes No
   If yes, how often?

   Once a week 2-3 days a week 4 or more days a week

C. Does your child attend any regular lessons or classes (for example Ballet lessons or Swim lessons)? Yes No
   If yes, what lessons or classes does your child attend?

   ____

D. Have you recently been on a vacation/gone on a trip with your child? Yes No
   If yes, when did you go?____

   Where did you go? ____

   Did you drive or take a plane?_______________

E. Are you planning a vacation/trip ***that you have talked about with your child***? Yes No
   If yes, when are you going? ____

   Where are you going?____

   Will you drive or take a plane?____________________

F. Have you recently taken you child to a local attraction (Zoo Atlanta, World of Coca Cola, Stone Mountain Park, Centennial Olympic Park, etc…)? Yes No
   If yes, where did you go (list as many as possible)? _________________________

____

G. Are you planning to take your child to a local attraction ***that you have discussed with your child***? Yes No
If yes, where do you plan to go (list as many as possible)?____________________

____

H. Have you done anything else with your child recently that is out of the ordinary (for example, had family portraits taken, attended a reunion, attended a festival, acted in a play, etc…)? Yes No
If yes, can you describe the activity (please use the back if you need more

space)?____

____

____

I. Are you planning on doing anything out of the ordinary ***that you have discussed with your child***? Yes No
If yes, can you describe the activity (please use the back if you need more

space)?____

____

____

Thank you ☺

Appendix B

Story One- Ego-RP

This is Patrick. This is Patrick's Mom. Patrick's mom tells him that his trip to the zoo is coming up. Patrick gets really excited! He shouts "YEAH!"

Why is Patrick excited?

1. His trip to the zoo is now.
2. His trip to the zoo is soon.

Story Two- Ego-RP

This is Rob. This is Rob's friend Kyle. Kyle tells Rob that he has to long way to go until his party. Rob is disappointed. He says "Ugh".

Why is Rob disappointed?

A. His party is later
B. His party is over

Story Three- Ego-RP

This is Ed. This is Ed's sister Ann. Ann tells him that the time for bed has come. Ed is sad. He says "Ugh!"

Why is Ed sad?

A. He has to get up now
B. He has to go to sleep now

Story Four- Ego-RP
This is Erin. This is Erin's teacher. Erin's teacher tells her that they are coming up on recess. Erin is happy. She says "alright!"

Why is Erin happy?

A. Recess is now
B. Recess is soon

Story Five- Time-RP

This is Stacy. This is Stacy's sister Carol. Carol says that ice cream follows lunch. Stacy is excited. She's says "Yippee!"

Why is Stacy excited?

A. Ice cream is now
B. Ice cream is soon

Story Six- Time-RP

This is Polly. This is Polly's dad. Polly's dad tells Polly lunch follows washing up. Polly is disappointed. She says "oh."

Why is Polly disappointed?

A. Lunch is over
B. Washing-up is now

Story Seven- Time-RP

This is Tamika. This is Tamika's mom. Tamika's mom tells Tamika that following the movie she has to clean her room. Tamika is mad. She says "argh".

Why is Tamika mad?

A. She has to clean her room now
B. She was to clean her room soon

Story Eight- Time-RP

This is Carlos. This is Carlos' dad. Carlos' dad tells Carlos he will arrive at the pizza shop ahead of his friend. Carlos is happy. He says 'Yes!'

Why is Carlos happy?

A. He will arrive first
B. His friend is at the shop

Appendix C

Concepts About Print Assessment

Purpose: Based on their home and early school experiences with print—bed time stories and read- alouds, big book shared reading, shared writing and their very independent adventures with pretend reading and writing—young children come to kindergarten and even first grade with different understandings about the arbitrary conventions that we use to communicate meaning in print.

