Fall 12-18-2020

Gesture Gives Bilingual Children a Hand with Spatial Vocabulary

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GESTURE GIVES BILINGUAL CHILDREN A HAND WITH SPATIAL VOCABULARY

by

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ABSTRACT

Monolingual children with better spatial language skills at school entry are more likely to succeed in school and pursue science, technology, engineering, and math (STEM) careers. Importantly, the amount of parent spatial talk, particularly when accompanied by gesture, serves as a strong predictor of monolingual children's spatial language abilities at school entry. However, relatively less is known about the effect of nonverbal spatial input on bilingual children's language development and whether nonverbal spatial input could play a causal role in facilitating children's spatial vocabularies in speech. In this study, we observed whether spatial language input with or without gesture plays a causal role in children’s spatial language acquisition both in immediate and extended discourse contexts. Sixty 4-to 5-year-old children (30 bilinguals , 30 monolinguals) were randomly assigned to receive instruction on 3D shape labels with or without gesture, preceded and followed by parent-child play with toys designed to elicit spatial language. The results showed that gesture input boosted monolingual and bilingual children’s production, but not comprehension, of the target shape terms. However, this effect did not promote spatial talk in the more extended context of parent-child play. Overall, the study shows that instruction with gesture leads to better learning of new spatial words compared to instruction without gesture in both bilingual and monolingual children.

INDEX WORDS: Bilinguals, Monolingual, Gesture, Instruction, Vocabulary, Spatial Language

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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

2020

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December 2020

DEDICATION

I dedicate this dissertation to three individuals who always believed in me: my devoted husband, Alexander, my loving mother, Jacqueline, and the memory of my best friend, Theresa J. Gutierrez.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank my advisor and dissertation chair, Dr. Şeyda Özçalışkan, for her invaluable guidance, wisdom, and patience. I also would like to thank my committee members, Dr. Rose Sevcik, Dr. Amy Lederberg and Dr. Elizabeth Tighe for their helpful suggestions and support along the way. The dissertation project was supported by a generous Provost Dissertation Fellowship; I would like to thank Dr. Lisa Armistead for her time and help in attainment of my goals. I am especially grateful to Sydney Ahearn, Felicia Hurst, Janice Edwards, Melinda Long and Yeni Garcia for facilitating data collection, and all the parents and children who took the time to participate in the study. A special thanks to all my wonderful research assistants Erika Alcantar-Anguiano, Indiara Gonzalez-Ortiz, Syrina Merilan, Eliza Galvez, Renee Brooks, Yanet Rubio Miranda and Jennifer Lara-Cedeno, who worked tirelessly on the transcription and coding of the data and to my friends Sonia Singh, Samantha Emerson, Sümeyra Öztürk, and Ebru Pınar for their feedback and support.

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1 INTRODUCTION

Children's ability to use spatial language (e.g., big-small, above-below, round-curvy) at the early ages is a significant predictor of their performance in science, technology, engineering and math (i.e., STEM) in school and their subsequent entry into a STEM career (Wai et al., 2009). Importantly the amount of spatial language monolingual children hear, particularly when accompanied with gesture, serves as a strong predictor of their spatial language abilities (Pruden, Levine, & Huttenlocher, 2011; Cartmill, Levine, & Goldin-Meadow, 2010). However, relatively little is known about factors that contribute to spatial language development in bilingual children, who are at greater risk for academic failure and are less likely to pursue STEM careers (Hernandez, 2004). Most of the earlier work with monolingual children was also correlational in nature, leaving unanswered the possible causal role parent spatial talk with gestures could play on children's spatial language development. In this study, we aim to fill in these two important gaps by examining whether adult spatial speech, with or without accompanying gesture, could play a causal role in the spatial language development of bilingual children growing up in dual language households as compared to monolingual children.

1.1 The effect of spatial language input with or without gesture on child spatial language development

Child spatial vocabulary use (i.e., words describing dimensions, locations, features, shapes) is a strong predictor of success not only in school but also in science, technology, engineering, and math (STEM) careers (Levine, Ratliff, Huttenlocher, & Cannon, 2012; Pruden et al., 2011; Newcombe, Levine, & Max, 2015). The paramount role spatial vocabulary plays on children's academic achievement and beyond could be explained by several factors. First and foremost, hearing spatial terms may increase children's awareness of spatial features and relations and, in turn, help them navigate school tasks, such using a map in a schoolyard, distinguishing letters while reading (e.g., d vs. b), and correctly arranging numbers and symbols in an equation (Gentner & Loewenstein, 2002). Parent spatial talk has also been shown to be an important predictor of children's spatial vocabulary use (Ferrara, Hirsh-Pasek, Newcombe, Golinkoff, & Lam, 2011; Pruden et al., 2011). For example, Pruden and colleagues (2011) observed children from 1;2 to 3;8 years of age and found that parents who produced more spatial words during one-on-one interactions also had children who used more spatial words.

Shape naming has been shown to be one of the first kinds of spatial talk that parents use with their young children (Verdine, Lucca, Golinkoff, Hirsch-Pasek, & Newcombe, 2016). This is probably due to the fact that geometric shapes are found everywhere (e.g., cube-shaped cubby, circle-shaped cookie) and that many toys for toddlers, such as sorters, puzzles, include shapes in their designs that elicit talk about shapes. Shape terms comprise only 0.11% of parent talk and 1.2% of math-related teacher talk (Rudd, Lambert, Satterwhite, and Zaier, 2008; Verdine et al., 2016). Accordingly, the rare use of shape terms in the classroom and at home presents a particularly important problem area given that 4- to 5-year-old children spend a larger part of their day at school (Vitiello, Booren, Downer, & Willford, 2012). This problem is further compounded by recent changes to preschool and kindergarten curricula, both of which emphasize mastery of labels for shapes as an essential factor in school readiness (Common Core State Standards Initiative, 2011; Office of Head Start, 2011). For example, standards require that children are not only able to "describe objects in the environment using shape names", but also can "analyze and compare two- and three-dimensional shapes," and "correctly name shapes…" (Common Core State Standards Initiative, 2010, p. 12) As such, understanding factors other than adult spatial talk (e.g., gesture) that can help further boost children's shape vocabulary is important for informing the development of school curricula at the younger ages. Research over the last decade suggests that not only spatial talk but also use of gesture with spatial talk might be particularly valuable in boosting children's knowledge of shape words. In an earlier study, Cartmill, Pruden, Levine, and Goldin-Meadow (2010) demonstrated that 3- to 4-year-olds, who saw their parents gesture more when using shape terms, dimensional adjectives, and words describing features, produced more spatial words than children who had parents that gestured less when talking about spatial concepts.

Earlier studies that focused on the effects of parent spatial talk (Ferrara et al., 2011; Pruden et al., 2011) or spatial talk with gesture (Cartmill et al., 2010) on children's spatial vocabulary development were correlational in nature and focused only on monolinguals. Thus, we do not yet know whether gesture could play a causal role in teaching spatial words to young monolingual children, and whether this facilitative effect is also present for bilingual children who are at greater risk for academic failure (Federal Interagency Forum on Child and Family Statistics, 2002). As the numbers of bilingual students in classrooms grow, so does the need to develop methods generalizable to different learners that help all children meet the academic goals expected of them (National Center for English Language Acquisition, 2006). There are several reasons to expect that gesture would improve the efficacy of spatial word instruction for both monolinguals and bilinguals. First, a considerable number of studies with monolinguals show that children show better learning when given instruction with gesture than without gesture (Acredolo & Goodwyn, 1998; Capone & McGregor, 2005; Ellis-Weismer & Hesketh, 1993; LeBarton, Goldin-Meadow, & Raudenbush (2015); Ping & Goldin-Meadow, 2008; Singer & Goldin-Meadow, 2005; Velenzo & Alibali, 2003). A smaller, but growing body of research also suggests that young bilingual children might show a stronger advantage in gleaning information from gesture, surpassing monolingual children in learning tasks that involve gesture (Yow & Markman, 2011; Yow, 2016; Church, Ayman-Nolley & Mahootian, 2004; Rowe, Silverman, & Mullan, 2013). As such, exploring whether gesture has added value during spatial word instruction can be particularly beneficial for bilingual children in furthering their academic success.

1.2 The role of observing gesture in monolingual language development

At the early ages, gesture serves as an important tool that helps young children understand what others are communicating to them. Parents often use their hands when communicating with their children and these gestures help children comprehend new words and concepts. Parents typically tailor their gestures to the developmental level of their children (Iverson, Longobardi, & Caselli, 1999; Özçalışkan et al., 2005a). For example, mothers across different cultures tend to produce simpler gestures (e.g., deictic gestures such as pointing at a toy) and at higher rates than the relatively more complex gestures (e.g., iconic gestures that characterize entities in terms of symbolic action or feature) when talking to their young children (Bekken, 1989; Iverson, Carpici, Longobardi, & Caselli, 1999, Özçalışkan & Goldin-Meadow, 2005a). Not surprisingly, children show earlier comprehension of the deictic gestures than iconic gestures (Hodges & Özçalışkan, 2018; Dimitrova, Özçalışkan, Adamson, 2017; Stanfield, Willimson, Özçalışkan, 2014)—a pattern that also becomes evident in their production of such gestures (Özçalışkan & Goldin-Meadow, 2005a; 2005b, 2011).

There is compelling evidence that suggests that children can understand the function of deictic gestures (i.e., points at entities) directed at them as early as age one (Behne, Liszkowski, Carpenter & Tomasello, 2012; Butterworth & Grover, 1988). For example, infants often look at the object that their mother is pointing to instead of fixating on their mother's hand (Butterworth & Grover, 1998; 1990; Grover, 1982). At this early age, infants also understand that adults are pointing to an object rather than a location (Woodward & Guajardo, 2002). Infants can also gauge the gesturer's communicative intent from deictic gesture. A study by Behne and colleagues (2012) found evidence that 12-month-old children could interpret adults' pointing as a cue to help them find hidden objects. Importantly, there is a tight link between deictic gesture production and comprehension. Children who point more are also more likely to understand adults' points, suggesting a bidirectional relationship between comprehension and production of pointing gestures (Behne et al., 2012).

