The importance of parents' "number talk" for the development of children's mathematical brain

Parents are the first and most essential teachers of a child—and we are now learning much more about the role parents can play in supporting early math learning.

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Executive summary

The human mathematical brain undergoes tremendous changes during the first few years of life. It is also clear that such changes are greatly influenced by environmental inputs, which parents are first in line to provide. Because they are the first and most essential teachers of their child, it is critical that they offer an environment supporting early math learning. This includes talking about numbers early and often. However, because many parents are apprehensive and have negative attitudes towards math, policies should target the most effective ways to accompany parents in building math-friendly interactions. Research suggests that this can be done by providing families with high-quality materials giving parents the opportunity to interact with their child around math. These may include books, games, computerized devices, or even educational TV shows, as long as these tools help caregivers build effective interactions around numbers at home.

Introduction

The human brain develops considerably during the first few years of life. Because these changes are largely shaped by environmental inputs, parents have a significant role to play in fostering their child's early cognitive development. Here we review evidence showing that differences in quantity and quality of parent-child interactions around math account for large variations in numerical skills by the time children enter preschool. These differences are not easily overcome by schooling, and cognitive science suggests that policies should target ways to support primary caregivers in fostering early math learning in young children.

How early does a child need to learn math? A common attitude among many parents is that math education remains primarily the responsibility of the school. For example, a recent study conducted in the US found that whereas 86% of parents of preschoolers considered that doing math at home might be beneficial for children, as few as 1.5% of these parents engaged in math activities every day[1]. This lack of emphasis on fostering early numeracy skills is especially striking when compared to attitudes towards early literacy skills. It is generally found that parents engage much more frequently in activities that promote reading (e.g., learning the alphabet, reading books, printing the child's name) than in activities aimed at fostering numerical skills (e.g., counting objects, knowing sums, playing games involving numbers). One of the reasons for this state of affairs may be that many parents consider early math skills to be less important for later success in school than early reading skills. However, recent studies indicate that this is clearly not the case. A growing body of research shows that children whose parents provide a strong math environment exhibit increased numerical skills. These early numerical skills strongly predict later math achievement from primary to high school. For example, a study conducted on almost 3,000 preschoolers in the UK found that mother's education and quality of home learning environment during preschool were the best predictors of high attainment in math when children are 10, over and above factors such as family income, quality of the preschool, socioeconomic status, and gender[2]. In fact, early math skills can also predict later reading and language skills[3] and are thus likely to have wide-ranging influences on overall academic success. Therefore, math learning is not just a matter of formal education. The foundational math skills that young children build before kindergarten are likely to be critical for their future academic success.

A brain wired for math but malleable

Neuroscience research suggests that there are at least two main reasons why young children may benefit from early math learning. The first reason is that, contrary to what has been thought for many years, children's brains are not "blank slates" or "empty vessels" into which adults pour math knowledge. Rather, psychological and neuroscience studies indicate that the human brain is endowed with basic mechanisms for intuitively representing numerical quantities, a faculty sometimes termed "number sense." Evidence suggests that this number sense is innate, shared with many other animal species, and may provide the foundations for the math skills that are formally acquired in school. For instance, studies have found that babies can appreciate the difference between two quantities (e.g., they can distinguish between 8 items and 4 items)[4] and even possess some intuitions about basic arithmetic operations (e.g., they understand that adding a number of items to a set increases the quantity of items in the set, whereas removing a number of items from a set decreases the quantity of items)[5]. Neuroscience research has identified neurons supporting this number sense at the back of both sides of the brain, around a region called the intraparietal sulcus (IPS) (see Figure 1). These neurons respond to changes in the quantity of a set of objects in children as young as 3 months old[4]. Several studies show the ability to distinguish between two different quantities in young children is associated with later math achievement[6]. Thus, neuroscience research indicates that formal math skills likely build upon evolutionally old mechanisms that support an intuitive sense of number. This explains why children may be able to develop a considerable body of informal mathematical knowledge well before school.

