Mathematical reasoning by five-month-old Saudi infants

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Infant's achievement may not sound too impressive to the average grabby adult.
I don't think anybody knows for sure how we acquire arithmetic skills and learn language.
Are babies born with hardwired arithmetical concepts and operations? The answer is no.
Are babies able to understand basic numerical concepts and operations? The answer is yes
Do human infants carry an evolutionary legacy of basic number skills? The answer is no.

Abstract

Mathematical competence in five-month-old infants from Saudi Arabia is investigated using a violation-of-expectation paradigm. The central idea of this research is to show that Saudi infants developed numerical expectations analogous to the arithmetic operations used by Karen Wynn experimental studies: 1+1=2 and 2-1=1. Wynn (1992) reported that four and five-month-old infants could determine the outcomes of simple addition and subtraction operations. Based on Wynn's findings, a series of studies were replicated (Simon, Hespos, & Rochat, 1995; Koechlin, Dehaene, & Mehler, 1997; Houdé, 1997; and Wakeley, Rivera, & Langer, 2000). The results are discussed within the theoretical framework of infant cognition.

Introduction

A century ago, William James argued that the infant's world is a blooming, buzzing mass of confusion. Infants were once, perceived by John Locke, as blank tablets. Charles Darwin observed "during the first seven days various reflex actions, namely sneezing, hickuping, yawning, stretching, and of course sucking and screaming, were well performed by my infant. On the seventh day, I touched the naked sole of his foot with a bit of paper, and he jerked it away" (1877, p. 285). What do infants inherit? What do they acquire? Do infants enter the world prepared to organize and make sense of their physical and social environments? How do infants learn language? (1) How do they acquire grammar? How do they learn to understand: spoken words? How they learn the name of animals and objects? How do infants learn to discriminate objects? How do infants form categories? How can we disentangle the contributions of nature and nurture, and then understand how they interact during development? What changes over development, and what remains constant? What are the implications of early development for later adaptation or dysfunction?

In this study, mathematical skills will be addressed and answered as we venture into the minds of infants.

Theoretical framework of infant cognition

Toward the latter part of the 1960th there arose, as never before, a great interest in understanding the mental capabilities of human infants (Piaget, 1968; Mehler & Bever; 1967; Bever, Mehler & Epstein, 1968), Energized by Piaget's writings (1941), and lately by Vygotsky's writings, both psychologists and the lay public became fascinated with the infant mind. Anecdotes were gathered and published, usually attesting to an infant's remarkable, unbelievable powers. It is true that the capabilities of infants have been underestimated. But overestimation is not the appropriate remedy. The corrective is to perform objective and replicable observations of infants' behavior. Interestingly, the human infant has suffered from the same sort of underestimation as that of animals prior to Darwin's, Piaget's and Vygotsky's time.

In fact, the failure to appreciate the mental capabilities of infants lasted until 1970s. Because babies lack speech and spend too much time eating and sleeping, the presumption was that not much cognition was going on inside the infant head. That view has been largely dissipated with the increasing application of objective, replicable measurement of infant behavior, particularly within the last quarter of the twentieth century. Laboratories and departments of infants' cognition have been created and active research programs have been multiplied. Psychological studies have focused its attention on two directions. One is psychoneurologically based, shaped by evolution and grounded within the theoretical framework of evolutionary psychology. The other is culturally based, shaped by learning processes.

Minds in the construction: Piaget's and Vygotsky's theory of infant cognitive abilities

Piaget's theory of cognitive numerical capacity of very young children (1941) has provided insightful understanding of children's cognitive abilities. According to Piaget, children's emerging conception of numbers is closely tied to the ability to reason logically. The ability to reason logically emerges over a series of stages. It develops from children's social interaction with the surrounding environment (Piaget, 1995). Piaget observed that infants, babies, and children learn to establish correspondence between two sets of objects and over time they acquire the concept of conservation (1941, 1968). Children's knowledge of physical objects was seen as a developmental achievement attained over the fist early two years of life (Piaget, 1954). In other words, child's knowledge of physical objects was constructed as a result of his/her experience with the physical world. But recent experimental studies (Baillargeron, 1995; Spelke, Philips & Woodward, 1995) suggest infant’s understanding of objects may be richer and constitute a core domain not yet developed in developmental psychology.

Infants extend their reach into a world of thought and action. According to dialectical developmental psychology, infants squirm, crawl, and toddle their way into mental life without needing to traverse genetically orchestrated developmental stages (Vygotsky, 1987, 1998, 1999).

Measurement and assessment of infants’ cognitive abilities

Research with infants is difficult because we are unable to ask infants questions, may become irritable or uncooperative, or may fall asleep. So, how do we conduct research with infants? Some innovative research methods examine, preferential looking responses, sucking patterns, measuring body’s movements (stabilometer). For example, mom's read an assigned story to their baby in-utero twice a day during the last trimester of pregnancy. When 2 days old, half of the infants heard the familiar story recorded in their mother's voice and half heard the story in a stranger's voice. The infants sucking patterns were established. Novel stories were played and then the infants were reinforced with the familiar passage for changes in sucking patterns.

Babies learn rapidly about the sights and sounds of their environment. Consider the following accomplishments in the infant’s life:

•At two days old infants recognize their mother's voice and prefer it over other sounds.

•Three-month-olds can discriminate primary colors, and prefer red and yellow over blue and green.

•Six-month-olds recognize a mobile two weeks after being exposed to it for only two 15-minute intervals.

•Seven-month-olds can match an angry or happy facial expression with the corresponding vocal expression. •Nine-month-olds will imitate simple actions which they see being performed on objects.

