Theories of Cognitive Development

John Opfer

Basic Questions

1) **What is innate?**
2) **Does children's thinking progress through qualitatively different stages?**
3) **How do changes in children's thinking occur?**
4) **Why do individual children differ so much from each other in their thinking?**
5) **How does brain development contribute to cognitive development?**
6) **How does the social world contribute to cognitive development?**

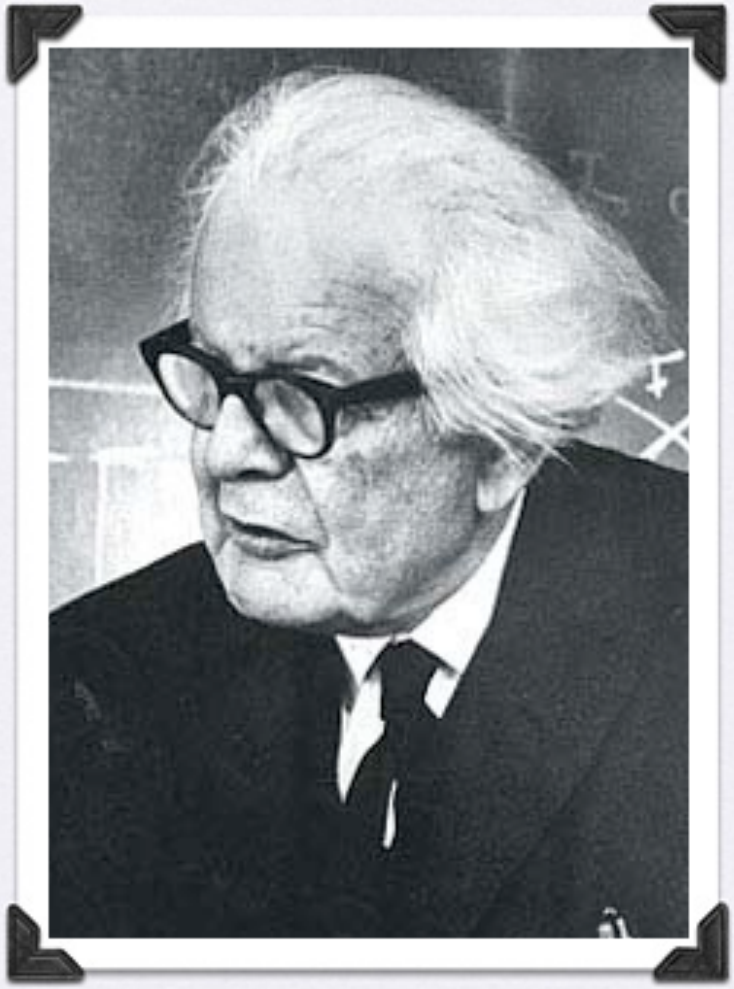
Influential Theories of Cognitive Development

- **Piaget's theory**
- **Sociocultural theories**
- **Core-knowledge theories**
- **Information-processing theories**