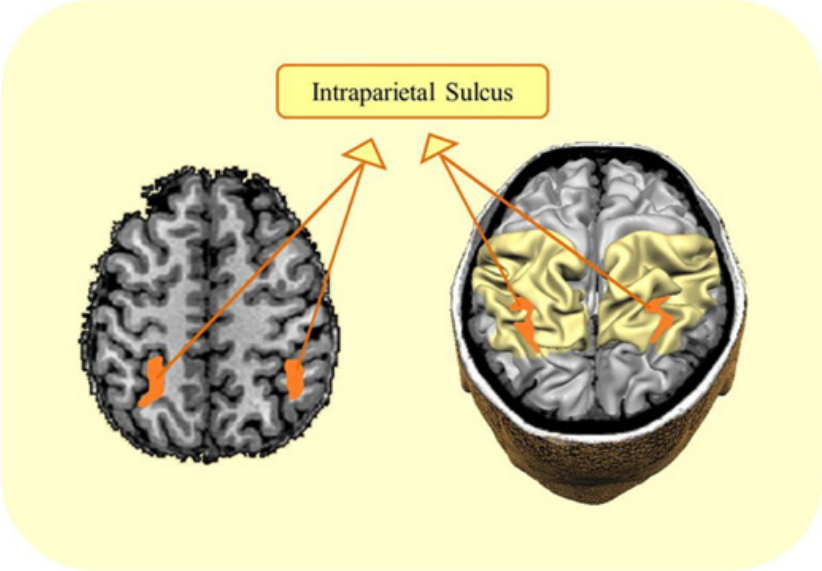

Figure 1. The mathematical brain. Location of the intraparietal sulcus (in orange) on a picture of the brain taken using a magnetic resonance imaging scanner (left) and on a 3D representation of the brain (right). (Reproduced from Ref. [7])

The second reason why young children may benefit from early math learning is that, even though there is no doubt that brain development is under the influence of genetic factors, it also takes place in constant interaction with the environment. For example, over the first few years of life, brain growth is associated with a significant increase in the number and complexity of connections between neurons (called synapses). Remarkably, this increase is under the influence of early experiences, such that connections that are repeatedly used will strengthen, whereas connections that are infrequently used will disappear (a process called pruning). Because the brain is perhaps at its most malleable (i.e., most able to form and eliminate new connections) within the first few years of life, environmental inputs during that period are likely to have wide-ranging effects on brain development. Perhaps the most striking example of such an environmental influence comes from a recent large-scale study showing a strong link between socioeconomic status (indexed by parental education and family income) and the size of the surface area of the brain (the part of the brain that supports cognitive processing) in children and adolescents[8]. This relationship was evident in areas that support language, reading, self-regulation, but also in areas involved in spatial and numerical processing around the intraparietal sulcus (see Figure 2). Thus, the development of the brain mechanisms underlying numerical processing is likely to be shaped by early experiences and may benefit from the extra parental support that is often characteristic of families with higher socioeconomic status. The question is, then, what specific component of this extra-parental support is critical to foster the development of children's numerical abilities.

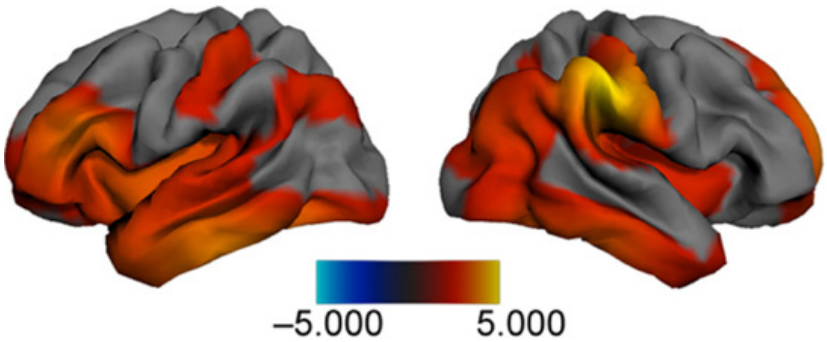

Figure 2. The malleable brain. Location of the parts of the brain (in shades of red and yellow) that are affected by parent education. These include the IPS. (Reproduced from Ref. [8])

