Early Number Knowledge In Dual-Language Learners From Low-SES Households

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Abstract

A large and growing proportion of American students are dual-language learners, and many live in or near poverty. In order to serve these students, educators must understand their needs. In this chapter we discuss the role of bilingualism in acquiring early number knowledge. Then we briefly review what is known about the ways in which young children represent number, including the approximate number system (ANS) and symbolic representations of exact numbers—both spoken and written. Next, we describe our own large study of early numeracy in preschool-age dual-language-learners (DLLs) from low-socioeconomic-status (SES) households, with comparison groups of high- and low-SES English monolingual preschoolers, as well as dual-language learners from high-SES households. The main conclusions we draw from this study are the following. (1) Educational delays in acquiring basic number skills are attributable to poverty, not to being a dual-language learner. (2) Pre-kindergarten programs such as Head Start seem to provide experience with counting and numbers that is crucial for low-SES children. (3) Given limited resources, it is reasonable to assess the early numeracy of low-income dual-language learners by testing only in their language of instruction, rather than in both of their languages. Testing only in the language of instruction is much less costly and yields very similar information. (4) The SES-related gap in math achievement is much more a gap in symbolic number knowledge (spoken and written numbers) than in ANS acuity. Thus, improving children's symbolic number knowledge should be the focus of interventions seeking to narrow this gap.

Keywords: bilingual, cardinality, children, counting, dual-language learners, education, Head Start, Hispanic, Latino, mathematics, number, preschool

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INTRODUCTION

As of 2015, one in every four American children is Hispanic, and approximately two-thirds of Hispanic children live in or near poverty (defined as less than two times the federal poverty level, Gennetian, Rodrigues, Hill, & Morris, 2015). In fact, Hispanic children now constitute the largest population of U.S. children living in poverty (Lopez & Velasco, 2011; Stepler & Brown, 2015). These children face serious educational challenges. Currently, Hispanic students lag at least a half a standard deviation behind their white and Asian-American peers in mathematics at the beginning of kindergarten and throughout K-12 schooling, with no narrowing of the gap in sight (Garcia & Jensen, 2009; Wiley, 2009). Given that students' educational performance during the early years of school is strongly correlated with their later achievement (e.g., Duncan et al., 2007), improved early education for Hispanic children from low-SES backgrounds may be critical to their long-term educational success.

The situation is complicated by the fact that many Hispanic children are dual-language learners (DLLs), meaning that they are exposed to and learning through two distinct languages before age five. As of 2013, 63% of Hispanic children were DLLs (childstats.gov, 2015). The numbers of these children in Head Start and Early Head Start have also increased dramatically in recent years. As of 2015, children whose home language was Spanish accounted for 48% of all Head Start and Early Head Start participants in California, and about 25% of children in those programs nationwide (CA Head Start Assoc., 2017; U.S. DHHS, 2017).

As educators and policymakers consider the needs of these children, one important area to think about is early mathematics and specifically early numeracy-- the understanding of counting and whole numbers that children acquire during the preschool years. A gap in number knowledge between young children from high- and low-SES households, independent of ethnic background, is already measurable by age three, and it only widens as children get older (Jordan & Levine, 2009a; National Research Council, 2009). Children from low-SES households come to kindergarten with significantly less knowledge of counting, numbers, and number operations than middle-SES children, and are four times more likely to show flat growth in these areas throughout kindergarten and early first grade (Jordan, Kaplan, Locuniak, & Ramineni, 2007; Jordan, Kaplan, Nabors Oláh, & Locuniak, 2006; see also Aunola, Leskinen, Lerkkanen, & Nurmi, 2004). Other foundational math tasks on which higher-SES children outperform their low-SES peers include reciting the counting list, counting objects, knowing the meanings of small numbers, understanding the cardinal principle (also called the cardinality principle), identifying written numerals, adding and subtracting small numbers, comparing numerical magnitudes, and estimating the positions of numbers on a number line (Griffin, Case, & Siegler, 1994; Jordan, Huttenlocher, & Levine, 1992, 1994, Jordan et al., 2007, 2006; Jordan & Levine, 2009b; Kirk, Hunt, & Volkmar, 1975; Ramani & Siegler, 2008; Starkey, Klein, & Wakeley, 2004)

DOES BILINGUALISM MATTER FOR EARLY NUMERACY?

Plenty of research has shown that growing up in a low-SES household is bad for early math learning, but much less is known about the effect of being a dual-language learner. Broadly speaking, early number development does interact with language development. Spoken and written numbers are linguistic symbols, and the number knowledge of 2-4-year-old monolingual English speakers is highly correlated with their expressive and receptive vocabulary, even when controlling for age and other variables (Negen & Sarnecka, 2012). It also seems that the grammar of a child's native language seems has some influence on how long it takes the child to learn the meanings of the first few number words: Children learning English or Russian—languages that make a grammatical distinction between singular and plural referents (e.g., my *child is* waiting in the car /my *children are* waiting in the car) learn the meaning of 'one' slightly earlier than children who speak Japanese or Mandarin—languages that rarely mark plurality (Le Corre, Li, Huang, Jia,

& Carey, 2016; Sarnecka, Kamenskaya, Yamana, Ogura, & Yudovina, 2007). Similarly, children learning Saudi Arabic or Slovenian—languages that grammatically distinguish between sets of one, two, and more than two—appear to learn the word for 'two' slightly earlier than children learning other kinds of languages (Almoammer et al., 2013).

The practical question for Spanish/English dual-language learners who are learning pre-K math is not about language-specific effects (Spanish and English do not differ much in the ways that might matter for early numeracy), but rather about the possible effects of learning two languages, period. For example if a child's home language is different from the language of instruction in his or her preschool classroom, how does this mismatch affect early math instruction? Does it hinder the child's early development of numeracy?

There is some evidence that bilingualism might confer cognitive benefits on children. Under controlled conditions, bilingual children may perform better than monolinguals on tasks involving inhibition, attentional control and perspective-taking (Bialystok, 2001, 2009; Hilchey & Klein, 2011; Fan, Liberman, Keysar, & Kinzler, 2015). However, these effects are disputed (e.g., Goldman, Negen, & Sarnecka, 2014; Morton & Harper, 2007; Paap & Greenberg, 2013) and assuming they do exist, the effects are too small to make much of a difference in educational or life outcomes. They are mainly interesting because of the insight they offer into how development in the domains of executive functioning and social cognition is shaped by experience. For our purposes, the relevant question about bilingualism (or more precisely, about being a dual-language learner) is whether it causes children to have a different profile of strengths and needs when it comes to pre-kindergarten math.

Not many studies have focused specifically on preschool math development in dual-language learners, but the available data suggest that numeracy development in this population of children is slow relative to national norms. For example, Xue and colleagues (Xue, Atkins-Burnett, and Moiduddin, 2012) used the Applied Problems test from the Woodcock Johnson III Tests of Academic Achievement (WJ III

ACH) to assess 675 Spanish-English bilingual preschoolers from Los Angeles Universal Preschool (LAUP) as part of the Universal Preschool Child Outcomes Study (UPCOS). They found that the DLLs scored below the national average for their age. Similarly, Iglesias (2012) studied 132 Spanish-English DLLs attending Head Start programs in Florida, and found that their performance on the Applied Problems and Quantitative Concepts subtests of the Woodcock Johnson III and its equivalent in Spanish ranged from average to low average when compared to national normative samples of monolingual peers.

Somewhat more encouraging findings came from a mathematics teaching intervention study with somewhat older children, which was conducted by Fuson and colleagues (Fuson, Smith, & Lo Cicero, 1997) in two predominantly Latino, low-SES, urban first-grade classrooms. One classroom was English-speaking; the other was Spanish-speaking. The intervention sought to support first graders' thinking of 2-digit quantities as tens and ones, and it was successful. By the end of the year, children in both classrooms accurately added and subtracted 2-digit numbers, and used units of tens and ones on various tasks. This performance was substantially above the norms reported in other studies for U.S. first graders of higher SES and for older U.S. children, suggesting that well-designed interventions in either English or Spanish may be able narrow or close the early math achievement gap, at least during the time that the interventions are being provided.

Taking this rather sparse literature as a starting point, we (the authors) wanted to examine the early numeracy development of DLL children from low-SES households in greater detail. Our specific questions were shaped by research on early number-development during the last several decades; in the next section we briefly review evidence about how young children represent numbers, including their representations of approximate number, spoken numbers, and written numbers.