Research on the relatively more complex iconic gestures (i.e., gestures that characterize entities by associated actions or features, e.g., flapping arms for bird flying) also shows that children can associate an iconic gesture to its referent somewhere between 2- to 3-years of age. Namy, Campbell, and Tomasello (2004) evaluated whether 1;6 and 2;2-year-old children map an iconic gesture versus an arbitrary gesture to a referent. The results showed that by 2;2, children were able to associate iconic but not arbitrary gestures with a referent, thus differing from 1;6-year-olds who were equally likely to map both types of gestures to the same referent—a difference marking a unique role for iconicity in identifying objects around age 2. Two year olds' comprehension of iconicity has also been shown for novel iconic gestures that children have not observed before (e.g., moving empty fisted hand up and down as if hammering; Namy, 2008); and this pattern was particularly pronounced for iconic gestures conveying action information (e.g., flap arms as if bird flying) than iconic gestures conveying feature information (e.g., hold stretched out fingers with thumbs connected as if a bird; Hodges et al., 2015; Stanfield et al., 2014; Tolar, Lederberg, Gokhale, Tomasello, 2008).

Importantly, adults rarely produce gestures in isolation when communicating with children. Instead, they typically accompany their gestures with speech, thus producing gesture-speech combinations. As shown in earlier work (Özçalışkan & Goldin-Meadow, 2005a; see Özçalışkan & Dimitrova, 2013 for a review), adults mainly produce three different types of gesture-speech combinations when interacting with their children, where gesture either *complements* (point at dog + 'dog'), *disambiguates* (point at dog + 'look at it') or *supplements* (point at dog + 'Do you want to pet it?') the information conveyed in their speech. Among the three, adults produce complementary gesture-speech combinations with the greatest frequency, as a way to teach their children new vocabulary items for different entities (Iverson et al., 1999, Özçalışkan et al., 2008; Özçalışkan & Goldin-Meadow, 2005a, 2006; O'Neill, Bard, Linnel, & Fluck, 2005).

Children, in turn, show early understanding of the gesture-speech combinations produced by adults. They can readily understand reinforcing gesture-speech combinations with deictic gestures (Zukow-Goldring, 1996) by age 1. They can also further this understanding to supplementary gesture-speech combinations—typically the ones with deictic or emblematic gestures—at age 1;6 (e.g., nodding for affirmation; Morford & Goldin-Meadow, 1992). There is also evidence that suggests that children comprehend disambiguating gesture-speech combinations with deictic gesture around age 2 (Clark, Huttenson, Van Buren, 1974). Toddlers are also more likely to look at the target object when identified by speech coupled with a disambiguating gesture (e.g., 'it is up there' + point at object) than when it is identified by speech alone (Clark et al., 1974). At the older ages, 3- to 5-year-olds can even infer indirect requests from supplementary gesture-speech combinations. For example, Kelly (2001) found that if an adult said 'it is going to get loud in here' while pointing at the door, 3-to 5-year-old children would often understand the indirect speech act conveyed through the gesture-speech combinations and would get up and close the door.

Not surprisingly, children comprehend gesture-speech combinations with iconic gestures at a relatively later age (Stanfield et al., 2013; see also Dimitrova, Özçalışkan, Adamson, 2017), particularly compared to combinations with deictic or conventional gestures (Butterworth et al., 1988). Previous work provides evidence that when an iconic gesture conveys additional information not found in speech (e.g. 'drink' + moving hand in a c-shape to mouth), 3- to 4-year olds can correctly choose the picture corresponding to the gesture referent (e.g., glass instead of cup with handle; Stanfield et al., 2013). Research also suggests that even 2-year-olds show the ability to understand gesture-speech combinations with iconic gestures when the iconicity is conveyed via action (Hodges et al., 2018; Tolar, Lederberg, Gokhale, &Tomasello, 2008), and when the response choices involve actual objects rather than pictures (Striano, Rochat, & Legerstee, 2003).

Importantly, observing adult gesture has not only short-term but also long-term gains for children. Correlational studies examining nonverbal parental input show that amount of parent gesturing is positively related to children's vocabulary skills. Tomasello and Farrar (1986) reported that the frequency with which parents used deictic gesture to indicate an object at child age 1;3 positively correlated with child vocabulary size at 1;8 years. In an experimental study, Acredolo and Goodwyn (1998) trained one group of parents to produce gestures with speech and another group to only use speech when interacting with their 1-year-olds. The results showed that parents who were instructed to gesture had infants who made greater vocabulary gains than infants whose parents did not use gesture. Iverson and colleagues (1999) also reported a positive relation between the amount of maternal pointing and child vocabulary use at age 1;2. Similarly, Pan, Rowe, Singer, and Snow (2005), in a study with 1;2 to 3;0-year- old children, found that parents who pointed more had children with faster vocabulary growth than children whose parents pointed less often. There is also evidence that suggests that the effect of parent gesture on child vocabulary is mediated through children's own gesture use. A study by Rowe, Özçalışkan, and Goldin-Meadow (2008) with 1;2- to 2;8-year-olds showed that parents who themselves gestured frequently had children who also gestured frequently and had larger vocabulary sizes than children whose parents gestured infrequently.

While most of the earlier work examined the effect of parent gesturing on general vocabulary skills, there is additional correlational evidence showing that parent gesture positively relates to specific sets of vocabulary words, such as the ones about shapes, features and locations. A study by Cartmill, et al. (2010) that followed children from ages 1- to 3-years, demonstrated a positive relation between amount of parent spatial talk with gesture and children's spatial language use. Cartmill et al. (2010**)** interpreted these findings as providing evidence for gesture enhancing spatial information encoded in speech, largely due to gesture being highly spatial itself. In sum, the aforementioned correlational studies—all with monolingual children—demonstrated that seeing gesture might help children learn new vocabulary items in general and spatial vocabulary words in particular.

1.3 The causal link between gesture and language learning for monolingual children

Previous research, as outlined in section 1.2, shows that observing gesture is positively related to language development. At the same time, however, most of this earlier work is correlational, leaving the possibility of a causal link between gesture input and language development unanswered. Does observing gesture simply correlate with vocabulary development or does it play a causal role in learning new words?

Research with school-aged monolingual children shows that adult gesturing during instruction plays a causal role in learning as evidenced across a variety of language and cognitive tasks. For example, teachers routinely gesture during math instruction, averaging around 2-3 gestures per minute (Flevares & Perry, 2001); and these gestures have been shown to boost math learning in 10- to 11-year-old children (Perry, Berch, & Singleton, 1995; Velenzo, Alibali, & Katzky, 2003; Singer & Goldin-Meadow, 2005). Children who receive verbal instruction with gesture show greater understanding of the math concept at hand (e.g., mathematical equivalence) than children who receive the same instruction only in speech (Perry, Berch, & Singleton, 1995). In an earlier study, Singer and Goldin-Meadow (2005) assigned 10- to 11-year-old children to a math lesson in which a teacher either presented two different math strategies across gesture and speech—with one in speech and one in gesture—or both strategies entirely in speech. The results showed that children who were exposed to the two strategies simultaneously across gesture and speech showed better learning than children who were exposed to the two strategies in speech alone. In a later study, Ping and Goldin-Meadow (2008) gave 5- to 7-year-old children instruction in learning Piagetian conservation tasks either with or without gesture. In line with earlier studies on math learning (Perry et al., 1995; Singer et al., 2005), children who saw instruction with gesture showed a better grasp of the conservation task than children who received the instruction without gesture (Ping et al., 2008). A similar positive effect of gesture on learning has also been shown for spatial tasks in a study by Valenzeno and colleagues (2003). The researchers found that the use of pointing and tracing gestures (e.g., tracing the shape of an object) by teachers when teaching the concept of symmetry in shapes boosted 3- to 4-year-old children's learning of bilateral symmetry.

Compared to numerous studies examining the causal link between seeing gesture and learning across different cognitive tasks during school years, relatively less is known about the causal effect of seeing gesture in learning language. However, the few existing studies suggest the possibility of a causal role for gesture in first language acquisition contexts. Ellis-Weismer, & Hesketh (1993) taught monolingual 5-year-olds three pseudo words that describe spatial locations using gestures (e.g., "wug" to mean beside + trace gesture from box to space next to box). The results showed that children who were exposed to pseudo words with gesture showed better comprehension of spatial locations than children who did not observe such gestures during instruction (Ellis-Weismer et al., 1993). Although this study did not directly test word learning, it is one of the first studies to show the important role adult gesture plays in teaching words associated with spatial locations in monolingual children. In a related vein, Capone and McGregor (2005) found that 2;3- to 2;6-year-old toddlers produced more of the instructed pseudo words for kitchen objects when these words were taught with iconic gestures than without such gestures. A more recent study also attempted to examine the effect of seeing vs. producing gesture in a word learning paradigm with 1;5-year-olds (LeBarton, Goldin-Meadow, & Raudenbush, 2015). The researchers found that experimentally increasing monolingual children's exposure to gesture—by producing and seeing gesture—resulted in greater increases in spoken vocabulary, compared to no exposure to gesture during word learning. The results also showed that children who were instructed to produce gesture while learning a novel object word produced a greater number of different words in naturalistic interactions with their parents, compared to children who were not instructed to gesture. The question still remains, however, whether gesture plays a similar causal role in the vocabulary development of bilingual children, particularly in learning labels for spatial concepts.