Jean Piaget

Beginning about 1920, Piaget developed the first 'cognitive' theory

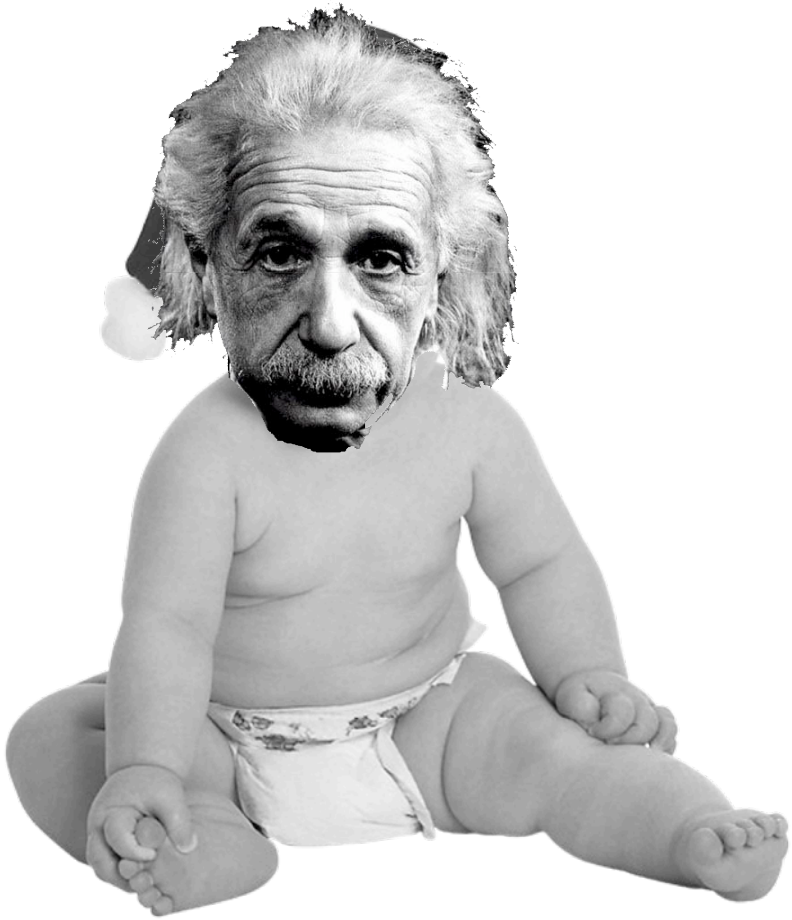
- infant cognition
- language development
- conceptual development
- mathematical and scientific reasoning
- moral development



Piaget's
Most Revolutionary Idea

Child as scientist

1. construct their own knowledge from experimenting on the world.
2. learn many things on their own without the intervention of older children or adults.
3. are intrinsically motivated to learn and do not need rewards from adults to motivate learning



Piaget's Principles: What changes?

- **There are distinct <u>stages</u> of cognitive development, with the following properties.**
  - <u>Qualitative change</u>: Children of different ages (and at different stages) think in different ways.
  - <u>Broad applicability</u>: The type of thinking at each stage pervades topic and content areas.
  - <u>Brief transitions</u>: Transitions to higher stages of thinking are not necessarily continuous.
  - <u>Invariant sequence</u>: The sequences of stages are stable for all people through all time. Stages are not skipped.

Piaget's Principles: What does not change?

- **Three processes work together from birth to account for continuities:**
  - Assimilation: People translate incoming information into a form they can understand.
  - Accommodation: People adapt current knowledge structures in response to new experience.
  - Equilibration: People balance assimilation and accommodation to create stable understanding.

Piaget's Principles: How do nature/nurture interact?

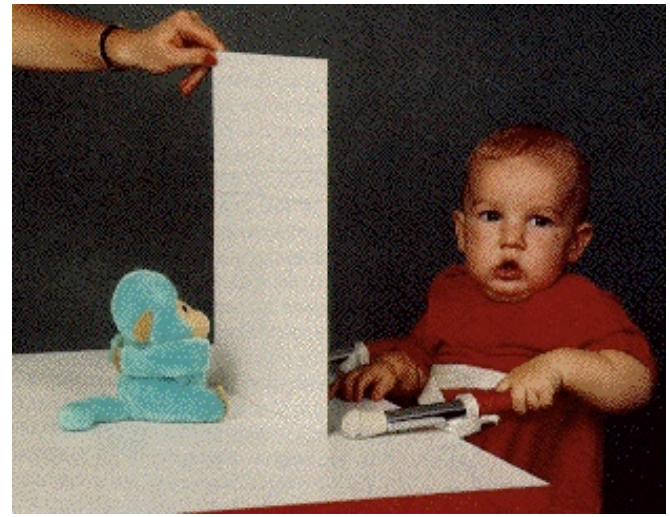
- **Nature and nurture interact to produce cognitive development.**
  - Adaptation: Children respond to the demands of the environment in ways that meet their own goals.
  - Organization: Children integrate particular observations into a body of coherent knowledge.