WAYS FOR YOUNG CHILDREN TO REPRESENT NUMBERS

The Innate, Approximate Number System

Broadly speaking, mental representations of number are either approximate or exact. Approximate number representations are the outputs of a built-in perceptual system that humans share with other animals (Dehaene, 2011; Feigenson, Dehaene, & Spelke, 2004; Gallistel, 1989). In recent years, people have taken to calling this the ‘approximate number system’ or ANS for short. (It has also been variously called the *analog-magnitude number system*, *nonverbal counting system* and simply *number sense*.) This system represents approximate numbers without using language. For example, humans and other animals can easily see the difference between 40 and 80 objects without having to count them. But we cannot see the difference between 40 and 41 objects, because the ANS is not accurate enough to perceive such fine distinctions. The system’s ability to tell the difference between two magnitudes is based on the ratio of one magnitude to the other. In other words, the difficulty of distinguishing between 40 and 80 items is the same as distinguishing between 20 and 40, or between 400 and 800, or any other pair where the ratio is 1:2.

Human infants and children have this approximate number system, but it is not as accurate as in adults. On average, six-month-old infants can discriminate ratios of 1:2 or easier, whereas most nine-month-olds can discriminate the more difficult ratio of 2:3 (Brannon, Abbott, & Lutz, 2004; Lipton & Spelke, 2003, 2004; Xu, 2003; Xu & Arriaga, 2007; Xu & Spelke, 2000; Xu, Spelke, & Goddard, 2005). Accuracy improves as children get older. For example, Halberda and Feigenson (2008) reported that on average, three-year-olds could discriminate sets with ratios of 2:3 or easier; four-year-olds could handle ratios of 3:4; five-year-olds succeeded with ratios of 4:5; for six-year-olds the threshold was 6:7; and for adults it was 9:10.

But these are only averages. In practice, estimation accuracy varies from person to person. Some studies have suggested an association between an individual’s ANS acuity and his or her math achievement (Halberda, Mazzocco, & Feigenson, 2008; Mazzocco, Feigenson, & Halberda, 2011b). This relation, however, is not a strong one and can probably be explained by a small subset of children who have both very poor ANS acuity and a math learning disability (Chen & Li, 2014; Fazio, Bailey, Thompson, & Siegler, 2014; Mazzocco, Feigenson, & Halberda, 2011a; Rousselle & Noël, 2007; van Marle, Chu, Li, & Geary, 2014).

Don't Trust the Standard Way of Measuring ANS Acuity in Preschoolers

When we try to measure young children's ANS acuity, we run into a problem: Children who don't understand how counting represents number (specifically, children who have not learned the cardinal principle of counting), often do not understand what experimenters are asking them to do. The standard way of measuring ANS acuity is to show participants two clouds of dots of varying sizes, and to ask which cloud has more. (For example, children might see a bunch of blue dots and yellow dots and be asked, "Are there more blue dots, or more yellow dots?")

The problem is that children who don't have a clear notion of cardinal number don't necessarily interpret the word 'more' to mean 'a greater number of'. How they interpret 'more' is unclear. They might think it means 'bigger dots,' in which case they might look for the biggest individual dot or try to decide which color dots are, in general, bigger. Or they might think it means 'more blue stuff,' in which case, they might choose the cloud covering a greater area. In any case, this spells trouble for researchers who want to use the task to measure children's ANS acuity. Assuming the stimuli are controlled for area and average or largest dot size, children will perform at chance. A number of studies have reported that children who know more number-word meanings seem to have better ANS acuity (e.g., Mussolin, Nys, Leybaert, & Content, 2012; Shusterman, Slusser, Halberda, & Odic, 2016; J. B. Wagner & Johnson, 2011; see also Abreu-Mendoza, Soto-Alba, & Arias-Trejo, 2013). However, when the data from these studies is closely examined, the pattern is usually one of chance performance by children who don't understand cardinality (see *Spoken Numbers,* below for a discussion of what this means) and above-chance performance by children who do understand cardinality. This is enough to create a significant positive association between knowledge of spoken numbers and ANS acuity even if the actual ANS acuity of children in the two groups does not differ. (For an in-depth exploration of this problem, see Negen & Sarnecka, 2014). The upshot for researchers is that measuring ANS acuity in young children is very tricky, and studies purporting to find links between young children's ANS acuity and any other measure should have their methods closely and skeptically examined.

Spoken Numbers

Although the ANS is the only innate system that humans have for representing magnitudes *per se*, cognitive scientists broadly agree that the ANS cannot be the source (or at least not the sole source) of exact-number concepts. This is because ANS representations are only approximate. If ANS representations are the only representations a person has, there is no way that person can distinguish between for example, 31 and 32 objects, because a ratio of 31:32 is too fine-grained for anyone to perceive. Such precise distinctions require *exact* numerical representations.

In order to represent numbers exactly, we need more than the ANS. We need some way of keeping track of individual things. We can do this on our own, using just our innate cognitive capacities, but only up to a point. Imagine a puppy playing on a grassy lawn. With a glance, you can say that there's only one puppy. If a second or even a third puppy is added, you still have no trouble saying exactly how many there are. But when a fourth puppy is added, it starts to get a little more challenging. Is that four puppies, or five? At six or seven puppies, it's hopeless. Now the only way to tell exactly how many there are is to catch and count them-- that is, to use the resources of spoken language.

When we think of children's math learning, we typically think of the exact, symbolic number system. Unlike the innate ANS, the exact-number system is a cultural invention and must be acquired anew by each generation. Children must learn the counting list (*one, two, three, four, five*, etc.), rules about how to count correctly (e.g., always say number words in the right order; count each object once and only once), and the cardinality principle (also called the cardinal principle), which says that the final word of a count tells you the number of items in the set that was counted (Gelman & Gallistel, 1978; Schaeffer, Eggleston & Scott, 1974).

Recognizing the central importance of counting and spoken numbers for early math, the California guidelines for preschool mathematics includes a strand called *Number Sense,*[1] which states that by 48 months of age, children should be able to recite the number-word list up to ‘ten’, to match the words ‘one,’ ‘two,’ and ‘three’ with the appropriate set sizes, count up to five objects without making a mistake, and answer the question *how many* with the last number word of a count (California Dept of Education, 2008)

But acquiring number sense is a lengthy process. In order to meet the guidelines at age 48 months, children must begin learning about numbers and counting much earlier than that—and in high-SES households, at least, they do. One study showed that high-SES children in Australia and Japan begin to recognize the counting list of their language and expect it to be paired with a correct counting procedure sometime between 15 and 18 months of age (Slaughter, Itakura, Kutsuki, & Siegal, 2011).

Many studies of early number development (albeit mostly with high-SES children) have shown the following pattern of development. First, children learn to recite the number list and to recite it in situations where the focus is on quantity. For example, one of us (BWS) had a child who, at 18 months old, discovered a tall stack of compact discs. He looked back and forth from his mother to the stack, pointing to it repeatedly and saying, “onetwothree, onetwothree, onetwothree!” He seemed to be expressing something like, “Hey! This is a lot of CD’s, isn’t it?”

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[1] Note that the term ‘number sense’ is used differently by different authors. As mentioned earlier, cognitive neuroscientists (e.g., Dehaene, 2011) have used it to refer to the innate, approximate number system. But in the education world, ‘number sense’ refers to the child’s understanding of the counting system and exact, whole-number concepts expressed as spoken and written numerals (e.g., Dyson, Jordan, & Glutting, 2013; Jordan, Glutting, & Ramineni, 2010; Jordan, Kaplan, Nabors Oláh, & Locuniak, 2006; Locuniak & Jordan, 2008).

Similarly, that child's brother at age 24 months, turned off the tap after filling the bathtub and said, "We needed *enoughs* of water. We needed *onetwothreefourfivesixseveneightnineTEN* of water." These anecdotes illustrate that even toddlers can learn the counting list and connect it somehow to quantification. But children this young don't typically know exactly what set sizes the words 'one' or 'two' or any other number words actually stand for (e.g., Baroody & Price, 1983; Briars & Siegler, 1984; Frye, Braisby, Lowe, Maroudas, & Nicholls, 1989; Fuson, 1988; S. H. Wagner & Walters, 1982; Wynn, 1990, 1992).

As children begin to learn the meanings of the number words, they learn the first three or four words one at a time, and in order (Sarnecka & Lee, 2009; Wynn, 1992). Many studies have demonstrated this pattern of learning, using a task that has many names: *Give-N, Give-a-number, Give-me-X,* the *Verbal Production Task,* and probably others. We generally use the shortest name: Give-N.

In the Give-N task, the experimenter asks the child to produce a set of some number of objects. We use a stuffed animal (e.g., Peter the Anteater, the UC-Irvine mascot) and a bowl of 15 identical small toys (e.g., green plastic trucks). We ask the child to 'Give *one* truck to Peter,' 'Give *two* trucks to Peter,' 'Give *five* trucks to Peter,' and so on. When the child gives something to Peter (by placing it on Peter's plate and sliding the plate over to him), we give them a chance to check or change their answer by asking, e.g., "Is that five?" when we asked for five. We also record whether children spontaneously use counting to produce the set. After five or six requests, we bring out a new animal and a new bowl of toys, and repeat the process all over again, asking for the same numbers in a different order. We do the whole thing three times.