1.4 The role of observing gesture in bilingual language development

Despite the vast amount of research illustrating the role of gesture in early monolingual development, the number of studies examining the role of gesture in bilingual language development remains relatively scarce. Bilingual children grow up in rich dual language environments containing a diverse set of linguistic structures (Bjelland, 2009; Ramirez & Kuhl, 2016); and most use greater amount and variety of words in the language they hear most often at home (Hoff & Core, 2013). Bilingual children also show differences in the content of their vocabularies in their two languages (Hoff et al., 2015). For example, bilinguals typically know words used at home in the language they hear at home, whereas they know more academic words in the language they hear at school (Bialystok, Luk, Peets, & Yang, 2010).

When compared in each language separately, bilingual children appear to lag behind their monolingual peers especially in their weaker language (Pearson et al. 1993; Hoff et al., 2012). Studies have found that bilingual children's expressive vocabularies in each language develop at a slower rate than monolinguals' largely because of the reduced input that they receive in each language (Hoff et al., 2012; Poulin-Dubois, Bialystok, Blaye, Polonia, & Yott, 2012; Kohnert & Bates, 2002; Pearson, Fernandez, & Oller, 1993). As a result, bilingual children have smaller vocabularies in each of their two languages compared to monolingual children – a gap that begins to narrow around age 4, particularly in the dominant language (Hoff, Rumiche, Burridge, Ribot, & Welsh, 2014). Bilingual children become comparable to monolingual children, however, when their total vocabulary size across their two languages is considered (Hoff & Core, 2015; Polonia & Yot, 2012). At the same time, having a smaller vocabulary size in a second language (e.g., English for children growing up Spanish-speaking households in US or French-speaking households in Canada) places bilingual children at academic risk, mostly because the language of instruction is different from the one they are exposed to at home (MacLeod, Castellanos-Ryan, Parent, Jacques & Seguin, 2017; Snow, Burns & Griffin, 1998). Furthermore, research with Spanish-English bilinguals in the United States shows that bilingual children's English language skills in kindergarten predict their academic success throughout eighth grade, making research efforts that develop interventions aimed at boosting English language skills important for success in school (Halle, Hair, Wadner, McNamara & Chien, 2012; Hoff et al., 2012; Hoff, Rumiche, Burridge, Ribot, & Welsh, 2014; Lonigan, Farver, Nakamoto & Eppe, 2013; Vagh, Pan, & Mancilla-Martinez, 2009).

The effect of observing gestures on learning among bilingual children remains relatively sparse in the field. One of the two existing studies examined monolingual and bilingual children's ability to use pointing gestures to infer a speaker's request (Yow & Markman, 2011). Three- to 4-year-old English monolingual children and bilingual children—with English as first and a different language as the L2 (i.e., Spanish, Mandarin, French, Portuguese, Russian)—were asked to locate a missing toy from two boxes. During the testing period, the experimenter either pointed from a position that was closer or further away from the box that contained the toy. Bilingual children were as likely as monolingual children to infer the correct location of the toy when the experimenter was pointing closer to the target toy. However, more bilingual than monolingual children performed correctly during the more difficult condition, when the experimenter pointed while seated furthest from the target toy, suggesting that bilingual children benefit more from gesture—particularly distal pointing— than their monolingual peers. A second study with 3- to 4-year-old bilingual children showed similar results. Yow (2016) asked children to identify a target referent accompanied by an ambiguous pronoun and a deictic gesture embedded in a narrative (e.g., experimenter says ‘She wants the ball’ while pointing to one of two pictures depicting female characters), compared to a condition where no such gesture was provided. The bilingual children differed from their monolingual peers in the gesture but *not* in the no gesture condition: bilinguals chose the correct target referent more often when it was accompanied by a gesture than the monolingual children. These results thus suggest that bilingual children make greater use of gestural cues than their monolingual peers. But why did the bilingual children pay greater attention to the experimenter’s gestural cues than the monolinguals? One possible explanation could be that, unlike monolinguals, children growing up in dual language environments regularly experience communication challenges when a speaker is mixing languages and have to constantly monitor which language a speaker is using in order to respond accordingly (Comeau et al., 2003; Tomasello, 2003; Yow et al., 2011). Researchers (Yow et al., 2011) argue that this greater vigilance in bilinguals leads them to develop heightened sensitivity to nonverbal cues, such as gesture, to more easily determine a speaker’s referent. However, it is still unknown how this sensitivity to gesture influences bilingual children’s emerging language abilities as compared to their monolingual peers as they continue to acquire more domain-specific vocabulary items.

The effect of seeing gesture in learning among bilinguals focused primarily on pointing gestures, leaving other gesture types as well as different types of gesture-speech combinations unexplored. However, we know from previous work with monolingual children that comprehension of different gesture types and gesture-speech combinations go hand in hand with children’s actual production of these gestures and gesture-speech combinations (Behne et al., 2012; Dimitrova et al., 2017; Özçalışkan et al., 2011; Woodward et al., 2002). At the early ages (ages 1-3), bilingual children produce similar amounts and types of gestures as monolinguals, using mostly deictic and conventional gestures, followed by iconic gestures; they also use gesture to primarily complement (e.g., 'cat' +point at cat) or supplement (e.g., 'mine' + point at cat) what they convey in speech, also showing similarities to monolingual children (Limia, Özçalışkan & Hoff, in prep; Nicoladis, Mayberry, & Genesee, 1999). This raises the possibility that comprehension of different types of gestures and gesture-speech combinations might emerge around the same time as their production in bilingual children as well. In addition, given the scarcity of gesture comprehension studies with bilinguals, it is not surprising that there is no evidence –even correlational – examining whether young bilingual children show the same advantage as monolinguals in learning spatial concepts when the instruction is accompanied by gestures. The lack of existing research thus marks a significant gap in our understanding of the role of nonverbal cues in bilingual children's spatial language development.

1.5 The causal link for gesture and language learning in bilingual children

The question about the causal role gesture might play on the language learning of bilingual children remains largely unanswered. There are only two experimental studies that examined the effect of observing gesture on learning. The first study by Church, Ayman-Nolley and Mahootian (2004) compared the performance of 6-year-old Spanish-speaking children with very low proficiency in English to that of English monolinguals, after providing both groups with instruction in English on a Piagetian conservation task. Half of the children in each group saw an instructional video with iconic gesture and the other half saw the same video without gesture. The results indicated that gesture helped boost learning in both groups, with better performance in the gesture condition compared to the no gesture condition. The authors concluded that gesture could be used to improve learning in bilingual children—in ways similar to monolingual children— particularly in domains where bilingual children face academic challenges in mainstream classrooms due to their limited English proficiency. Another study by Rowe, Silverman & Mullan (2013) examined the effect of learning with gestures *vs*. pictures in learning novel words with 4;8-year-old bilinguals with either high or low L2 proficiency. The bilinguals were exposed to English as their first language, along with an L2 other than English (i.e., Spanish, French, German, Mandarin, Romanian, Portuguese, Hindi) at home. The children were taught novel pseudo words (e.g., mip) and their English equivalents (e.g., mip is a book) presented with either an iconic gesture or a picture. Afterwards, the experimenter assessed comprehension by asking the children to select an object corresponding to the taught novel labels (e.g., 'Can you give Max his mip?'). The authors found that seeing gesture alongside novel words—but not pictures— was most beneficial for the bilingual children with low L2 proficiency, designating gesture as a powerful nonverbal supplementary tool for teaching new words to bilingual children who have limited proficiency in L2.

Overall, the few extant studies provide promising evidence that gesture can boost learning among bilingual children. However, we do not yet know whether instruction with gesture facilitates bilingual children's production of spatial words— a domain vital to school success—and whether this facilitative effect is similar to or different from children learning only one language (i.e., monolinguals).

1.6 The Study

In this study, we aim to extend prior work further by experimentally manipulating gesture during instruction and observing its effects on 4- to 5-year-old English-Spanish bilingual and

English-speaking monolingual children's acquisition of spatial vocabulary words in English. The study focuses on one category of such spatial talk, namely 3D shape terms (e.g., cube, sphere), which form part of the core academic curricula in the United States (Common Core Standards, 2020). We have two specific aims:

(1) Our first aim is to determine whether observing gesture during instruction facilitates learning labels for 3D shapes for bilingual children as it does for monolingual children. Our prediction is that children—bilingual or monolingual–will benefit more from instruction with gesture than without gesture, based on earlier work (McGregor, 2005). We also expect that bilingual children will show greater gains from instruction than monolingual children, but only when the instruction is accompanied with gesture, based on earlier work that showed better performance in gesture comprehension among bilingual children compared to their monolingual peers (Yow et al., 2016).

(2) Our second aim is to determine whether the beneficial effect of instruction with gesture generalizes beyond the target 3D shape words to other spatial vocabulary words (e.g., words for spatial relations, features, dimensions) for bilingual children as compared to monolingual children. Our prediction is that the instruction with gesture will have a greater beneficial effect in generalizing beyond the target 3D shape words than instruction without gesture in both groups, based on research showing that gesture training increases children's general vocabulary production in parent-child interactions (LeBarton et al., 2011). We also expect that the beneficial effect of gesture will be greater for bilingual children than monolingual children, with bilinguals in the gesture instruction group showing significantly larger improvement in the amount and variety of spatial labels produced in English compared to monolinguals after training. This prediction is also based on evidence that bilinguals are more

sensitive to gesture than monolinguals (Yow et al., 2016) and on research showing that bilinguals learn new words in each of their languages as well as their monolingual peers when given equal input (Alt, Meyers, & Figueroa, 2013).

Overall, this study will establish whether observing gesture plays a causal role in learning new spatial words that are crucial to academic performance in bilingual and monolingual children. Importantly, these findings will help create better teaching strategies generalizable to different learners (bilinguals vs. monolinguals) in early school settings.