Overview of Piaget's Stages

1. **Sensorimotor stage (birth to 2 years)**
   - Knowledge tied to sensory and motor abilities
   - *Fails tests of the object concept*
2. **Preoperational stage (2 to 7 years)**
   - Objects and events are represented by mental symbols
   - *Fails tests of conservation*
3. **Concrete operational stage (7 to 12 years)**
   - Children can reason logically about concrete objects and events.
   - *Fails to engage in systematic hypothesis testing*
4. **Formal operational stage (12 years and up)**
   - Children can reason abstractly and hypothetically.

Piaget's Sensorimotor Stage

- **Substage 1 (birth to 1 month): <u>Reflexive Activity</u>**
  - Building knowledge through reflexes (grasping, sucking).
  - No attempt to locate objects that have disappeared
- **Substage 2 (1 to 4 months): <u>Primary Circular Reactions</u>**
  - Reflexes are organized into larger, integrated behaviors (grasping a rattle and bringing it to the mouth to suck)
  - Still no attempt to locate objects that have disappeared.



Piaget's Sensorimotor Stage

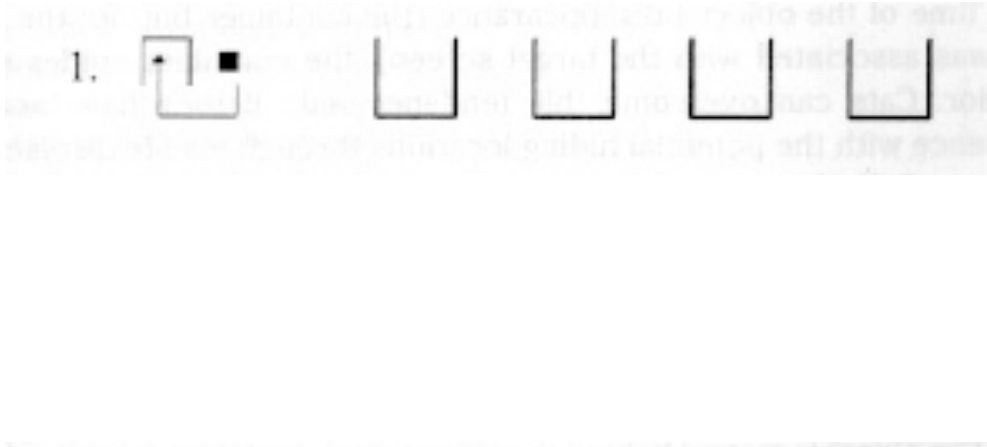
- **Substage 3 (4 to 8 months): <u>Secondary Circular Reactions</u>**
  - Repetition of actions on the environment that bring out pleasing or interesting results (banging a rattle).
  - Search for objects that have dropped from view or are partially hidden
- **Substage 4 (8 to 12 months): <u>Coordination of Secondary Reactions</u>**
  - Mentally representing objects when objects can no longer be seen, thus achieving "object permanence."
  - Search for completely hidden objects but makes "A-not-B error."

A not B error

Piaget's Sensorimotor Stage

- **Substage 5 (12 to 18 months): <u>Tertiary Circular Reactions</u>**
  - Actively and avidly exploring the possible uses to which objects can be put
  - Ability to follow visible displacements of an object
- **Substage 6 (18 to 24 months): <u>Symbolic Thought</u>**
  - Able to form enduring mental representations, as demonstrated by "deferred imitation," the repetition of others' behaviors minutes, hours, or days after it has occurred.
  - Ability to follow invisible displacements