In thinking about this task, researchers have sometimes worried that children might perform badly on it even if they understand the logic of counting, because it might not occur to the children to use counting in order to produce the sets (Gelman, 1993). In order to avoid this problem, researchers sometimes use additional follow-up questions, telling children to count and check their answers. For example, when a child was asked to 'Give FIVE trucks to Peter' but actually put eight trucks on the plate, the experimenter might say, "Can you count and make sure it's five?" or "Hmm. I don't think that's five. Can you count and fix it so it's five?" (Le Corre, Van de Walle, Brannon, & Carey, 2006). These extra prompts make little difference to children's performance, which looks quite similar to when children are asked only a single follow-up question (e.g., "Is that five?"). However, the extra prompts do generate some amusing video data, because many children who don't understand the cardinal principle (and thus don't know how to use counting to produce a set of five) *do* have a vague notion that the last word of a count should correspond to the number of items in the set. So faced with a set of say, eight objects, they do things like count the set properly but change the last word to five ("one, two, three, four, five, six, seven, five") or just keep saying five until they get to the end of the set ("one, two, three, four, five, five, five, five").

Studies using the Give-N task have revealed a predictable pattern of development, such that any given child's performance can be described in terms of his or her *number-knower level* (e.g., Condry & Spelke, 2008; Le Corre & Carey, 2007; Le Corre et al., 2006; Lee & Sarnecka, 2010, 2011; Negen & Sarnecka, 2012; Sarnecka & Gelman, 2004; Sarnecka & Lee, 2009; Slusser, Ditta, & Sarnecka, 2013; Slusser & Sarnecka, 2011; Wynn, 1990, 1992). These number-knower levels are found across language environments, not only in children speaking English or Spanish (or both), but also in child speakers of Arabic, Japanese, Mandarin Chinese, Russian, Slovenian, and even Tsimane', the language of a farming and foraging people by the same name who live in rural Bolivia (Almoammer et al., 2013; Barner, Libenson, Cheung, & Takasaki, 2009; Li, Le Corre, Shui, Jia, & Carey, 2003; Piantadosi, Jara-Ettinger, & Gibson, 2014; Sarnecka et al., 2007).

Here's how a child's number-knower level is diagnosed using the Give-N task. At the earliest or 'pre-number-knower' level, the child makes no distinctions among the meanings of different number words. On the Give-N task, pre-number knowers might give one object for every request, or always give a handful, but the number given is unrelated to the number requested. At the next, or 'one-knower' level, the child gives exactly one object when asked for ‘one,’ and gives two or more objects when asked for any other number. After this comes the ‘two-knower’ level. Two-knowers give one for ‘one,’ and two objects for ‘two,’ but do not reliably produce any larger exact sets. The two-knower level is followed by a ‘three-knower’ and a ‘four-knower’ level, although not all studies find four-knowers. It may be that some children make the leap from ‘three-knower’ directly to the next level—the level where they use the cardinal principle to determine the meanings of number words higher than ‘four.’

Note that the cardinal principle is not just a simple rule saying, ‘the last number of a count tells you how many are in the set.’ A rule like that is easy enough to teach kids, and it leads to the kind of amusing ‘fixes’ in the Give-N task that we described earlier. The cardinal principle is actually much more profound—it is the understanding (certainly implicit, because no parent talks about it this way) that the cardinal meanings of number words like *five* and *eight* depend on their place in the counting list. The fifth word in a counting list means 5; the eighth word means 8. And so, the way to produce a set of objects that matches a particular number word is to count out one object for each word in the number list, starting at one and stopping when you get to the number requested.

There are many reasons to think that a child’s number-knower-level tells us something important about his or her conceptual understanding of numbers. For example, one-knowers understand that each number word means something different from all the others, and that the number words have something to do with quantity (Sarnecka & Gelman, 2004). One-knowers also seem to understand that numbers apply to discontinuous quantities such as crayons), but not to continuous quantities such as water (Slusser et al., 2013). Two-knowers from high-SES households in fact do often answer the question ‘how many’ by repeating the last word of a count, but don’t seem to know that the last word tells the number of items in the set (Sarnecka & Carey, 2008). Understanding seems to dawn gradually. For example, three- and four-knowers seem to understand that number words appearing later in the count list denote larger quantities, although they don’t quite know how to map exact quantities to specific number words (Sarnecka & Carey, 2008).

An important step forward seems to come when children figure out how the cardinal principle connects each number in the list to an exact set size. Children who understand the cardinal principle identify *number* (as opposed to some other property of sets such as total summed area or contour length) as the dimension of experience that number words describe (Slusser & Sarnecka, 2011). Similarly, only cardinal-principle-knowers seem to understand that each ‘next word’ in the list corresponds to the addition of one more item to the named set (Sarnecka & Carey, 2008). And there is a near-perfect correlation between understanding the cardinal principle (as tested by the Give-N task) and understanding that the members of two sets of the same number (e.g., five peaches and five apples) can be matched up in one-to-one correspondence with each other (Sarnecka & Wright, 2013). One way we think of it is that when children understand the cardinality principle, they understand what exact numbers are.

Cardinality understanding is a prerequisite for the kindergarten and first-grade number learning that predicts math achievement in later years (Geary & vanMarle, 2016; Jordan et al., 2007, 2006; Jordan, Kaplan, Ramineni, & Locuniak, 2009; Merkley & Ansari, 2016). So a central concern of the present study was to investigate what dual-language learners from low-SES households know about these key aspects of the spoken-language number system: Counting, number meanings (i.e., their number-knower levels) and the cardinality principle.

Written Numbers

The other number representations that may be relevant to early education are written numerals (Geary & vanMarle, 2016; Merkley & Ansari, 2016; Purpura & Lonigan, 2015; Raghubar & Barnes, 2017). Children must learn to recognize and later to write the numerals 0-9, and in the early elementary grades children will learn how to represent place value in multi-digit numerals. But at the preschool level, most of researchers' attention has been focused either on children recognizing single-digit numbers, or on children's understanding of how number lines represent the counting list.

OUR STUDY

The study we describe in this chapter examined the early number knowledge of Spanish-English dual-language-learners from very low-SES households who were attending Head Start programs in Orange County, California. For each aspect of early number development that we measured, we were interested in two comparisons. The first was a within-child comparison of performance in Spanish and English. We wanted to know whether children's performance depended on the language of testing, and for that reason we tested all linguistic/symbolic measures twice: Once in Spanish and once in English. We also wanted to know how children's performance was related to the language of math instruction in their Head Start program, which was English.

The second comparison of interest was between different populations of children in Orange County. We wanted to know how the low-SES DLL children's number knowledge compared to that of three other groups of Orange County preschoolers: English monolingual Head Start students; English monolingual students at tuition-based preschools, and dual-language learners (with a variety of home languages, of which Chinese was the most common) at tuition-based preschools. This was not a controlled comparison in the experimental sense, because these groups of children differed in many ways. Our reasoning was simply that these are actual groups of children who live in Orange County and will enter Orange County schools together, and so this is the range of early numeracy development that educators and policymakers need to understand.

WHAT WE MEASURED AND WHAT WE FOUND

All of our assessments were administered by research assistants who were native bilingual speakers of English and Spanish, almost all of whom grew up in the same communities as the participants and their families, and still lived in those communities during the time of data collection. Following best practices for the assessment of bilingual students (Espinosa, 2014), we conducted all of our language-dependent assessments (that is, assessments of vocabulary and of spoken and written number knowledge) twice (once in English and again in Spanish) in an order that was counterbalanced across participants. Demographic data were collected in whichever language the respondent preferred, and the approximate number system assessment was done in the child's preferred language or in a combination of languages—whatever worked best to facilitate communication.

Family Demographics

When they signed their child up for the study, parents were asked to complete a demographic questionnaire that asked about the child's racial and ethnic background, household SES, the language(s) spoken in the home, and education levels of the child's caregivers. Most of the children in the low-SES DLL (95%) group were Hispanic/Latino, and spoke Spanish in addition to English. Most of the high-SES DLLs were Asian, and Chinese was their most common other language. High-SES DLL families also used more English at home: Only 33% of low-SES DLL families reported speaking mostly English at home, whereas 55% of high-SES DLL families did.

The differences in household income and education between the four groups were stark. For low-SES DLLs, over one third of families reported an annual household income of less than $10,000. The rest reported incomes from $10,000 to $30,000. Among the low-SES English monolingual families, the most common answer was $20-30,000. So the low-SES DLL households actually had a lot less money than the Low-SES monolingual households. In contrast, 100% of the parents in both high-SES groups-- monolingual and DLL—ticked the box for the highest income category on the questionnaire, which was 'over $75,000.'