The importance of talking about numbers to young children

In a landmark study published in 2010, Susan Levine and colleagues discovered that a critical factor supporting the development of the numerical brain may be how much parents talk about numbers at home[9]. As pointed out earlier, there

are large differences in children's mathematical skills when they enter preschool. Consider the concept of cardinality, that is, understanding that a given number word (e.g., four) corresponds to a specific number of things (e.g., four apples). Although that concept may seem trivial to most adults, its acquisition is a significant milestone in children's mathematical development. All typically developing children eventually learn the cardinal meanings of number words. However, not everyone reaches this milestone at the same time. While some children understand the cardinal principle before age 3, others take one or two additional years to master it. This means that some children can be 1 or 2 years behind others when they enter preschool! Such differences in early math skills are concerning because they tend to persist throughout the entire elementary school years[9].

Levine and colleagues hypothesized that one source of these early differences could be how often parents talk about numbers to their child. They tested that hypothesis by observing the natural interactions between 44 parents and their 14- to 30-month-olds while they were at home. Over the course of a year and a half, the researchers made several visits to each household. They recorded precisely how often parents would use number words when engaging in activities with the child, such as playing a game, reading a book, or singing. The researchers made two important discoveries. First, they noticed that there were striking differences in how frequently parents used number words at home. While some parents uttered only 4 number words in over 7.5 hours of visits, others used as many as 257. For instance, some parents would systematically count items while reading books (e.g., "Let's count the balloons. Ready? One, two, three, four, five."), while others would hardly do so. Second, the researchers discovered that the total amount of words used by parents when children were 14 to 30 months old was strongly predictive of children's understanding of the concept of cardinality later at preschool entry (i.e., when children were 46 months old). Importantly, this was true over and above differences in socioeconomic status. Therefore, variations in the amount of "number talk" used by parents may account for an important share of the differences in math skills observed when children enter preschool.

In a subsequent study, the same researchers noticed that some types of parental "number talk" appear to matter more than others[10]. For instance, counting or labeling sets of objects that are visible to the child (e.g., counting bees while reading a book) is more predictive of children's later cardinal knowledge than counting with no visible objects (e.g., picking up a child while saying "One, two, three, whoo!"). The size of the numbers that parents talk about also makes a difference. Number talk referring to sets from 4 to 10 was found to be more predictive of cardinal knowledge than number talk referring to sets smaller than 4. Overall, these studies suggest that parents can do one simple thing to foster the development of their child's numerical brain: talk about numbers early and often.

How to promote parents' "number talk"?

The idea that parents should talk to their children about numbers and math might seem trivial to some. However, it is important to consider that many families still consider that math learning remains primarily the responsibility of the school. A significant number of parents are also apprehensive about math and do not feel comfortable talking about math to their children. Furthermore, math-anxious parents may not naturally provide the high-quality support that children need for effective math learning[11]. How can we then promote high-quality "number talk" among these families? A recent study indicates that a promising avenue is to provide math-apprehensive parents with high-quality materials that give them the opportunity to talk about math with their child[12]. In that study, the researchers tested the idea that replacing bedtime stories that parents often read to their child with a math discussion would bolster children's math skills. They recruited 587 first-graders from socioeconomically diverse schools in the Chicago metropolitan area and gave each family a tablet computer to use during the school year. Some families were told to use the tablet to read classic bedtime stories, while others were told to use it to work through simple math problems with their child. Each day a different problem (or a different bedtime story) would be downloaded on the tablet, and the parents would then have the opportunity to talk about numbers, arithmetic, or geometry to their child before bedtime. To evaluate the effect of the intervention, the researchers assessed the math skills of all children at the beginning and the end of the school year. The results were striking. Children whose parents used the tablet regularly to work through math problems outperformed children whose parents were hardly using the tablet by about three months at the end of the year. These children also significantly outperformed children whose parents were using the tablet regularly to read bedtime stories. An interesting aspect of the study is that the intervention was especially effective for children whose parents were apprehensive about math. Thus, this study demonstrates that providing parents with materials that give them the opportunity to talk to their child about math can make a big difference in math learning.

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