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NUMERACY

Early Numeracy: The Transition from Infancy to Early Childhood

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Introduction

Number concepts emerge before formal schooling. Preschool children exhibit verbal skills, such as counting, and basic concepts of equivalence, ordinality, and quantitative transformation. Although researchers agree that these abilities exist in early childhood, they continue to debate when, and by what mechanisms, these abilities emerge. In other words, what are the developmental origins of early numeracy?

Subject

Research on numeracy has traditionally focused on verbal counting. However, the notion that numeracy might emerge in infancy and toddlerhood shifted the focus toward nonverbal abilities. This shift expanded the range of behaviours included in early numeracy, a change that has direct implications for early childhood education and assessment. This shift also raised questions about the developmental origins of math disabilities and gaps in mathematical achievement, such as those associated with difference socioeconomic groups.

Problems

Current developmental accounts differ in the weight given to nonverbal versus verbal representations.

Some argue the core conceptual structure for number is inborn and takes the form of a nonverbal representation that is similar to verbal counting.[1,2,3] On this view, a major developmental achievement is mapping verbal number words onto their nonverbal referents.

Others claim innate processes contribute to numerical development but do not constitute a complete conceptual system for number.[4,5] These accounts incorporate both preverbal counting and a second representational format based on object tracking. They characterize verbal counting as a conceptual catalyst that permits integration of the two nonverbal representations,[5] thereby transcending their inherent limitations and achieving a true concept of number.[4]

Yet other accounts incorporate object-based representations but claim that these representations develop during early childhood.[6] On this view, object representations of number are not precise, even for small sets. Instead, they are thought to approximate number with increasing accuracy due to (1) age-related increases in working memory capacity, and (2) interactions between partial knowledge of the number words and recognition of small numerosities in specific contexts.[6,7,8]

Some argue that number concepts are extracted from the counting system itself, without support from nonverbal representations. Studies have shown that children do not understand counting principles until they have mastered counting procedures.[9,10] It has also been argued that children cannot connect labels for small sets to the conventional counting system because they cannot pick out the natural number sequence from other sequences.[11]

Research Context

Because research has focused on the emergence of verbal numeracy within a nonverbal conceptual base, existing experiments include a mixture of verbal and nonverbal methods. In the verbal realm, investigators measure various subcomponents of counting (e.g., asking children to recite the count list, count a set of objects, or name a set’s cardinality). In the nonverbal realm, investigators use object-based tasks that do not require verbal counting. With very young children and infants, looking time procedures (e.g., habituation) and reaching tasks are common.

Key Research Questions

A major aim has been to describe the numerical sensitivity of infants and very young children. Researchers want to know how much children understand about number before acquiring conventional skills. The specific profile of nonverbal strengths and weaknesses is sometimes used to argue for a particular developmental account. Another major research goal is describing the emergence of verbal numeracy in great detail. In this research, the potential interactions between verbal and nonverbal numeracy is carefully considered.

Recent Research Results

Numerical sensitivity in infants

Early habituation research indicated infants could discriminate between small sets of objects. For example, when babies were shown a series of object sets equated for number (e.g., two), but varying in color, shape, and position, their looking time gradually decreased. When a new number of objects was shown (e.g., three), looking times increased, suggesting that infants detected the change in number.[12,13] Similar experiments have suggested infants can discriminate large sets of items in both visual and auditory displays,[14,15] perform simple calculations over objects,[3] and detect numerical relations across modalities.[16,17]

Nonverbal measures in early childhood

Children perform object-based number tasks much earlier than they demonstrate similar understandings in verbal tasks. For example, preschoolers solve simple object-based addition and subtraction problems (e.g., 2 + 2) years before they can solve analogous verbal problems.[6,8,18] Similarly, children judge ordinality and equivalence in forced choice tasks much earlier than they can compare the same sets verbally, via counting.[6,19,20,21,22,23,24] Competence on nonverbal measures emerges between 2½ and 3 years of age.

Development of verbal counting

Verbal counting encompasses three major subskills. First, children must learn the sequence of count words. The first 10 count words are usually memorized by age 3 years.[25,26] Children learn to generate numbers using the decade structure (teens, twenties, etc.) around 6 years of age. Second, young counters must coordinate words and objects, such that each item in a set is tagged once and only once. Children make many errors as they discover and master tagging procedures, peaking in frequency between 36 and 42 months of age.[25] Third, children learn that the last word in a count represents its cardinal value (e.g., when you count, "1-2-3," you have three things). Interestingly, children gain this insight before mastering verbal counting procedures, which suggests they access the cardinal word principle via experiences with small sets.[4,25,26,27,28,29] In fact, small set sizes (i.e., 1-3) may provide the only context for discovering the cardinal word principle because these can be both counted and labeled without counting.[4,26,27,28,29,30,31,32,33]

Research Gaps

A persistent problem has been reconciling infants' apparent precocity for number with the struggles exhibited by preschool children on similar tasks. For example, if infants can represent and compare large object sets as some have claimed,[15] why can't preschool children match large sets until after they have learned to count?[34,35] Such discrepancies have fueled vigorous debate about the meaning of the infant work, and articulating these literatures remains a significant challenge. For example, researchers have only begun to ask whether infant sensitivity to quantity is connected to preschool numeracy and, likewise, whether preschool numeracy is connected to subsequent achievement in school mathematics.[36]

Another unexplored question is how children coordinate discrete and continuous quantity. Infants' perception of continuous amount is well established. Some have argued use of continuous amount actually explains infants' performance on numerical tasks.[37,38] Regardless of whether infants process continuous quantity, discrete number or both, research is needed to determine what causes them to shift attention from one type of quantification to the other, as well as the developmental changes that occur as children learn how continuous and discrete quantity are related (e.g., size does not affect counting, unless you are counting measurement units).

Finally, much remains to be learned about the interactions between nonverbal quantification and verbal counting. Some contend that whatever preverbal infants can do or understand is necessarily innate because it emerges without verbal input.[4] However, others have argued that even infants who do not speak about number themselves have nonetheless been exposed to number language, and thus it is not clear that infant competencies are either nonverbal or innate.[39] A related issue is how children acquire the meanings of the number words and the extent to which this relies on a nonverbal foundation. Current research is also exploring whether acquisition of the plural mediates these interactions.[40]

Conclusions

Evidence of numerical competence in infants has raised interesting questions about the origins of numeracy and the conceptual resources young children use to acquire verbal counting. However, further research is needed to reveal what this infant competence entails and precisely how it connects to subsequent nonverbal and verbal development.

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