Differences in caregiver education were even more dramatic, with 43% of caregivers for low-SES DLLs having less than a high school diploma. In the English monolingual low-SES group the most common level of education was ‘High School Diploma or G.E.D,’ and over a quarter of caregivers in this group had some college education. So caregivers in the low-SES DLL households had less education than those in the low-SES monolingual households. Among caregivers of children attending the tuition-based preschools, all but one had a college education and most (65% of DLLs; 75% of English monolinguals) had graduate degrees. Thus our participants illustrate the wide differences in education and income that divide families in Southern California, and increasingly—as income inequality grows and higher education continues to become less affordable—in other parts of the United States as well (Duncan & Murname, 2014; Reich, 2015).

Receptive Vocabulary

The first thing we assessed was children’s receptive vocabulary (i.e., the words they understood) in both English and Spanish. We did this using standardized measures—the PPVT for English (Dunn & Dunn, 2007; see Fig. 1) and the TVIP for Spanish (Dunn, Lugo, Padilla, & Dunn, 1986; see Fig. 2). In these measures, children are presented with a set of four pictures and are told to, e.g., “Put your finger on *bicycle*,” or “Put your finger on *climbing*.” We included this vocabulary assessment not because we thought it was particularly diagnostic of numeracy development (although general receptive vocabulary and number knowledge are strongly correlated (Negen & Sarnecka, 2012), but as a general measure of which language the children were more familiar with.

Results of the vocabulary assessments for low-SES DLLs showed that as a group, they knew more Spanish than English. Although their vocabulary scores in both languages were lower than the national norms for their age, both the PPVT and the TVIP were normed on monolingual speakers of each language, so the norms are not necessarily appropriate for DLLs. Comparing low-SES DLLs to other groups of children showed two effects that surprised no one: High-SES children had much bigger vocabularies than low-SES children, and monolingual speakers had bigger vocabularies than DLLs of the same age.

ANS Acuity

The ANS is a system that children have available from infancy represent number information (at least approximately). Given the math achievement gap that we see between children from different backgrounds, and the interest among cognitive scientists in the question of how individuals' ANS acuity may relate to their math achievement, we wanted to measure the ANS acuity of the children in our study.

However, as discussed earlier in this chapter, the standard way of measuring ANS acuity does not ensure that child participants are actually trying to point to the dot cloud with the greater *number* of dots. Our solution was to modify the standard task (see Fig. 3). We did this by having the children complete a set of training trials in which the ratio of the dot clouds was a very easy 1:3. For example, children might see a card with 8 dots in the right-hand cloud and 24 dots in the left-hand cloud. These set sizes are so different that they should be very easy to tell apart, even for young children. So if children didn't get these trials right, we could be confident that they weren't answering on the basis of numerosity. As is standard for these tasks, we controlled the dot clouds in our stimuli for area, such that half of the trials were area-congruent, (meaning that the cloud with a greater number of dots also had more total dot-area) and the other half were area-incongruent (meaning that the cloud with the greater number of dots had less dot-area). During the training trials, we gave children feedback to help them understand what we wanted them to do. For example, when children incorrectly chose the dot cloud with fewer dots but greater area, we said, "Well these dots are *bigger*, but this side has *more* dots. They're *smaller*, but there's *more* of them." We continued with the training trials until the child either got eight trials in a row correct or quit playing. Children who did get eight training trials in a row correct moved on to the test trials.

The ratios tested were 1:2 (= .50), 7:12 (= .58), 2:3 (= .66), 17:24 (= .71), 3:4 (= .75), 4:5 (= .80), 5:6 (= .83), 7:8 (= .87), and 9:10 (= .90). For each trial, the child was shown a large card with two dot clouds, side by side. Each dot cloud contained between 20 and 100 black dots. To keep children motivated, experimenters gave them feedback after every trial. If the child correctly chose the side with more dots, the experimenter said, “That’s right—this side has more.” If the child chose incorrectly the experimenter said, “Uh oh, this side has more dots, you see?” Trials were presented too rapidly for children to count the dots, and no children were observed attempting to count.

Results of the ANS Task

The changes that we made to the ANS testing procedure ensured that for those children who did complete the task (that is, who reached criterion on the training trials and then went on to complete at least one block of test trials), we can be confident that what we measured really was their ANS acuity. However, these changes also meant that a lot of children simply could not complete the task. Over one-third of the children we tested never succeeded at eight training trials in a row, and so never moved on to the test trials. Another handful of children got through the training trials, but performed at chance on all the test blocks (even at easy ratios like 1:2), indicating that they still were not drawing on ANS representations to pick the more numerous dot cloud.

Most of the children who failed to get through the training trials were from the low-SES group. In fact, they were mostly children who did not yet understand the principle of cardinality. This replicated the results of an earlier study from our lab (Negen & Sarnecka, 2014), where we found that many children who have not yet grasped the cardinality principle simply don’t understand what experimenters want them to do on the ANS task. Understanding the cardinality principle seems to be connected with identifying *numerosity* as the perceptual domain that number words and counting are about. Perhaps another way to say that is that when children come to understand the cardinality principle, they begin to link counting with ANS representations.

In practical terms, this means that we (researchers using this method) can’t say much at all about the relation between preschoolers’ ANS acuity and their knowledge of symbolic numbers, because we can’t readily measure the ANS acuity of the children who don't know much about symbolic numbers. Knowledge of the spoken-number system (specifically, the cardinality principle of counting) seems often to be needed in order for children to understand the ANS measurement task.

Returning to our study results, if we look at the data from children who did get through the training trials and complete the ANS task, we find (not surprisingly) that older children performed better than younger ones. There was no evidence that dual-language learners performed better or worse than English monolingual learners. This finding is consistent with earlier studies from our lab, which found no effect of monolingual or DLL status on ANS performance (Goldman et al., 2014).

Among the children we were able to test, the present study also found that children from high-SES households performed better than those from low-SES households. Does that imply that the math achievement gap between children from high- and low-SES backgrounds arises because of differences in their ANS acuity? It is possible, but we think unlikely. The difference, while statistically significant, is not big enough to matter in practical terms. If we look at the mean coefficient of variance (a standard measure of ANS acuity; lower numbers are better) for the high- and low-SES children in our sample, we find that it was .42 for the high-SES group and .47 for the low-SES group. What does this mean in real life? Imagine a set of 50 items (e.g., a flock of 50 birds flying through the air). If asked to guess how many birds there are, a person whose ANS coefficient of variance is .42 (like the low-SES kids in our study) should estimate somewhere between 26 and 73 birds. A person whose coefficient of variance is .47 (like the high-SES kids in our study) should be slightly more accurate, estimating somewhere between 29 and 71 birds. We can measure that kind of difference in the laboratory, but it hardly seems to account for the big differences in math achievement between the groups. This is especially true when we consider the much bigger differences that showed up in children's knowledge of counting and spoken numbers.

Spoken Numbers

To measure children's knowledge of the spoken-language number system, we asked them to count to ten; to count rows of three and six objects (Fig. 4); and to complete the Give-N task described earlier (Fig 5). We gave these tasks in English to all participants, and also in Spanish to the children who spoke Spanish (these were mostly the low-income dual-language learners). On the first two counting tasks, children in all groups did pretty well, but the Give-N task was a different story.

First let's consider the counting tasks. When we asked children to count to ten, virtually all of the children in the high-SES groups performed at ceiling, as did the majority of children (⅔ of monolinguals and ¾ of dual-language learners) in the low-SES groups. Not surprisingly, older children counted better than younger children did, but neither monolinguals nor DLLs did better overall. We saw similar results when we asked children to count rows of objects. Almost all of the children in the high-SES groups performed at ceiling, and so did most of the children in the low-SES groups (89% of DLLs and 72% of monolinguals). So on these two counting tasks, although we saw an SES difference, it did not seem insurmountable.

On the Give-N task however, SES differences in performance were alarming. Recall that the Give-N task measures which number-word meanings (one through six) children know. It also measures whether children understand the cardinality principle, which is an important index of their conceptual understanding of counting and the spoken-number system. When we gave children this task, most children in the high-SES groups performed at ceiling, showing that they understood the cardinality principle. Less than half of the children in the low-SES groups did so.