2 METHODS

2.1 Participants

The sample consisted of 60 children, including 30 monolingual (M_{AGE} = 4;4; *SD*=.0;4; 18 males) English learners and 30 bilingual (M_{AGE} = 4;6, *SD*=0;5; 16 males) English-Spanish learners. The inclusion criteria were that the child (1) completed both visits and (2) could understand and produce no more than 3 out of the 5 spatial words tested in the study.[1] The sample size was based on similar earlier work on gesture comprehension and word learning with bilinguals that showed an effect size of η^2 = .48 with a sample of 62, with six groups (Rowe, Silverman, & Mullan, 2013), along with a G*Power analysis for a mixed repeated-measures ANOVA (with four groups), which indicated that a minimum sample size of *n*=48 across groups will provide .80 power to detect reliable medium effects (η^2 = .25) at $\alpha = .05$. At entry into the study, monolingual and bilingual children were assigned to one of two conditions (gesture, no gesture),

[1] Data were collected from 7 additional children (3 bilinguals, 4 monolinguals), who did not meet criteria for inclusion: 2 children did not complete training and 5 children either understood or produced more than three of the 3D shape labels tested in the study, thus resulting in a final sample size of 30 per group.

with 30 children per condition (see Table 1).

Table 1. Sample characteristics by group and condition

	Monolingual M(*SD*)		**Bilingual M(*SD*)**	
	Gesture	No Gesture	Gesture	No Gesture
n	14	16	16	14
Gender	(7M, 8F)	(8M, 8F)	(8M, 8F)	(9M, 7F)
Age (Years; Months)	4;5 (*0;4*)	4;3 (*0;3*)	4;7 (0;*5*)	4;7 (*0;4*)
Vocabulary				
English	68.21 (*12.14*)	60.25 (*10.55*)	48.13 (*15.93*)	38.43 (*14.89*)
Spanish	N/A	N/A	30.19 (*12.13*)	31.14 (*15.73*)
Vocabulary (English +Spanish)	68.21 (*12.14*)	60.25 (*10.55*)	78.32 (*16.44*)	69.57 (*19.07*)

M=mean, *SD*=standard deviation, M=male, F=female

Monolingual children were exposed to only English at home (100%) and bilingual children were exposed to Spanish at home and English either at home (64%) or in school (36%). The vocabulary size of bilingual children across their two languages was greater than the vocabulary size of monolinguals in English ($t(58) = 2.70$, $p < .01$, $d = .66$) as assessed by the Expressive One Word Picture Vocabulary Test Bilingual Edition (EOWPVT) in English and Spanish separately for the bilinguals and the EOWPVT in English for the monolinguals (see Table 1; Brownell, 2000, 2001). This difference in vocabulary is deemed typical, as has been shown in prior studies (Hoff et al., 2012; Ramirez & Kuhl, 2016). On average, the bilinguals also knew more words in English ($M_{\text{EOPVT}} = 43.97$; $SD = 16.07$) than in Spanish ($M_{\text{EOPVT}} = 30.63$; $SD = 13.69$; $t(29) = 3.07$, $p < .01$, $d = .56$). There were however, no differences in children's vocabulary size in English in the two conditions (gesture vs. no gesture), either among monolinguals ($t(29) = 1.92$, $p = .07$, $d = .50$) or bilinguals ($t(29) = 1.83$, $p = .08$, $d = .65$). All of the children were enrolled in pre-kindergarten programs, with the majority (98% bilinguals, 93% monolinguals) enrolled in Head Start programs; and the two groups were comparable in family socio-economic-status (SES), assessed by family income. The majority of bilingual (57%) and monolingual (63%) parents reported a household income of less than $50,000 annually. However, parents of monolinguals were more educated than parents of bilinguals: 75% of monolingual compared to 30% of bilingual parents had at least a college degree. The majority of the parents in both the monolingual (23/30) and bilingual (28/30) groups were mothers; the remaining 9 parents were fathers.

2.2 Data collection

Children were visited twice in their homes or at their school, based on parents' preferences. The first visit began with a structured parent-child play with three different toys (i.e., Legos, Puzzle, Shapes) followed by two pre-tests, one measuring children's comprehension and the other measuring their production of target spatial vocabulary items. Next, each child completed a brief experimental training on five target 3D shape words. This was followed by two post-tests of the target words, and a second parent-child play with the same three toys. In the second visit, conducted on a separate day, children were administered a standardized vocabulary assessment in school. Further details on each task are provided below.

Parent-child interaction prior to training: First, children and their parents were video recorded for approximately 15 minutes (M =14.27; SD =2.66) with three different toys (i.e., puzzle, Legos, shape sorter) that elicited spatial language and served as the baseline for children's spatial vocabulary use before the training. The toys included the five target 3D shapes (i.e., cone, sphere, cube, cylinder, sphere, prism), along with others. However, we explicitly asked the parents not to label 5 target shapes to avoid its potential effects on children's learning. Bilingual children and their parents were instructed to use English as much as they could during the interaction, without mixing their two languages. Parent-child play prior to training was shorter for the monolinguals compared to the bilinguals ($M_{MONOLINGUALS}$ = 11.17 minutes; SD = 2.32 vs. $M_{BILINGUALS}$ = 14.23 minutes; SD = 2.66; $t(58) = 4.81$, $p < .01$, $d = 1.06$). Parents were asked to listen to a Tom and Jerry video with some headphones and complete a demographic questionnaire while facing a wall as their children received the training in order to avoid biasing parents towards using more spatial talk or gesture during parent-child play.

Pre-tests for spatial vocabulary: Each child was tested on his or her knowledge of five target 3D shapes (i.e., cylinder, sphere, prism, cube, and cone)—the same shapes that children are expected to name correctly at entry to kindergarten, according to the Geometry Common Core Standards Initiative (2018). The shapes also correspond to objects that young children commonly encounter in their everyday environments (i.e., soda can: cylinder, ball: sphere, box: cube, tent: prism, ice-cream: cone). The experimenter introduced the child to a penguin puppet (i.e, "This is Bill"), who the child was asked to help in learning about objects (i.e., "Bill does not know very many shapes. Can you help him learn about shapes?"). First, we assessed children's production of the target shape terms. To familiarize the child with the task demands, each child completed three familiarization trials, using familiar 2D shapes (i.e. circle, square, and triangle). During familiarization the child was presented with a 2D shape – one at a time – and asked to help the puppet label it (i.e., Can you tell Bill the name of this shape?). Children did not show difficulty in understanding the practice trials, with all children completing at least 2 of the 3 practice trials successfully.

Following the familiarization trials, we assessed children's *production* of labels for the five target shapes. The experimenter presented the child with the five target 3D shapes, one at a time and in randomized order, using the same instruction as in the warm-up trials. The child's first response in English was scored as correct or incorrect. No correct label was provided in case of mislabeling on part of the child. Children provided correct labels at an average of *M*= 0.13 (*SD* = .47).

Next we assessed children's *comprehension* of the target shape terms. We first practiced with three 2D shapes (i.e., circle, square, triangle) to familiarize the child with the comprehension task. All 2D shapes were placed on the table, and the child was asked to give the puppet the shape the experimenter labeled (i.e., "Can you give Bill the square?). Once the child handed the shape to the experimenter, the experimenter placed it back with the rest of the target shapes, so that each response involved choice among 3 objects. Children did not show difficulty in understanding the practice trials, with all children completing at least 2 of the 3 practice trials successfully. After the familiarization phase, the experimenter arranged all of the five target mini 3D shapes (i.e., cylinder, sphere, prism, cube, and cone) in front of the child and asked the child to give Bill the target shapes, one at a time, using the same instruction and procedure as in the familiarization trials. We randomized the order of placement for the shapes and the order with which they were requested by the experimenter. Only a child's first selection was recorded as correct or incorrect. No correction was provided in the case of an incorrect choice. Children identified objects correctly at a mean rate of *M* =1.43 (*SD* =1.20). Only children who understood or produced the label for no more than 3 target shapes correctly were allowed to continue with the study. [2]

Spatial vocabulary training: Following the pre-tests, each child participated in a 3D-shape word training with the experimenter on the five target shapes (i.e., cylinder, sphere, prism, cube, and cone). During the training, the experimenter introduced the task (i.e., "Today we will learn about different shapes") and placed each shape in front of the child, one at a time. Then the experimenter began by labeling the target shape three times (i.e., "Look at the cube. Do you see the cube? That is a cube."). Next, the experimenter labeled the target shape twice more by providing a key description and likening it to an everyday object (i.e., "A cube has six sides. A cube is like a box."). To ensure that the children were paying attention during instruction, the experimenter asked the child to say the name of the target shapes (i.e., "Can you say cube?") and then repeated the label once more (i.e., "That is a cube."). The experimenter repeated the script twice for each shape before proceeding to the next shape. Therefore, children heard 14 labels for each shape. The experimenter then concluded the session by placing all the target shapes in front of the child one more time and briefly reviewing the target shapes in the order they were taught (i.e., "Today we learned about cylinder, sphere, prism, cube, and cone."). The order of labeling for the 5 different shapes was counterbalanced across participants. The training was provided in one of two ways: with gesture *vs*. with no gesture. Children in the **no gesture condition** (15 monolinguals, 15 bilinguals) were only given a spoken label for each target shape, as described above. Children in the **gesture condition** (15 monolinguals, 15 bilinguals) were provided with gestures (i.e., pointing to the shape) that accompanied *the* spoken labels for each target shape.

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[2] It is important to note here that 14 of the 60 children (8 monolinguals, 6 bilinguals) understood 3 of the labels correctly; the majority understood 2 (*n* = 13/60), 1 (*n* = 14/60) or none (*n* = 18/60) of the object labels. Only 1 of the 60 children produced 3 of the labels correctly; the remaining children produced either 1 (*n* = 5/60) or none (*n* = 54/60) of the labels correctly.