An assessment of each child's level of understanding, and sometimes misunderstandings of these conventions helps teachers know what their students are attending to in print and what still needs to be learned. This knowledge enables teachers to design and focus teaching points in literacy mini- lessons and other classroom literacy experiences that move children forward in their understanding of how print works. Where is the front of the book? Where does the story start? Where do I start reading and where do I go after that? What is a letter? What is a word? These are important literacy understandings that can develop through guided hands-on experience with reading and writing in the literacy workshop.

An assessment of emergent literacy print concepts should include:

- Book orientation knowledge
- Understanding of principles involving the directional arrangement of print on the page
- The knowledge that print, not picture, contains the story
- Understanding of important reading terminology such as *word, letter, beginning of sentence,* and *top of page*
- Understanding of simple punctuation marks

(Gillett and Temple, 1994, *Understanding Reading Problems: Assessment and instruction.* Harper Collins: NY. p. 70)

Directions: In assessing concepts of print, the teacher sits with the child, one-on one, and reads an engaging early level text, asking the child to help with the reading. The book used should have distinct layout of print and illustrations, good spacing between words, multiple lines of text on each page, some basic sight words (I, me, and, is, was, etc.) and basic elements of punctuation (periods, quotation marks, question marks, exclamation points). Because the teacher reads the book to the child with the child looking on and responding to prompts, the text we are using is *Honey for Baby Bear* at a level F. This text has varied and sophisticated text layout and punctuation. (Other sample texts, levels C-F might include: *Where is Hannah? Ben's Teddy Bear*, *A Friend for Little White Rabbit, Nick's Glasses, Dan, the Flying Man, Going to Lucy's House*).

The teacher should be very familiar with the text (story, layout and features, punctuation, etc.) before reading with the child. Have ready two brightly colored index cards, a pencil and the record sheet. This assessment incorporates prompts that help the teacher observe a student‟s behaviors in response to the prompts and note these on the record sheet. (While working with the child, you will want to make small tick marks to note correct responses and keep moving, but later note the child‟s specific behaviors and responses.)

Based upon the research of Clay, M. M. (2000). *Concepts About Print: What have children learned about printed language?* Portsmouth, NH: Heinemann. ©TCRWP

Participant Number: ___________________________ Date:____________________

Concepts of Print

Choose a book that has distinct layout of print and illustrations, good spacing of words and multiple lines of text. Begin by telling the child, "I'm going to read you this story and I want you to help me. It is called ___________"

1. Orientation or layout of text/ Front of book: Hand the child the book, holding it vertically so that the spine faces the child. Ask:

- ***"Where is the front of the book?"***
- ***"Where is the back of the book?"***
- ***"Open the book to where the story begins."*** Child can open the book to title page or first page of story.

Score one point for each

2. Print, not pictures, carries the message: With the book open to page 1, ask the child:

- ***"Show me the picture."*** Describe and discuss details of the picture.
- ***"Show me the words."***

Only score one point if both are correct

3. Direction of print: On the same page ask:

- ***"Show me where to start reading"***

If child's response is vague, prompt, ***"Where exactly? Show me with your finger."***

- Point to the first word, read it and ask: **"*Where do I read after this?"***

Only score one point if both are correct

4. Page sequencing: Point to the last word on the left page and ask:

- **"*Where do I read after this?"***

Score one point

5. Difference between letter and word: Give the child the two strips of paper. Demonstrate how they slide together and apart on a page in the book. On the same page ask:

- ***"Show me one letter."***
- ***"Show me one word?"***
- ***"Show me the first letter in a word."***
- ***"Show me the last letter in a word."***

Score one point for each

6. Return Sweep: Turn to a page with at least 2 lines of text. Read the top line and keeping your finger on the last word ask:

- "**Where do I read after this?"**

Score one point

7. One-to-One Correspondence: Point to the first word on a new page and before reading, ask the child:

- ***"Point to each word as I read this line."***

Does the child follow and match text as you read?

Score one point

8. Punctuation: Point to the period, tracing it with your pencil and ask:

- **"Do you know what this is?"**

If so, ask: ***"What is this for?"***

Score one point