To us, this difference in Give-N performance between high- and low-SES kids is the most important (and most worrying) finding of the study. Many studies in our lab and others have linked children's conceptual understanding of numbers and counting to their grasp of the cardinality principle (e.g., Carey, 2009; Condry & Spelke, 2008; Geary & vanMarle, 2016; Izard, Pica, Spelke, & Dehaene, 2008; Sarnecka & Carey, 2008; Sarnecka & Gelman, 2004; Sarnecka & Wright, 2013; Slusser & Sarnecka, 2011; Thomas &

Sarnecka, 2015). As we discussed in the context of the ANS task above, children who understand cardinality seem to know *what numbers are* in a way that they didn't before. They can interpret the phrase 'more dots' to mean *a greater number of dots* (Negen & Sarnecka, 2014). They know that two sets with the same number of items can be placed in one-to-one correspondence with each other (Sarnecka & Wright, 2013). Grasping the cardinality principle truly seems to be an important breakthrough in developing numeracy. So to find out that less than half of low-SES students understand cardinality in the year before they go to kindergarten was truly sobering. If children don't understand how counting represents number; if they don't understand what number words mean; what hope do they have of understanding the kindergarten math curriculum? When one sees the magnitude of the gap in conceptual understanding of numbers among preschoolers, the SES-related math achievement gap in grades K-12 seems almost inevitable.

Written Numbers

The third area that we wanted to measure was children's knowledge of written numbers. In a literate society like ours, children must learn to read written number symbols. We measured children's knowledge using three tasks: Written Numeral Identification; Scaffolded Number Line, and Classic Number Line.

Written numeral identification. In this task, children were asked to identify the written numerals one through ten. The materials used in this task were a foam card in the shape of a house and a set of small laminated cards showing the written numerals 0 to 10 (see Fig.6). The experimenter introduced the game by saying, "Here are some numbers. I'm going to look for zero. This is zero. (Experimenter shows the laminated card with the number zero on it to the child.) I'm going to put zero in its home, like this. (Experimenter places the number on the sticky square in the house and then puts it back in the pile.) Now it's your turn. Can you find the number one and put it in its home?" Once the child put a number on the square, the experimenter asked, "Is that one?" Children were asked for the numbers one through ten in numerical order and were given generalized positive feedback (e.g., “thank you!”) on every trial, regardless of their responses. Numeral identification was coded as correct or incorrect, based on children’s responses.

The results revealed, unsurprisingly, that older children knew more written numerals than younger ones. More worryingly however, children from higher-SES households knew many more written numerals than children from lower-SES households. A majority of the higher-SES children (including about three-quarters of high-SES dual-language learners and two-thirds of high-SES monolinguals) performed at ceiling, correctly identifying all the numerals 1-10. Among low-income children, few performed at ceiling. Among the low-SES dual-language learners, the most common score in both Spanish and English was 1, meaning that children correctly identified only one of the ten numerals. This is the score that we would expect to see if children were randomly guessing. It seems that knowledge of written numerals is an area of SES difference already in preschool.

Scaffolded number line. For this task, children were asked to place numbers on a number line. Unlike the classic number line task described below, though, this task was ‘scaffolded’ because the children couldn’t place the numbers just anywhere: There were a series of spaces and they had to choose which space to put the number in (Fig.7). The experimenter set up the task by placing a foam board number line with the numbers zero and ten already placed on it, with nine empty squares for the other numbers in between. The experimenter also put a set of laminated cards (the same ones used in the Numeral Identification task) with the numbers one through nine in a pile next to the number line. The experimenter introduced the game by saying, “This is a number line. It starts with zero and goes to ten. And, this is five. (Experimenter picks the laminated card with the number five out of the pile.) It goes right in the middle, like this.” (Experimenter places the five on the fifth square of the line.) Leaving the five where it was, the experimenter said, “Now it’s your turn. I’ll give you a number and you put it in its place on the number line. Okay, here’s the number seven. Can you show me where it goes?” Children were asked for the numbers one through nine (excluding five, which stayed on the line throughout as an additional scaffold) in a preset, randomized order. They were given generalized positive feedback (e.g., “thank you!”) on every trial, regardless of their responses. Children’s responses were coded as correct or incorrect, based on whether they placed each number in the correct location or at least in the correct region (above or below five) on the number line.

The results of this task were similar in many ways to those of the Written Numeral Identification task. Older children performed better than younger ones, and children from high-SES households performed better than those from low-SES households. This task seemed to be more difficult than the Written Numeral Identification task: Even in the high-SES groups, fewer than half of the children performed at ceiling. In the low-SES groups, very few children performed at ceiling and the most common score was again 1, the score we would expect if children had no idea at all where to put the numerals.

Interestingly, we noticed a strong relation between children’s performance on this task and their knower-level. It’s hard to say exactly what chance performance is on this task, but many children tried to place all their numbers in the middle of the board (perhaps trying to imitate the training trial, where the experimenter placed the number 5 in the middle). In practice, they had to choose between the 4th or the 6th spot, since the 5th spot was occupied by the number 5, which stayed on the board the whole time. A child who always put the number in the 4th spot would get a score of 20. On average, pre-knowers, 1-knowers, 2-knowers and 3-knowers (as measured by the Give-N task) scored worse than that mark. But the children who performed at ceiling (correctly placing all of the numbers on the line) were generally either 4-knowers or CP-knowers. This correlation suggests that in order for children to map numerals to a number line, they must first build a counting-list representation of number (which is what the Give-N task measures).

Classic number line. This task may be familiar to readers from other studies. Children were given a line with numbers at either end (zero on the left; ten on the right) and asked to point to the place on the line where another number should go (Fig. 8). For example, if the child was asked where five should go, the correct answer would be right in the middle of the line. Children were asked for the same numbers as in the scaffolded number-line task in a preset, randomized order.

As in the other written-number tasks, older children performed better than younger ones but more strikingly, high-SES children performed much better than low-SES children. In fact, the average performance for children in the low-SES groups was 1.944. The way this task is scored, a child who always put their mark in the center of the page would get a score of 2.0. In other words, there was no evidence that the children were doing anything other than guessing. There was no effect of being a dual-language learner vs. monolingual; what mattered was SES and to a lesser extent, age.

Comparing Low-SES DLLs' Performance in English and Spanish

Better English performance on counting tasks. The vast majority of low-SES dual-language learners performed at ceiling in English for both counting tasks, meaning that they counted out loud to ten, and also correctly counted six objects in a row. Many children also performed at ceiling in Spanish, but there were some who performed noticeably worse in Spanish than in English. For example, a significant minority of children counted to ten in English but only to six in Spanish. (Many of them recited the first six counting words in Spanish as a sort of nursery rhyme: *Uno, dos, tres; cuatro, cinco, seis*.) In general, when children counted higher in one language than the other, the language in which they counted higher was English—presumably because English was the language of instruction in their Head Start classrooms, and most of their experience with counting happened at Head Start.

Cross-language consistency in number-knower levels and numeral identification. On the Give-N task, children generally scored at the same knower-level in both their languages. That is, a three-knower tested in English was still a three-knower when tested in Spanish and vice versa. Children's performance in the Written Numeral Identification task also tended to be the same across languages, even if we exclude the group that appeared to be simply guessing. This suggests that these two tasks measure conceptual knowledge that transcends particular languages. That is, having mental symbols for sets of 1, 2, 3 and 4; understanding the principle of cardinality; and matching written numerals to particular number words. (For a related finding, see K. Wagner, Kimura, Cheung, & Barner, 2015.)

Floor effects in number-line tasks. It was hard for us to judge anything about the cross-linguistic consistency of performance on the Scaffolded Number Line or Classic Number Line tasks simply because most children performed so poorly on both of them. A child who always selected the 4th spot in the Scaffolded Number Line task would get a score of 20. A child who always pointed to the middle of the line in the Classic Number Line task would get a score of 2. Most children's scores hover around those marks on both tasks, in both languages, which suggests that our data contain strong floor effects. Among the small number of children who performed better, their performance was largely consistent across their two languages. There was no evidence that they performed better, as a group, in either English or Spanish.

Overall Conclusions of the Study

We drew four main conclusions from this study. (1) Being a dual-language learner does not adversely affect early number learning, but poverty certainly does. (2) Head Start provides crucial early math input to these students. (3) Future studies need not necessarily test young, low-SES DLLs in both of their languages in order to measure their number knowledge—testing only in the language of instruction may give equally valid results. (4) Interventions to improve low-SES students' math achievement should focus on symbolic number knowledge (spoken and written numbers), not the ANS.

Conclusion 1: Being a Dual-Language Learner Does Not Cause Educational Delays; Being Poor Does

Perhaps the most striking overall finding of our study was the huge gap between high- and low-SES children's knowledge of symbolic (i.e., spoken and written) numbers. This is not news. What we looked for but didn't find was a big difference between monolinguals and dual-language learners at similar SES levels. This was most clear in the high-SES groups, where dual-language learners and monolinguals performed equally well on most measures. Of course, in the real world one rarely finds groups that differ in only one way. For example, our high-SES dual-language learners were mostly the children of highly educated East Asian parents who had moved to the U.S. for graduate school or work—hardly a random sample of DLLs in the world, or even in the U.S. But the monolingual group had even more highly educated parents, and children in the two groups performed equally well.