The training was only provided in English, as we were primarily interested in effect of gesturing on learning spatial words in an academic environment that relies on English.

Post-test for spatial vocabulary: The children were next administered a post-test with the puppet using the same five 3D target shapes. First, the experimenter assessed production of the labels. She presented the child first with the same three 2D shapes (i.e., circle, square, triangle) used in the familiarization trial, followed by the five target 3D shapes, presented one at a time, using the same instructions and order as in the production pre-test. Only the child's first verbal response in English was scored as correct or incorrect.

Second, the experimenter assessed each child's comprehension of the five 3D target shapes. The experimenter first presented the three 2D shapes (i.e. circle, square, triangle) used in the familiarization trial, followed by the five target 3D shapes, using the same instructions and order as in the comprehension pre-test. Only the child's first selection was recorded as correct or incorrect.

Parent-child interaction after training: The post-tests were followed by another 10-15 minute (M =12.73; SD = 2.91) parent-child play with the same three toys provided by the experimenter, using the same instruction as in parent-child play prior to training. The parent-child play after the training was also shorter for the monolingual compared to the bilingual group ($M_{\text{MONOLINGUALS}}$ = 11.40; SD = 2.45 vs. $M_{\text{BILINGUALS}}$ = 14.07 minutes; SD = 2.74; $t(58) = -3.97$, $p < .01$, d = .92).

Children's general vocabulary assessment: On a separate day, children's expressive language abilities were assessed in one or both of their languages, using the Expressive One Word Picture Vocabulary Test (i.e., EOWPVT; Brownell, 2000; 2001). The monolingual and the bilingual children completed the English and Spanish-English bilingual version, respectively.

The standard procedure for the Spanish-English bilingual version is to allow the child to provide a label in either language, but we modified this procedure to allow only English labels in the English assessment and only Spanish labels in the Spanish assessment in order to obtain independent assessments of child vocabulary in each language, following a procedure used in earlier work (Anthony, Solari, Williams, Schoger, & Zhang, 2009; Hoff et al. 2015). Language of testing was counterbalanced across participants for the bilingual group—with half of the bilinguals completing the test in English first and the other half in Spanish first.

2.3 Transcription, Coding, and Scoring

Child extended spatial vocabulary in parent-child interaction: Children's responses in all parent-child videos were transcribed for speech using the Codes for Human Analysis Transcript (CHAT), and segmented into utterances. An utterance was defined as a string of words (typically a sentence) separated by a pause. Sounds that were articulated words found in the dictionary, referring to entities, properties, or events (e.g. 'doll'), along with onomatopoeic (e.g. 'meow') and evaluative (e.g. 'woops') sounds were transcribed and counted as words, following earlier work (Özçalışkan & Goldin-Meadow, 2009). We also counted incomplete sounds that were close approximations of words as words (e.g., 'anana' for 'banana').

We further coded the speech produced by the children for spatial language, using a coding system originally developed by Cannon, Levine and Huttenlocher (2007). The categories of spatial language included *size* (e.g., big, little), *shape* (e.g. triangle, square), *location and direction* (e.g., in, below), *orientation and transformation* (e.g. turn, flip), *quantity* (e.g, half, a lot), *feature* (e.g, curvy, flat), and *order patterns* (e.g., next, first). We then lumped across categories of spatial language use, computing token and type frequency of each child's spatial vocabulary in English. For example, if the child produced the words 'circle' and 'square' twice each, we counted the child's use as consisting of two types and four tokens. We only computed bilinguals' spatial vocabulary in English, because the goal of this project was to examine the efficacy of an instructional strategy on improving children's spatial vocabulary in the language of schooling (i.e., English), which is also the language that has been shown to predict children's academic achievement (Halle, Hair, Wandner, McNamara, & Chien, 2012). We excluded all non-spatial uses of spatial words, i.e., homonyms (e.g., "I left my hat"), metaphors (e.g., You have a big heart"; "I am full"), proper names (e.g., "Big Bird"), and non-spatial uses of verb particles and prepositions (e.g., "Turn off the light", "Play with me") from our analysis.

Spatial vocabulary for target 3D shapes: The number of labels each child correctly produced (range=0-5) and comprehended (range=0-5) was computed, separately for the pre-test (prior to training) and post-test (after training).

Child vocabulary: Children's expressive vocabularies, assessed by the Expressive One Word Picture Vocabulary Test, were computed for raw vocabulary in English and Spanish. We used raw scores to make the monolingual and bilingual children comparable in each condition following earlier work (Hoff et al., 2012; Pearson et al., 1993). Using raw vocabulary scores allowed us to sum up the bilinguals' scores across both languages and to obtain a total vocabulary score that can be directly compared to the monolingual group's raw scores in one language.

Reliability: Four coders, blind to the hypotheses of the study, first transcribed and then coded for spatial talk a randomly selected 15% of the parent-child interaction data, separately for the monolinguals and bilinguals. Reliability scores, using Cohen's Kappa were: κ= .93 for segmentation into utterances, κ=.85 for word tokens, and κ=.92 for number of spatial words.

Reliability for scoring of the pre- and post-test responses on production and comprehension of target spatial words was assessed by two coders using video recorded observations. One coder scored all of the pre- and post-test responses, and a second coder scored a randomly selected 15% the responses, with perfect reliability scores for both comprehension (κ=1.0) and production (κ=1.0).

2.4 Data Analysis

To determine whether observing gesture during instruction facilitates learning labels for 3D shapes for bilingual children as it does for monolingual children, we tabulated the number of correct responses children provided, separately for pre- and post-test (score range=0-5). We then compared the number of correct responses children provided at pre- and post-test—separately for comprehension and production—using mixed three-way ANOVAs, with training condition (no *gesture, gesture*) and group (*monolingual, bilingual*) as between and testing period (*pre-test, post-test*) as within subject factors.

To determine whether training with gesture promotes spatial talk beyond the 5 target 3D shapes, we tallied the token and type diversity of spatial words (collapsed across spatial coding categories) each child produced. To account for the group differences in the length of the observation sessions and for the variability in the speech production (see Tables 1A an 2A in appendix), we converted all raw frequencies into rates per minute for spatial word types and tokens produced, dividing the number of spatial word types or tokens by the total parent-child interaction time, separately for before and after the training. We examined potential changes in rate of child spatial token and type use during the parent-child interactions, using a mixed ANOVA, with condition (*no gesture, gesture*) and group (*monolingual, bilingual)* as between- and testing period (*pre-training, post-training*) as within-subject factors.

3 RESULT

3.1 Immediate effect of observing gesture on learning spatial words

We first examined whether seeing gesture helped facilitate monolingual and bilingual children's comprehension and production of 3D spatial words. Beginning with **comprehension**, we found no effect of training condition (F(1, 56) = 1.02, p = .32). However, we found an effect of group (F(1, 56) = 6.18, p = .02, η_p^2 = .10)—with monolinguals performing better than the bilinguals—and an effect of testing period, F(1, 56) = 10. 13, p < .01, η_p^2 = .15, with better performance in the post-test compared to the pre-test. None of the two-way (testing period x group, F(1, 56) = 1.17, p = .28, testing period x condition, F(1, 56) = .85, p = .36, group x condition, F(1, 56) = 1.20, p = .28), or three-way (testing period x group x condition, F(1, 56) = .66, p = .42) interactions were significant (see Figure 1). Children also showed some variability in their comprehension of the labels for the different 3D shapes—with best comprehension scores for the word 'cone' and the lowest comprehension scores for the word 'cylinder' (see Table 2 for children's comprehension scores for each 3D shape).

Turning next to children's **production**, we found an effect of training condition (F(1,56) = 6.44, p = .01, η_p^2 = .10), an effect of group (F(1,56) = 4.54, p = .04, η_p^2 = .08), and an effect of testing period (F(1,56) = 51.48, p < .01, η_p^2 = .48), which interacted with condition (F(1,56) = 4.18, p = .05, η_p^2 = .07), but not with group (F(1,56) = 56.00, p = .67). As can be seen in Figure 2, children—monolingual and bilingual—performed better in the gesture condition, but only in the post-test (Bonferonni, p = .01). Also, similar to comprehension, monolingual children produced a greater number of correct labels than bilinguals. None of the other two-way (testing period x group, F(1, 56) = .18, p = .67; group x condition, F(1, 56) = .49, p = .49) or three-way (group x condition x testing period, $F(1, 56) = .15$, $p = .70$) interactions were significant. Similar to comprehension, children showed some variability in their production of the labels for the different 3D shapes: the label for 'cone' was produced at the highest rate, while the label for 'sphere' was used at the lowest rate (see Table 3 for children's production scores for each 3D shape).

In summary, children benefited from instruction with gesture in their production—but *not* comprehension—of labels for 3D shapes, and monolinguals showed a slight advantage in both understanding and producing the labels compared to bilinguals.

3.2 Extended effect of observing gesture on learning spatial words

We examined whether the facilitative effect of instruction with gesture extends beyond the immediate word learning context, resulting in greater token and type diversity of English spatial word production in parent-child interactions in monolingual and bilingual language acquisition contexts.

First looking at *spatial word tokens*, we found no effect of condition ($F(1,56) = .81$, $p = .37$) or testing period ($F(1,56) = 2.41$, $p = .23$), but an effect of group ($F(1,56) = 23.50$, $p = < .01$, $\eta_p^2 = .30$)—with monolingual children producing a greater rate of spatial word tokens than their bilingual peers. Moreover, there was a significant interaction between group and testing period ($F(1,56) = 6.46$, $p = .01$, $\eta_p^2 = .10$), with greater rate of spatial word production at post training parent-child play but only among monolinguals (Bonferroni $p = .01$). There was no two-way interactions between group and condition ($F(1,56) = .23$, $p = .64$) or testing period and condition ($F(1,56) = .40$, $p = .53$) , and no three-way interaction between testing period group and condition ($F(1,56) = .17$, $p = .68$; see Figure 3).