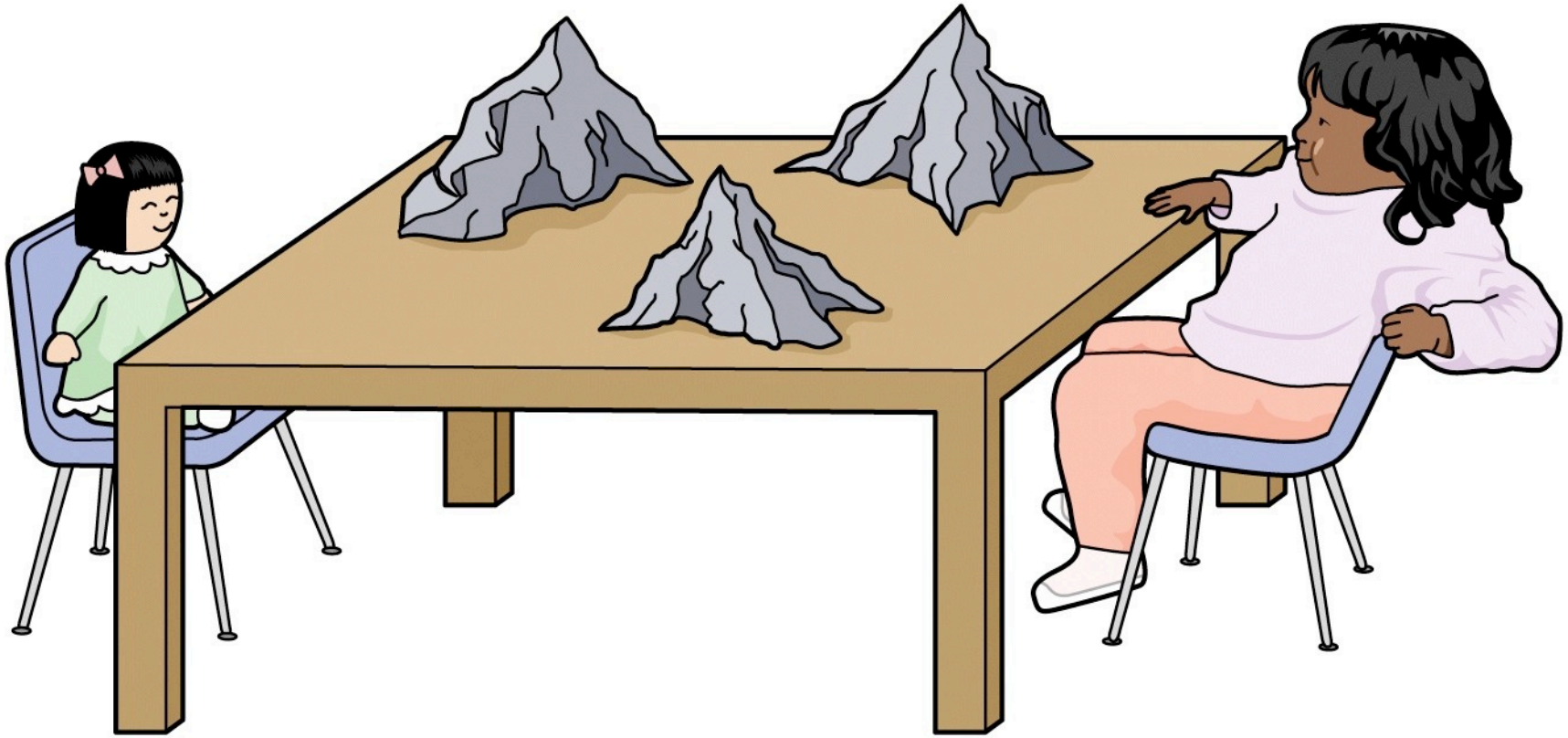
Invisible Displacement



Piaget's Preoperational Stage

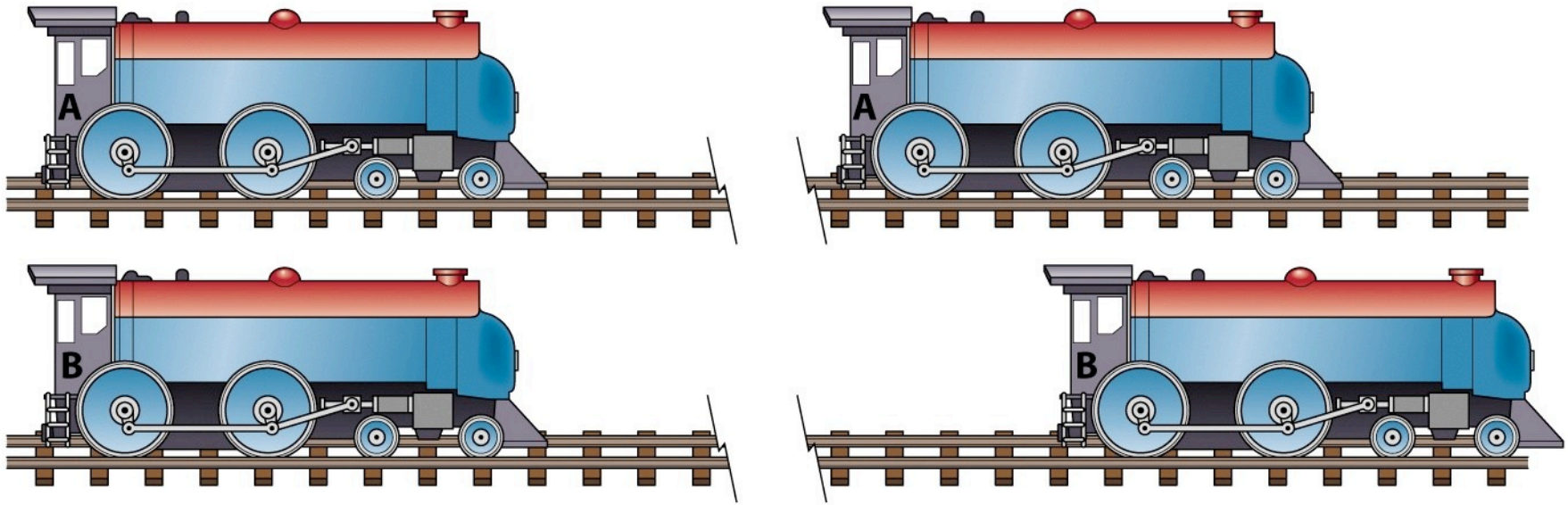
- **Development of symbolic representations, that is, the use of one object to stand for another.**
  - For instance, a stick becomes a horse; an eyepatch and kerchief make a pirate.
- **Characteristic Errors**
  - Egocentrism: Looking at the world only from one's own point of view.
  - Centration: focusing on a single, perceptual feature to the exclusion of other features

Egocentrism



Egocentrism