These findings will be unsurprising to researchers, whose conversations about bilingualism and development are more often about the potential *benefits* of growing up bilingual. But discussions among policymakers are legitimately concerned with questions about how to serve students with limited English proficiency. To us, a take-home point from our study is the difference between preschool-age dual-language learners and older bilingual students who have completed some years of schooling in their first language. For older students, the challenge is to build on what they already know, and to help them continue learning while at the same time adjusting to English as the language of instruction. But for dual-language learners (who by definition are still young children), they just don't have much of a prior knowledge base to import. Particularly in the case of the low-SES children in our sample, they seem to have had very little exposure to numbers or counting in any language.

Conclusion 2: Low-SES Kids Don't Seem to Get the Experience With Counting and Numbers at Home That High-SES Kids Get; What They Know, They Learned at Head Start

When we designed this study, we were concerned that if we tested DLLs only in English, we might accidentally underestimate their knowledge. We assumed that early number knowledge is learned informally, through everyday interactions where caregivers use number words when talking with children, demonstrate counting to children, point out patterns and spatial relationships in children's environments, and so forth. We assumed that, because most of the literature on early number knowledge is based on studies with high-SES children, and that seems to be how high-SES children learn numbers.

We thought that the low-SES DLLs in our study, whose caregivers typically speak Spanish with them, would be more familiar with numbers and counting in Spanish than in English. (Just as their vocabularies were greater in Spanish, so did we expect their number knowledge to be greater.) So we decided to test children twice on all measures of spoken and written numbers-- once in Spanish and once in English.

We were surprised to discover that the children performed as well or better in English than in Spanish. Rather than learning numbers at home, in Spanish, and translating those concepts for an English-speaking classroom, these children seemed to have learned the numbers in English-- presumably *in* the English-speaking classroom, and then to varying degrees translated them (or not) into Spanish.

This was an unexpected gift to us as researchers. Most of the time when you measure children's knowledge, you can't tell where the knowledge came from. And while no one should be surprised that four-year-olds from low-SES households have far less number knowledge than four-year-olds from high-SES households, comparing their performance in their two languages gives us some insight into the origin of the number knowledge they do have. Despite having larger vocabularies in Spanish than in English, the low-SES dual-language learners actually performed as well or better in English (the language of instruction in their Head Start programs) on all number measures, suggesting that they primarily learned about numbers and math at their Head Start programs rather than at home.

This seems like an important finding, and one that should be kept in mind when assessing the value of publicly funded preschool programs. If we only compare low-SES students to high-SES students, we will see a huge gap in their early math knowledge and school readiness. One interpretation of this gap, by people who oppose publicly funded preschool, could be that the Head Start programs attended by the low-SES students are not working, because they fail to close the gap between rich and poor students. But what we can infer from this language difference (i.e., from the fact that low-SES DLLs perform as well or better in

English than in Spanish) is that whatever knowledge the children *do* have, they acquired in an English-language environment-- presumably their Head Start classroom. In other words, if they didn't have Head Start, they would be getting virtually no early math experience at all, placing them even further behind the high-SES kids.

There may be another implication of this finding, for education policy makers who are making choices about how to spend limited resources to provide educational services for low-income Hispanic preschoolers. Of course we would like to see more resources devoted to these services overall. But assuming a fixed amount of money to spend, our findings suggest that getting English-language pre-K services to more children would be a better investment (at least in terms of improving math outcomes) than spending more money per child on bilingual services, but reaching fewer children. More exposure to spoken and written numbers and counting games-- in any language—seem to be what the children in our study needed. Although there are many compelling arguments in favor of bilingual preschool education (e.g., Castro, 2014; Castro, Garcia, & Markos, 2013; Garcia & Jensen, 2009; Hammer et al., 2014, 2014; Winsler et al., 2014), the added value of bilingual instruction in math seems small compared to the value of serving more children overall, even if the services are provided only in English.

Conclusion 3: A Methodological Note for Early Numeracy Researchers

Just as policymakers must decide whether to spend resources on bilingual vs. English-language education, so must researchers decide whether to spend resources on bilingual testing of DLLs. Although there are many good reasons to conduct bilingual assessments of DLLs (Espinosa, 2014), we did not find enough differences in our participants' Spanish vs. English performance on any number measure to justify the added time and expense of testing them twice. If we had tested them only in English, we would have saved a lot of time, increased the pool of research assistants we could recruit from (because they wouldn't have to be bilingual), and ended up with virtually the same picture of the their number knowledge as we got by testing them twice. Of course, there was no way to know that except by doing this study. And there are certainly other research questions (e.g., those relating to language and literacy development) for which it would make sense to take separate measurements in the child's two languages. But given these results, our future studies of early math development in this population of children will probably stick to English-language assessments.

Conclusion 4: The SES Gap in Math Achievement is a Gap in Symbolic Number Knowledge (Spoken and Written Numbers) Much More Than ANS Acuity, and Interventions Should Focus on Improving Symbolic Number Knowledge

As discussed earlier in this chapter, it is difficult to accurately measure the ANS acuity of young children. But where we were able to measure ANS acuity, it did not differ very much between children from high- and low-SES households. It differed enough for us to measure, but not enough to matter much in everyday life (or in math class), and the difference seems very unlikely to be the source of the huge gaps we find in children's knowledge of spoken and written numbers already by age 4 (For related findings, see Geary & vanMarle, 2016; Merkley & Ansari, 2016; Raghubar & Barnes, 2017).

Given that spoken and written numbers are already the focus of most preschool math curricula, the message from our findings seems to be, 'if it ain't broke, don't fix it.' Rather than trying to modify preschool math instruction to include more training of the ANS system (or of non-numeracy skills such as shapes and patterns), low-SES students should be provided with as much experience as possible of counting and number words. Once they have begun to master spoken numbers (that is, once they have learned the first few number-word meanings and the cardinality principle) they will be much better able to use the visual representations such as written numerals and the number line.

Thus, in a sense our conclusions can be summed up as an argument that low-SES DLLs would have more success in math if they had more opportunities to learn about and use numbers before starting kindergarten. Let’s not spend resources on interventions to improve children’s ANS acuity, or even to provide bilingual preschool if it means that fewer children could attend preschool overall. Instead, if we want to narrow the math achievement gap, let’s focus on making developmentally appropriate, play-based preschool experiences with numbers and counting available as many low-SES DLLs as possible.

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Figure Captions

Figure 1. Example of stimuli used in the Peabody Picture Vocabulary Test, or PPVT (Dunn & Dunn, 2007)

Figure 2. Example of stimuli used in the Test de Vocabulario en Imagenes Peabody, or TVIP (Dunn et al., 1986)

Figure 3. Example of stimuli used in the Approximate Number System task

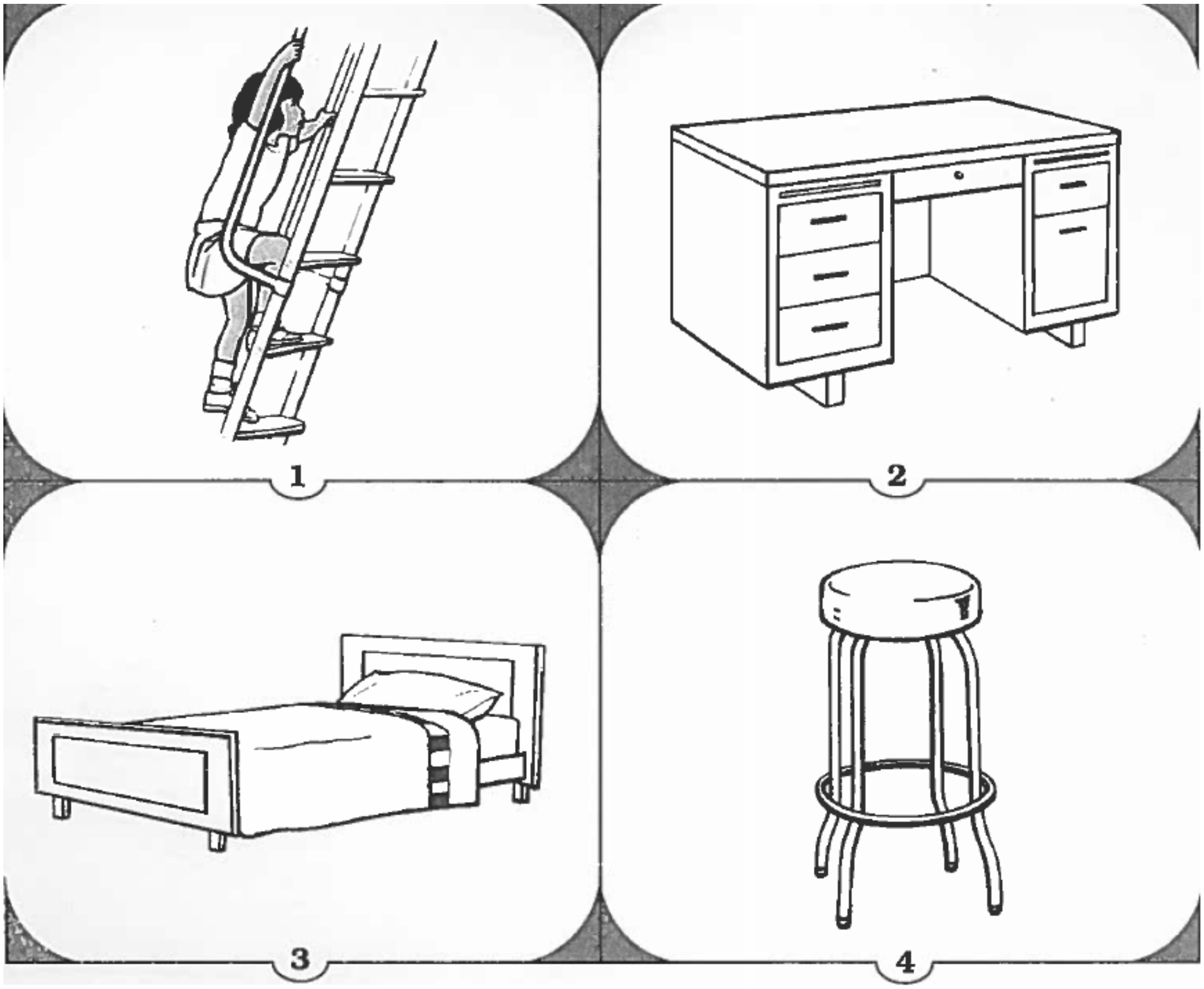
Figure 4. Example of stimuli used in the Counting Objects task