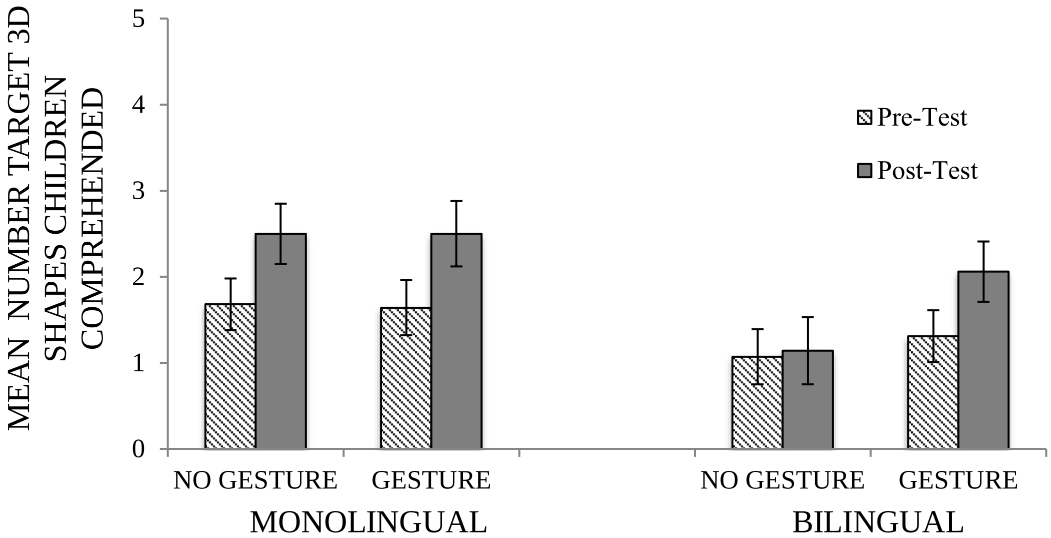

Figure 1. Mean number of target 3D shape words (i.e., cube, cone, prism, sphere, cylinder) monolingual and bilingual children comprehended correctly at pre-test (striped bars) and post-test (gray bars); error bars represent standard errors.

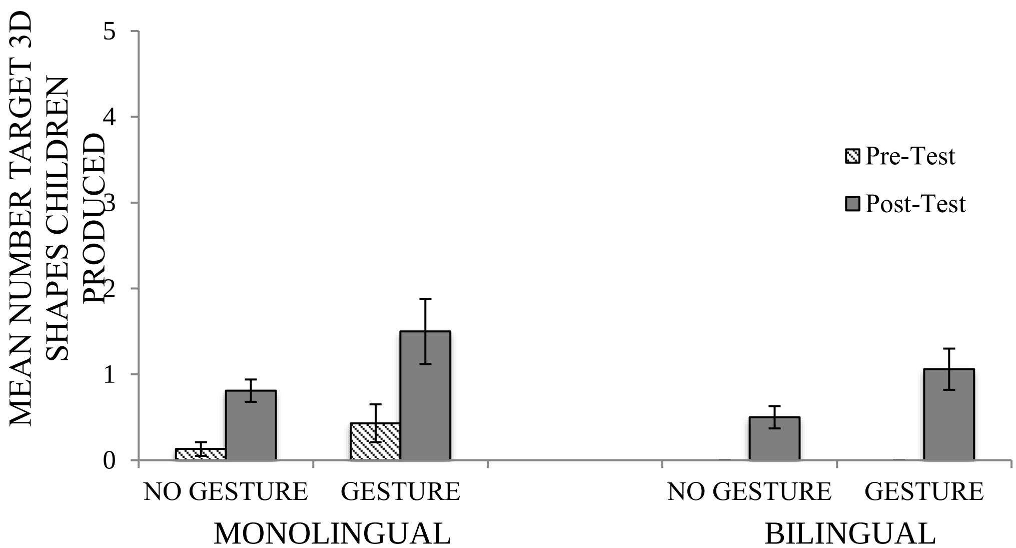

Figure 2. Mean number of target 3D shape words (i.e., cube, cone, prism, sphere, cylinder) bilingual and monolingual children produced correctly at pre-test (striped bars) and post-test (gray bars); error bars represent standard errors

The patterns were identical for the diversity of spatial word use. Children's production of spatial word *types* showed no effect of condition ($F(1,56) = 1.66$, $p = .20$) or testing period

(*F*(1,56) = 1.45, p = .23), but an effect an effect of group (*F*(1,56) = 24.20, $p < .01$, $\eta_p^2 = .30$)—with monolingual children producing a greater rate of spatial word types than their bilingual peers. There was also a significant interaction between group and testing period

Table 2. Children's mean comprehension of each 3D shape term

	Monolingual M(*SD*) (*n* = 30)				**Bilingual M(*SD*) (*n* = 30)**			
	No Gesture		Gesture		No Gesture		Gesture	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Cube	.31 (.48) *n* = 5	.56 (.51) *n* = 9	.29 (.47) *n* = 4	.36 (.50) *n* = 5	.36 (.50) *n* = 5	.36 (.50) *n* = 5	.31 (.48) *n* = 5	.31 (.48) *n* = 5
Cone	.63 (.50) *n* = 10	.88 (.34) *n* = 14	.43 (.51) *n* = 6	.86 (.36) *n* = 12	.36 (.50) *n* = 5	.36 (.50) *n* = 5	.44 (.51) *n* = 7	.69 (.48) *n* = 11
Cylinder	.31 (.48) *n* = 5	.31 (.48) *n* = 5	.43 (.51) *n* = 6	.36 (.50) *n* = 5	.14 (.36) *n* = 2	.07 (.27) *n* = 1	.38 (.50) *n* = 6	.25 (.45) *n* = 4
Prism	.13 (.34) *n* = 2	.38 (.50) *n* = 6	.29 (.47) *n* = 4	.36 (.50) *n* = 5	.00 (.00) *n* = 0	.21 (.43) *n* = 3	.00 (.00) *n* = 0	.38 (.50) *n* = 6
Sphere	.31 (.48) *n* = 5	.38 (.50) *n* = 6	.21 (.43) *n* = 3	.57 (.51) *n* = 8	.14 (.36) *n* = 2	.14 (.36) *n* = 2	.19 (.40) *n* = 3	.31 (.48) *n* = 5

M=mean, *SD*=standard deviation, +G=gesture, -G=no gesture

Table 3. Children's mean production of each 3D shape term

	Monolingual (n = 30)				Bilingual (n = 30)			
	No Gesture		Gesture		No Gesture		Gesture	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Cube	.00 (.00) *n* = 0	.13 (.34) *n* = 2	.07 (.27) *n* = 1	.29 (.43) *n* = 4	.00 (.00) *n* = 0	.00 (.00) *n* = 0	.00 (.00) *n* = 0	.13 (.34) *n* = 2
Cone	.06 (.25) *n* = 1	.56 (.51) *n* = 9	.29 (.47) *n* = 4	.64 (.50) *n* = 9	.00 (.00) *n* = 0	.21 (.43) *n* = 3	.00 (.00) *n* = 0	.56 (.51) *n* = 9
Cylinder	.00 (.00) *n* = 0	.06 (.25) *n* = 1	.0 (.00) *n* = 0	.29 (.47) *n* = 4	.00 (.00) *n* = 0	.07 (.27) *n* = 1	.00 (.00) *n* = 0	.13 (.34) *n* = 2
Prism	.06 (.25) *n* = 1	,13 (.34) *n* = 2	.07 (.27) *n* = 1	.21 (.43) *n* = 3	.00 (.00) *n* = 0	.07 (.27) *n* = 1	.00 (.00) *n* = 0	.13 (.34) *n* = 2
Sphere	.00 (.00) *n* = 0	.00 (.00) *n* = 0	.0 (.00) *n* = 0	.07 (.27) *n* = 1	.00 (.00) *n* = 0	.07 (.27) *n* = 1	.00 (.00) *n* = 0	.13 (.34) *n* = 2

M=mean, *SD*=standard deviation, +G=gesture, -G=no gesture

($F(1,56) = 6.08$, $p = .02$, $\eta_p^2 = .10$), with monolingual—but *not* bilingual—children producing a greater variety of spatial word types at post training (Bonferroni $p = .01$). None of the other two-way (group x condition ($F(1,56) = .58$, $p = .45$; testing period x condition ($F(1,56) = 1.19$, $p = .28$) or three-way (testing period x group x condition ($F(1,56) = .008$, $p = .93$) interactions were

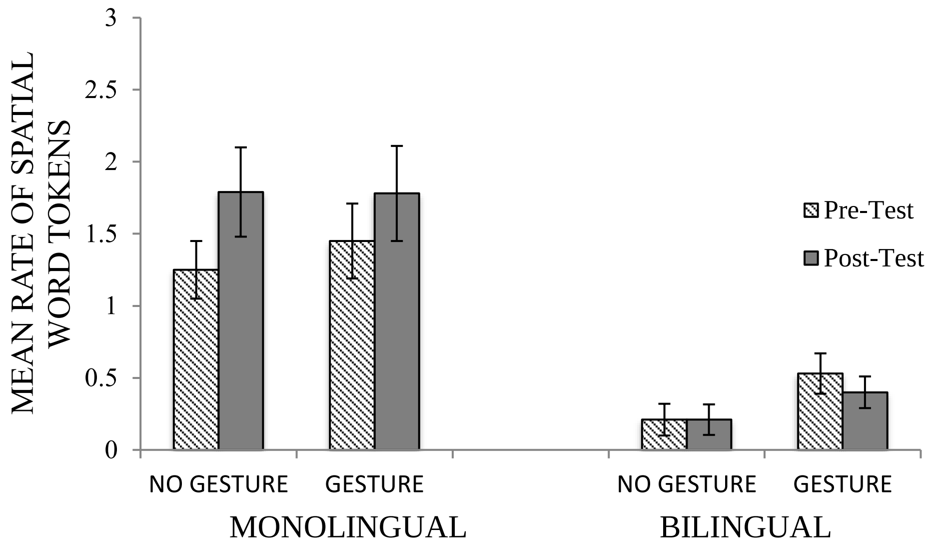

Figure 3. *Mean number of spatial word tokens monolingual and bilingual children produced in English per minute of parent-child play; error bars represent standard errors.*