Do children think differently than adults? How important are environmental influences? Can young infants add and subtract? Do children use clues to search for hidden objects? Do babies know that actions lead to reactions? How do babies learn about the causal relations among the events happening around them? How do babies identify their mother tongue? Do babies remember hidden faces? What knowledge of language do infants have before they speak?

Very young children and even infants are known to have surprisingly complex cognitive abilities to perceive and respond to basic components of speech sound, verbal and non-verbal communication, engage in conversation, show musical competency, recognize their mother's voice and prefer it over other sounds at only two days old and within weeks they can discriminate between her voice and the voices of others (Mehler, J., Bertoncini, J., Barrière, M., & Jassik-Gerschenfeld, D. (1978). Complex cognitive abilities appear long before the development of speech or the ability to use language. These findings raise the question of the earliest age at which the nervous system and brain can adequately process, learn and remember events. Increasing research results in the area of infant cognition suggest that the answer is "well before birth". In short, the womb appears to be the first school of structured learning, first place of shared close social relations, first concert hall for music learning competency and personality formation.

For many years, the capabilities of infants have been ignored, or have been studied only with respect to issues dealing with language. However, in recent years, systematic programs of research have undertaken to elucidate the origin of mathematical skills (Houdé, 1997; Simon, Hespos & Rochat, 1995; Mix, Levine & Huttenlocher, 1997; Starkey, Spelke & Gelman, 1990; Wakeley, Rivera, & Langer, 2000; Wynn, 1992) and problem solving at the earliest stages of human development.

Learning in the womb

The womb envelops a fetus in musical sounds, the heart drums, the intestines burble, the sound of the blood stream, and the mother speech. In other words, the fetus is busy learning the rhythms, sounds, and meanings of his/her mother language. Te womb is a learning environment for the fetus. The fetus reacts to his/her mother state of mental life. The fetus reacts to his/her mother anxiety, anger, and happiness.

Method

The experiment

Our experiment tested whether infants would enumerate moving objects. We employed a technique which has proved extremely useful in infant's assessment of cognitive capacities.

Participant

Seventeen healthy, normally developing babies, ranging in age from 5 months, seven days to 5 months 25 days (mean age 5 months, 16 days). Six infants were excluded from the experiment due to fussiness or to inactiveness to the display. All infants were recruited from Riyadh city.

Apparatus

The apparatus was modeled as closely as possible on the Wynn (1992) experiment. Each infant sat on lap of his father or in baby seat facing a large box with dolls display stage, 70 cm high by 100 cm wide by 40 cm deep. The distance between the infant and the stage is 100 cm. The stage was constructed from wood. Two doors cut in the right and left side of the stage and a moving screen allowed the visible addition and subtraction of the objects (toy dolls). A hidden door in the back of the stage allowed the experimenter to add or remove the toy dolls stealthily. A screen, 40 cm wide by 25 cm high, rotated on a horizontal rod connected to the front of the stage. Three invisible students placed on each door. One placed on the right side, one the left and one on the back. An invisible hand enters the doll from the right or left side door.

Procedure

Infants were assigned to either addition or subtraction conditions. Five experimenters worked together to run the experiment. The first two experimenters were in the testing room in each side of the box and one behind it. One experimenter controlled the screen, and one experimenter sat in the control room and recorded looking times.

Pre-test. Infants were presented with two trials to familiarize them with the rotation of the screen, the movement of the hand, and the sight and sound of the dolls.

Test. Infants were shown eight test trials with each of the four outcomes presented twice. The screen began flat against front of the stage. The right side experimenter placed one doll (in the addition condition) or two dolls (in abstraction condition) on the stage, and the screen was rotated up to vertical. The experimenter then either add or subtract one doll from the display through the door on the side of the stage. Hidden from the sight, the second experimenter adds or removes dolls as needed through the trap door to produce the outcome. The screen was rotated down to its starting position to reveal the outcome. Looking times to each display were recorded. A look was considered valid if it was longer than two seconds. A trial was terminated when the infant looked away from the display for a maximum of 70 seconds.

Results

The main question addressed by this research was whether looking times to one, and two items varied as a function of addition or subtraction manipulation. The looking times at correct answer of conditions 1+1=2, and 2-1=1 were significantly higher than of incorrect answer of conditions 1+1=1 and 2-1=2. In the addition condition infants looked significantly longer at the outcome 1 (M = 53.47 s, SD = 4.45 s) than at an outcome of 2 (M = 17.11 s, SD = 3.120 s)

The looking times at correct answer of conditions 2-1=1, and 2-1=2 were significantly higher. In the subtraction condition infants looked significantly longer at the outcome 2 (M = 59.41 s, SD = 3.75 s) than at an outcome of 1 (M = 32.00 s, SD = 4.00 s).

The results of this study showed that in the addition condition, infants looked significantly longer at an outcome of one than two and the subtraction condition, infants looked significantly longer at two than one. The crucial question, though, is what is the appropriate way to explain these findings? The familiarity hypothesis explanation argues that infants should look longer at the outcome that is most familiar to them. In the case of addition, this would be an outcome of two. In the subtraction condition, it would be an outcome of one. The directional hypothesis explanation assumes only a directional understanding of addition and subtraction. In the addition condition, infants would look longer at outcomes in the opposite direction than expected. In the case of addition, outcome one is directionally incorrect and should be looked at longest. In subtraction, outcome of two is directionally incorrect and should be looked at longest. Finally, a pure computational explanation would predict that infants should look longest at all of arithmetically incorrect outcomes.

Conclusion

The cognitive capacities of infants are fascinating, but one should be cautious about attributing sophisticated cognitive processes to infants when simpler processes will suffice. I believe it is still an open question as to whether 4-5 month-old infants can actually add and subtract. Further research is needed to delineate infants’ understanding of object permanence, quantity and their development of numerical knowledge.

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