Figure 5. Example of stimuli used in the Give-N task

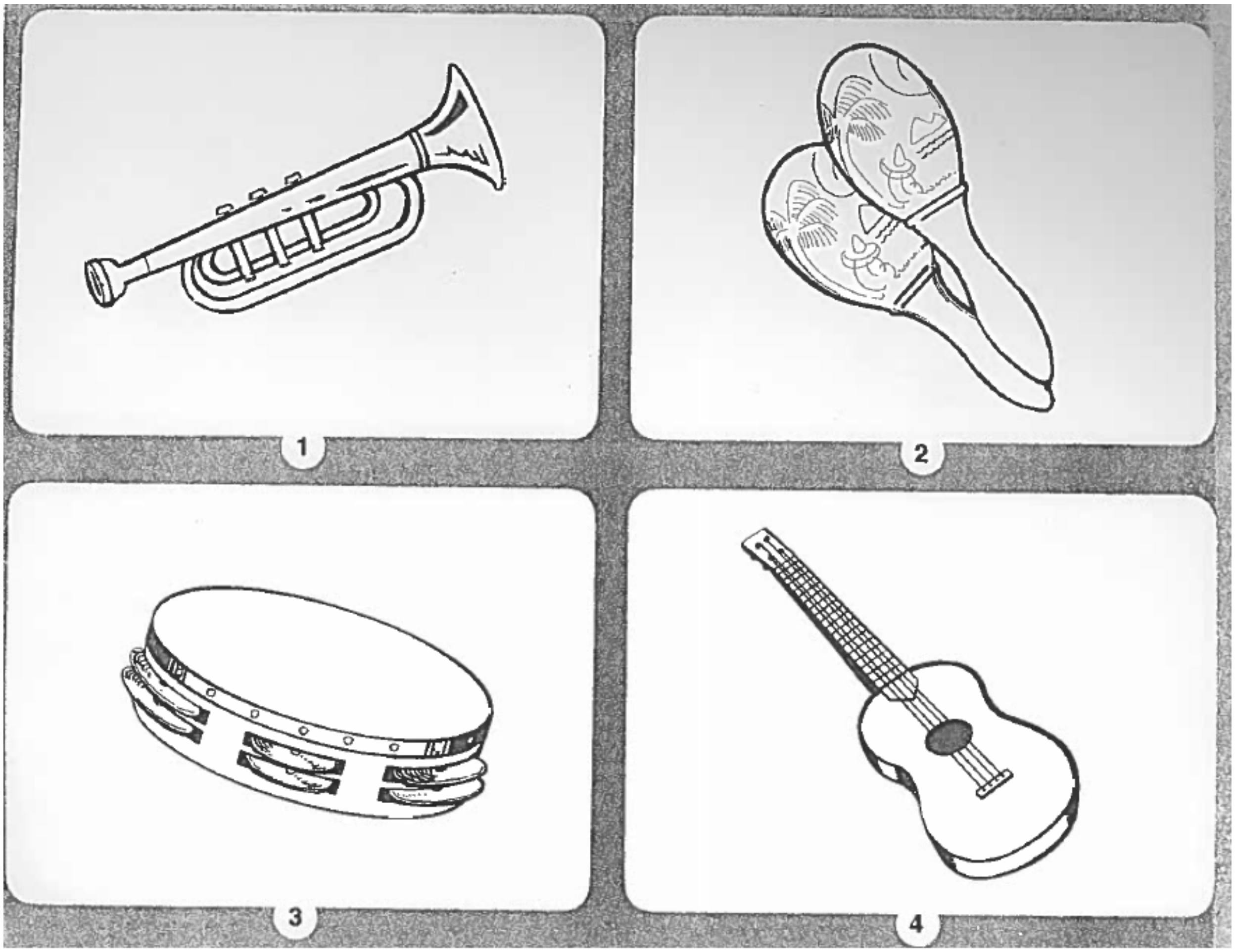
Figure 6. Example of stimuli used in the Written Numeral Identification task

Figure 7. Example of stimuli used in the Scaffolded Number Line task

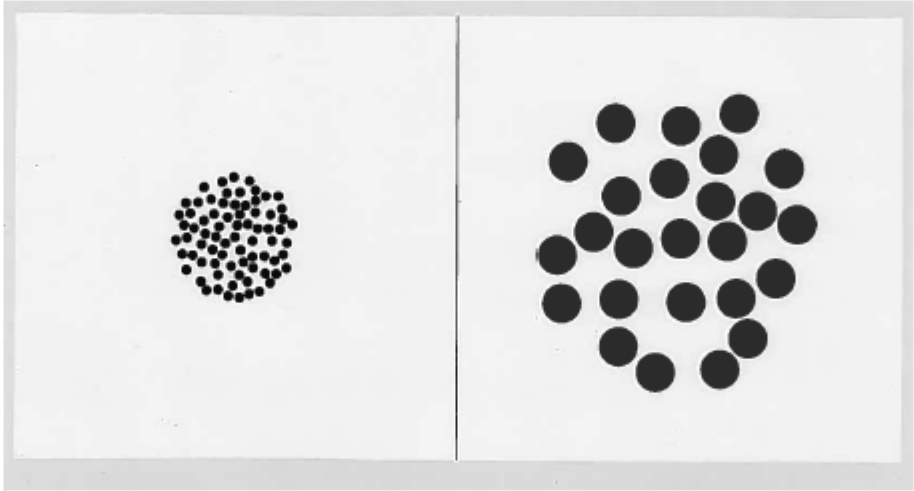
Figure 8. Example of stimuli used in the Classic Number Line task



"Can you point to 'climbing'?"