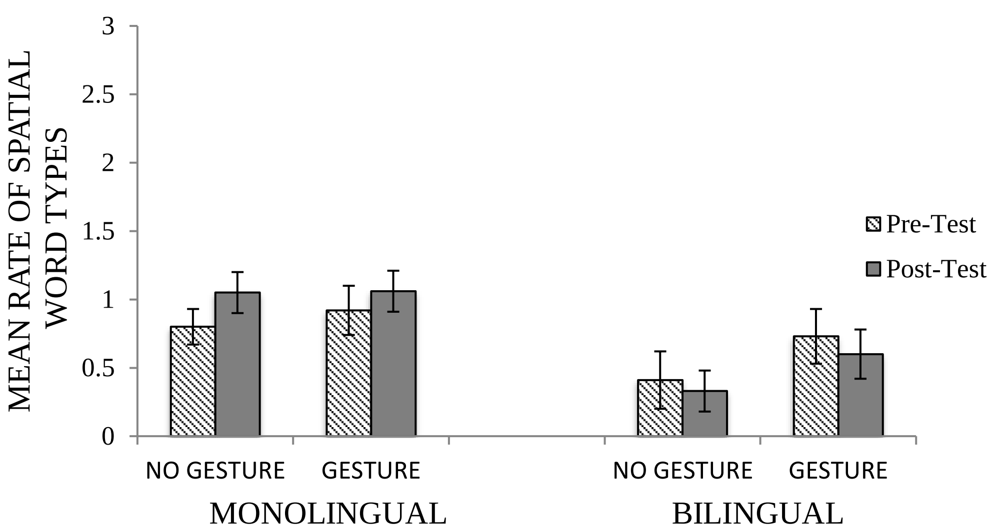

Figure 4. *Mean number of spatial word types monolingual and bilingual children produced in English per minute of parent-child play; error bars represent standard errors.*

significant (see Figure 4; also see Table 3A in the Appendix for children's spatial word production by category). [3]

In sum, instruction with gesture facilitated monolingual and bilingual children's production of spatial terms for 3D shapes—an effect that did not extend to more extended contexts of speech production.

4 DISCUSSION

In this study, we asked whether 4-to 5-year-old bilingual children were as likely as their monolingual peers to benefit from instruction with gesture in learning spatial words for 3D shapes and whether this beneficial effect would generalize beyond the target words and the immediate learning context to other spatial words in other contexts. Our results showed that instruction with gesture had a facilitative effect on the production, but *not* the comprehension, of target spatial words. The beneficial effect of gesture on producing target labels in the immediate word-learning context, also, did not generalize to production of other spatial words in more extended contexts (i.e., parent-child play). The effect of instruction—with or without gesture—however showed positive gains for monolingual children in the more extended contexts, with monolingual but not bilingual children showing greater token and type diversity of spatial word production in parent-child play following instruction. Overall, our results suggest that instruction with gesture facilitates both bilingual and monolingual children's production of new spatial words in the immediate word learning context, but the positive effect of gesture training does not

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[3] The patterns observed for bilinguals' spatial token and type production in English remain unchanged if their spatial word production in both languages were included in the analysis with no effect of training for either spatial word tokens ($F(1,56) = .15$, $p = .70$) or spatial word types ($F(1,56) = .51$, $p = .48$).

extend to other spatial words in more extended contexts for either monolingual or bilingual children.

Our study— the first of its kind— showed that gesture plays a causal role in learning to produce spatial words. Both the bilingual and the monolingual children showed greater gains in their production of novel 3D shape words when instructed with gesture than without gesture. What could explain this difference in performance with just one training session? One possible explanation comes from neuroimaging studies involving associative learning: researchers examining the activation patterns in the language-centers of the brain show that Broca's area is activated not only when hearing speech but also when observing gesture—a link that is taken as evidence for multi-modal integrated networks (Fadiga, Craighero, & Roy, 2006; Glenberg, 2008; see McNeill, 2005). That is, seeing gesture alongside speech may enhance word learning because it integrates motor information with sensory information resulting in greater neural connections in the Broca's area (Macedonia & Knosche, 2011). Another likely possibility is that observing gesture impacts learning through its effects on children's cognition. Goldin-Meadow (2000) suggests that gesture leads to better learning by reducing the cognitive load associated with processing a spoken message. In our case, the experimenter gestured in synchrony with the word, therefore, linking the word to a visible shape in the immediate context. The experimenter's pointing gesture to the shape thus may have made the meaning of the word more obvious and cognitively easier by freeing up the cognitive resources necessary for the child to process the word. Another explanation could be that gesture helped learning by enhancing the child's attention to the label and its associated referent, thereby, promoting fast mapping. For example, Booth, McGregor and Rohlfing (2008), found that experimenter pointing during instruction increases attention and subsequent word learning in 2-year-old children. Similarly, gesture might have been especially useful in increasing the attention of the 4- to 5-year-old children in our study, who typically have lower attentional span compared to older children (Mahone, 2005).

At the same time, the beneficial effect of instruction with gesture was relatively modest, with a mean increase of $M = .83$ ($SD = .91$) words. One reason for the modest effect could be the length of our training. We repeated each word 15 times, but only in one training session, thus providing relatively minimal practice opportunities for the children. Even though we know that learning can occur quickly when words are first encountered (Horst, McMurray, & Samuelson, 2006), increased word learning might require repeated exposure over several training sessions, allowing better retention of labels in memory (Mather & Plunkett, 2010). However, our finding showing that gesture can effectively improve word production in just one training session raises the possibility that it could serve as a powerful tool in teaching spatial concepts to children in the classroom where more extended training is typically the norm (Bruner, 2001).

If gesture boosts novel word label production, why didn't it also facilitate *comprehension* of the target shape labels? One likely explanation could be that the children in our study were at the cusp of producing, but *not* comprehending, the spoken labels for the target shapes. Gesture has been shown to be particularly helpful in learning concepts that the children are at the threshold of learning (Goldin-Meadow et al., 2003; Singer et al., 2005). Majority of the children in our study (70%) were already able to comprehend the labels for up to three of the five target shape names, but only a few (10%) could correctly label any of the same five shapes prior to instruction. This suggests that the children in our study were on the cusp of learning spoken labels for the target shapes, and accordingly were more susceptible to the beneficial effects of gesture for production of the labels for these shapes.

Another possible reason could be that the difference was an outcome of the type of instruction provided to the children. During training, the experimenter was modeling production but not comprehension of 3D shape labels. As such, it is possible that the beneficial effects of labeling with gesture did not generalize to comprehension because no such modeling was given. Future studies that include training in comprehension of labels (e.g., asking children to point to the correct shape labeled by the experimenter), along with production, might shed further light on the possibility of training type having a differential effect on the production vs. comprehension of spatial labels.

We also found that monolinguals—irrespective of training condition or testing period —showed better comprehension and production of the target shape terms than bilinguals. This finding is not surprising given that bilinguals lag behind monolinguals in language development (Hoff et al., 2012) —a lag that is typically associated with the amount of English language exposure that they receive in their homes (Hoff et al., 2012). Our original prediction was that the bilinguals would benefit more from instruction with gesture based on their greater sensitivity to pragmatic cues, including gesture, as shown in earlier experimental work (Brojde et al., 2012; Diesendruck, 2005; Yow et al., 2016). However, our study showed no group differences in the production of spatial labels after training. At the same time, we found that prior to training, bilinguals knew slightly fewer 3D shape labels than their monolinguals peers in English, but they nonetheless made similar gains as monolinguals after training with gesture—suggesting that instruction with gesture might have more pronounced positive effects on spatial word learning for bilinguals. This, in turn, raises the possibility that more extended instruction with gesture targeted to bilinguals could have the potential to reduce spatial vocabulary disparities bilingual children face in English in school settings.

Children also showed some variability in their comprehension and production of the 6 target 3D shapes. For example, across both groups, the children were least likely to comprehend the label for cylinder and more likely to learn cone; and in production they were more likely to say cone and least likely to say sphere. The length of the words might account for this variability: words with greater number of syllabi pose greater difficulties, as in the case of cylinder vs. cone (3 vs. 1 syllable). In addition, some of the shapes were more familiar to the children as they resembled the types of commonly experienced objects: cone as hat or ice cream cone vs. prism as tent, which was not quite as common. Future work that systematically examine familiarity of the objects resembling the shapes of the 3D geometric forms, along with the lexical complexity of the word form labeling these shapes, is needed to further understand the relative contribution of these factors to the learning process.

Even though we found an effect of instruction with gesture in the immediate word learning context, this effect did not extend to spatial word use in other discourse settings—a result that differs from earlier work that showed such extended effects. What might underlie the difference in our findings? One possible explanation could be the extent of training with gesture. For example, a study that *did* find extended effects of gesture (LeBarton et al., 2015) provided their participants with training sessions once a week for six weeks. As such, spacing learning over several sessions might have been key in promoting children's ability to generalize their emerging knowledge of words to other interactive contexts in this study (see Vlach , Sandhoffer, & Kornell 2008; Vlach, Sandhofer, & Bjork, 2014) by cueing children to the importance of word-object pairs in their environment (see also Csibra & Gergely, 2009; Csibra, 2010). Accordingly, increasing the number of instruction with gesture sessions in our study might have provided children with the critical amount of exposure, needed to make the leap from the immediate word learning to more extended use of spatial words in other interactive contexts.