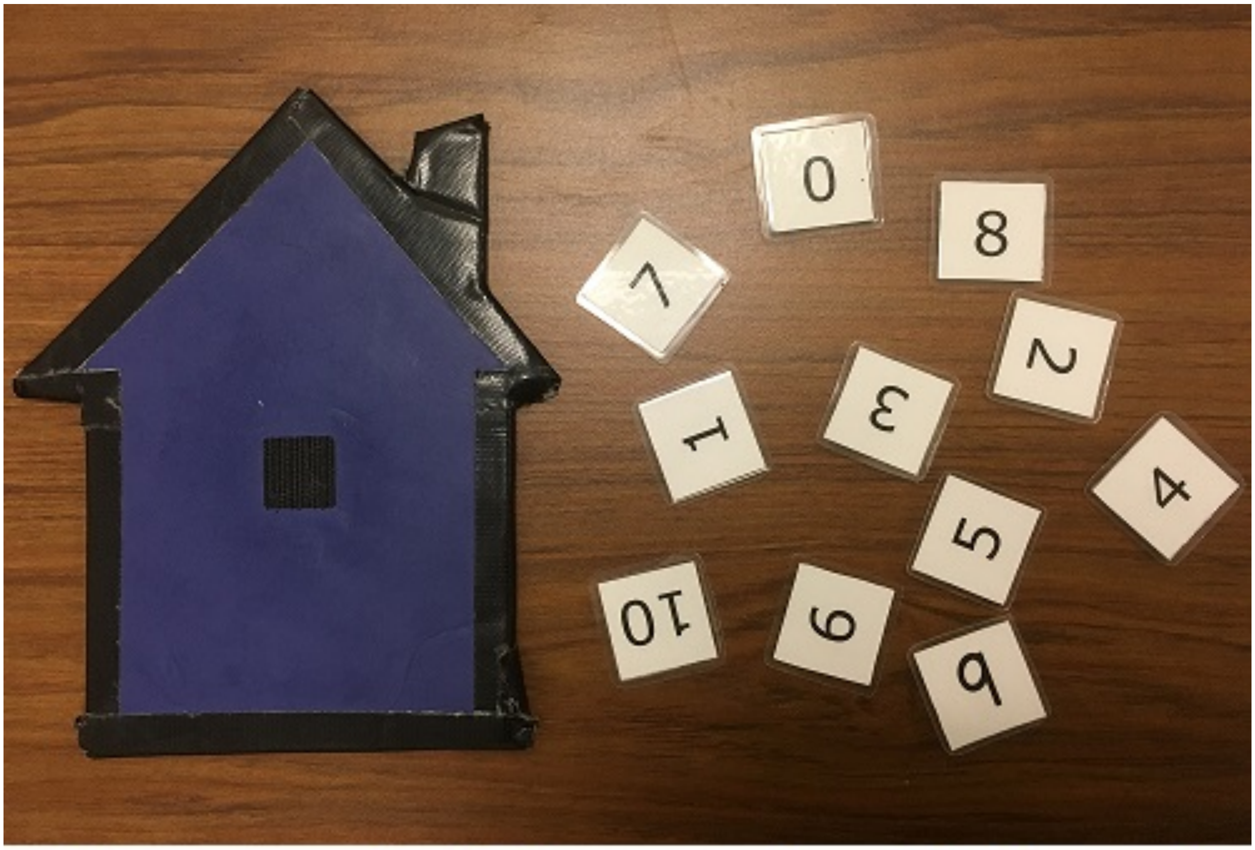
“Señala trompeta.”



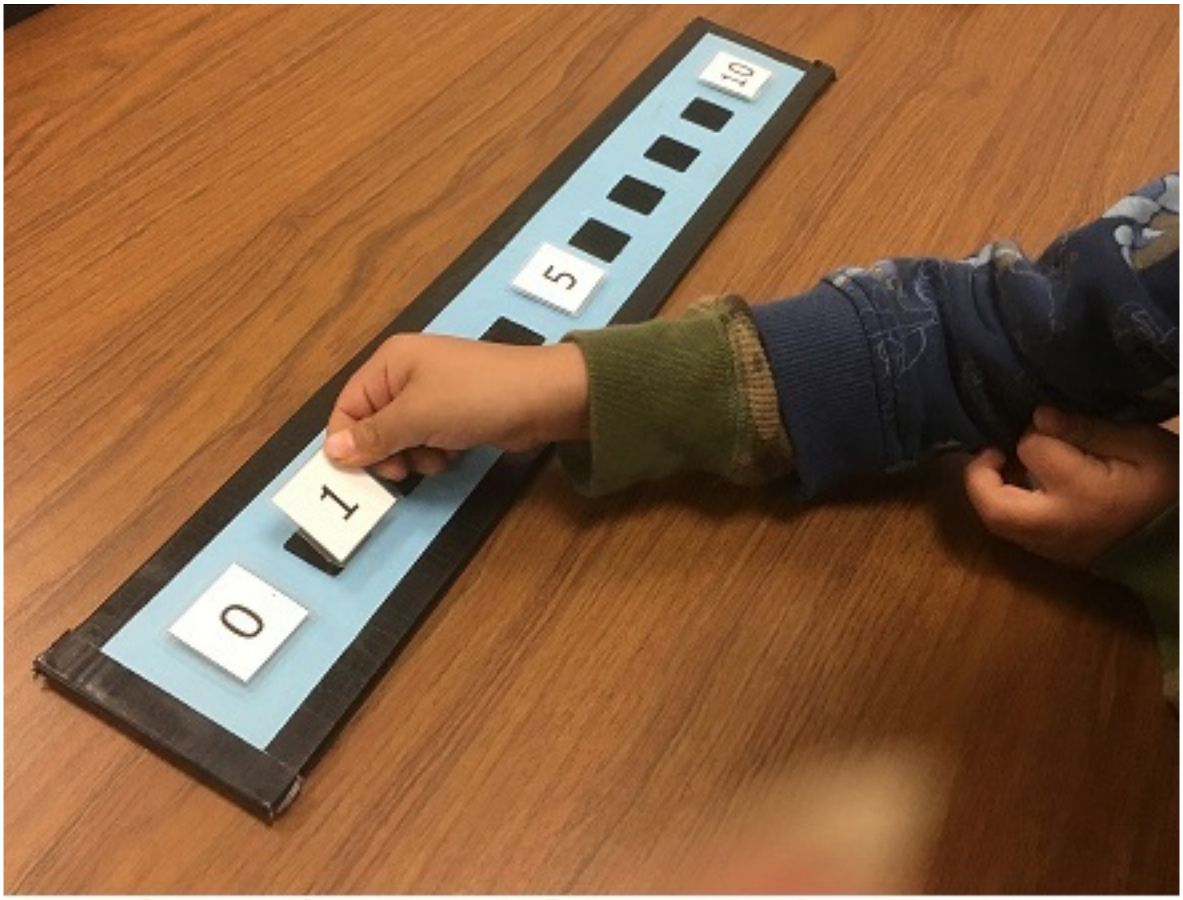
"Which side has more dots?"

"Can you show me how you count these?"

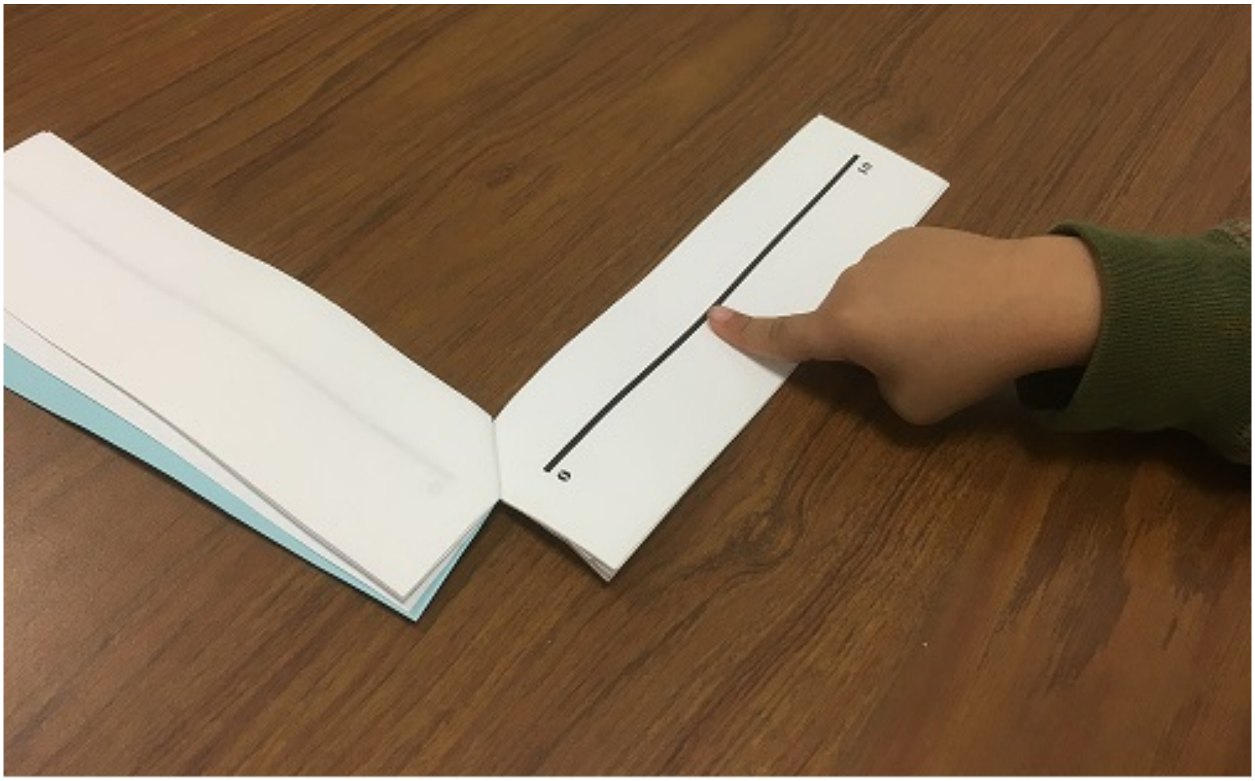
"Can you give him FIVE?"



"Can you find the number ONE and put it in its home?"



*"Okay, here's the number ONE
Can you show me where it goes
on the number line?"*



"Now point to where TWO should go."