Alternatively, it could be that simply *observing* gesture was not enough to promote spatial word use in extended contexts. There is evidence suggesting that children who mimicked an instructor's gestures were more likely to transfer their newfound knowledge to new content that was not explicitly taught during instruction than children who did *not* mimic but only passively watched the instructor gesture when solving Piagetian type cognitive tasks (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007; Cook & Goldin-Meadow, 2006). Furthermore, increasing children's gestures during the training could have an impact on word retrieval, thus helping them access greater number of spatial words. Evidence from monolinguals and bilinguals suggests that gesture facilitates speech production by helping children retrieve words from memory (Nicoladis, 2002; Pine, Bird, Kirk, 2007). For example, Nicoladis (2002) found that the more bilingual children gestured, the longer their sentences were in parent-child interactions. Another study with monolinguals (Pine et al., 2007), provided evidence that children increased their word production when allowed to gesture and, conversely, decreased their word production when they were not allowed to gesture. As such, future work that examines not only observing but also producing gesture during instruction might shed new light on the potential extended effects of training with gesture on spatial language production in other interactive contexts.

Earlier experimental work that examined effect of gesture on vocabulary development in monolingual children was longitudinal (LeBarton et al., 2015), while our study involved a single training session sandwiched between two sessions of parent-child play before and after instruction with gesture—a difference that might have contributed to some of the variation in the patterns of findings for extended effects of gesture training. We know from this earlier work that children who were told to mimic the experimenters' gesture during training used notably more gestures and words in later extended discourse contexts with their caregivers than children who were not told to gesture. The increase in child gesturing might have, in turn, given parents greater opportunities to translate their children's gestures into words. For example, a parent's translation, "That is a bear", when observing their child point to a BEAR might have resulted in greater number of referents initially gestured by the child, subsequently entering children's vocabularies as words. Earlier longitudinal studies examining child vocabulary development using spontaneous parent-child interactions, in fact, provided robust evidence for this possibility. These studies show that greater number of gesture referents entered children's spoken vocabularies as words when translated into words by parents across different learners, including monolinguals (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007), bilinguals (Limia, Özçalışkan, & Hoff, 2019) and even children with neurodevelopmental disorders who show difficulties in gesture production (Dimitrova et al., 2016). Given these findings, future studies that examine the effect of instruction with gesture in spatial vocabulary development with a longitudinal parent-child interaction component might provide additional evidence for added benefits of observing gesture for spatial vocabulary production in extended discourse contexts.

Different from bilinguals, monolingual children – regardless of condition – increased their spatial language production, using greater number and diversity of spatial words in extended discourse contexts. But why did the bilinguals *not* show similar improvements in spatial word use as the monolinguals in more extended contexts? One possible explanation could be that monolingual children's greater stride in spatial language use post instruction was simply an outcome of parallel increases in their overall word production. A close look at children's overall production of speech—both for types and token— reveals this might be the case. There was an increase in overall word production during parent-child play before and after instruction for monolinguals (M_{BEFORE}=1.91, *SD* = 1.29 vs. M_{AFTER}= 2.23, *SD* = 1.89, $t(29) = - 1.93$, p = .06), but not for bilinguals (M_{BEFORE}= 1.03, *SD*= .97 vs. M_{AFTER}= 1.18, *SD* = .72, $t(29) = - 1.59$, p = .12), suggesting that increase in spatial word use in monolinguals could be an outcome of overall increase in speech production.

An alternative explanation could be that bilinguals might need more extended training to show similar effects as monolinguals. Although bilingualism does not affect immediate retrieval of new words (Kaushanskaya & Marian, 2009), research shows that bilinguals' limited experience in each language may affect their long-term retention of concepts in a single language compared to monolinguals (Kan & Sadagopan, 2014). Given that the bilinguals have less experience with English, they might also be more likely to forget what they have learned after the experimenter instruction—with or without gesture—deterring generalization to other spatial words in extended discourse contexts.

In sum, our study provides the first evidence for the causal role gesture plays in spatial vocabulary development of bilingual children—mirroring a pattern akin to monolingual children. These findings have important implications for bilinguals who are academically at risk for failure as they enter school with lower English skills than their monolingual peers (Garcia & Jensen, 2009; see also Hoff et al., 2012). Our study identifies gesture as a powerful tool for teaching spatial words to bilingual children in an immediate vocabulary instruction context; it also raises the possibility of the need for more intensive instruction with gesture to achieve vocabulary gains beyond the immediate learning context to more extended discourse settings.

4.1 Limitations and Future Directions

It is important to mention that the bilingual children in our study were all more dominant in English than in Spanish. As such, we do not know how effective instruction in English would be to Spanish-dominant bilinguals—a potential venue for future research. We also provided instruction in only one language, leaving an important question to pursue in future studies about added benefit of instruction in both languages. Along a similar vein, we do not know whether our findings with a high gesture language, i.e., Spanish, are generalizable to other bilingual speakers of different language pairs – particularly bilinguals who speak a low gesture language such as Chinese (Smithson, Nicoladis, & Marentette, 2011). Furthermore, most of our bilingual participants came from low-income families, placing a limitation to the generalizability of the results to bilinguals coming from high-income families. However, having bilinguals from low-income households is not demographically atypical of Latino families served by most educational agencies (Hernandez, Denton, & MacCartney, 2008). At the same time, future studies that examine effect of instruction with or without gesture in more high-income families can deepen our understanding of the role gesture on spatial language development across different SES groups.

4.2 Implications

The number of children who speak two languages is large and growing (Pew Research, 2013). It is estimated that by 2030, 40% of school children will be bilingual in the U.S. (Hoff, 2009). Often these are Hispanic children who speak English and Spanish, a group that constitutes 17% of the nation's population, designating them as the fastest growing population in America. Alarmingly enough, Hispanics are statistically at risk for academic failure since they enter school with lower English skills than their monolingual peers and the language of mainstream instruction in the U.S. is English (Garcia & Jensen, 2009). Despite these statistics, very little research has been done to identify new instructional strategies that facilitate learning in bilingual children exposed to two languages. As a result, the effect of seeing gesture during instruction on bilingual children's spatial vocabulary— a significant predictor of academic success (Wai et al., 2009) — was not well understood. However, this study was the first to provide evidence for the positive effect of gesture on instruction in bilinguals: observing adult gesture during spatial word learning facilitated production of spatial words among bilingual children.

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APPENDIX

Table 1A. Summary of Children's Overall Language Production

	Monolingual M(*SD*) (*n* = 30)				**Bilingual M(*SD*) (*n* = 30)**			
	No Gesture		Gesture		No Gesture		Gesture	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Word Tokens	228.94 (117.30)	288.06 (196.59)	225.64 (139.64)	255.50 (188.10)	167.00 (106.59)	192.29 (125.28)	194.75 (141.30)	240.19 (127.23)
Word Types	94.13 (35.45)	103.56 (50.24)	94.93 (48.16)	100.71 (54.62)	62.64 (22.79)	71.43 (23.84)	80.25 (41.57)	84.75 (44.28)

Table 2A. Summary of Children's Spatial Word Rate Production

	Monolingual (*n* = 30)				**Bilingual (*n* = 30)**			
	No Gesture		Gesture		No Gesture		Gesture	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Spatial Tokens								
Dimensions	.17 (.18)	.28 (.24)	.21 (.29)	.17 (.20)	.02 (.06)	.03 (.09)	.10 (.17)	.05 (.08)
Shapes	.53 (.42)	.84 (.78)	.58 (.61)	.84 (.69)	.33 (.60)	.21 (.40)	.35 (.35)	.32 (.47)
Locations	.23 (.29)	.32 (.34)	.31 (.27)	.42 (.38)	.05 (.12)	.07 (.18)	.13 (.18)	.11 (.17)
Orientations	.05 (.14)	.02 (.05)	.01 (.05)	.00 (.02)	.01 (.03)	.00 (.00)	.00 (.02)	.00 (.00)
Continuous Amounts	.19 (.25)	.29 (.37)	.17 (.15)	.27 (.27)	.00 (.00)	.00 (.00)	.12 (.24)	.06 (.11)
Features	.02 (.05)	.01 (.03)	.09 (.22)	.06 (.11)	.00 (.00)	.00 (.00)	.01 (.02)	.05 (.10)
Pattern	.05 (.11)	.03 (.10)	.07 (.12)	.01 (.03)	.00 (.02)	.02 (.06)	.01 (.04)	.00 (.02)
Spatial Types								
Dimensions	.10 (.10)	.15 (.12)	.11 (.12)	.11 (.11)	.02 (.06)	.03 (.07)	.07 (.10)	.03 (.05)
Shapes	.34 (.24)	.51 (.50)	.34 (.34)	.46 (.28)	.16 (.25)	.14 (.31)	.25 (.24)	.19 (.24)
Locations	.16 (.20)	.19 (.14)	.21 (.16)	.28 (.23)	.03 (.09)	.03 (.09)	.13 (.18)	.08 (.11)
Orientations	.02 (.05)	.02 (.04)	.01 (.03)	.00 (.02)	.01 (.03)	.00 (.00)	.00 (.02)	.00 (.00)
Continuous Amounts	.13 (.14)	.16 (.12)	.14 (.14)	.16 (.12)	.00 (.00)	.00 (.00)	.07 (.12)	.06 (.12)
Features	.02 (.04)	.01 (.03)	.05 (.10)	.04 (.09)	.00 (.00)	.00 (.00)	.01 (.02)	.04 (.07)
Pattern	.03 (.06)	.01 (.03)	.05 (.09)	.01 (.03)	.00 (.02)	.01 (.02)	.01 (.02)	.00 (.01)