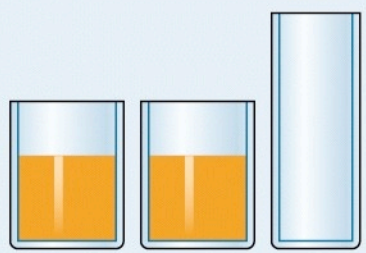
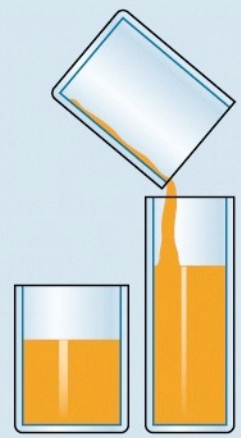
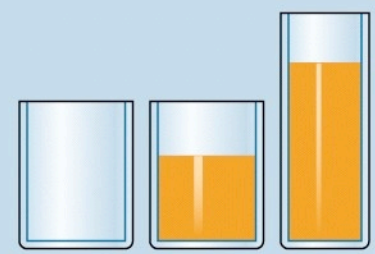
Centration



Piaget's Concrete Operations Stage

- **Stage in which logical thinking begins.**
- **Exemplified by the conservation concept.**
  - Children understand the conservation concept when they understand that changing the appearance or arrangement of objects does not change their key properties.

Conservation Concepts

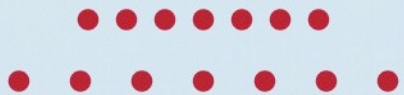
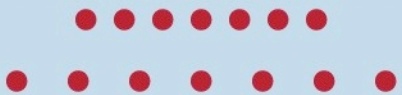
	PHASE 1	PHASE 2	PHASE 3
CONSERVATION OF LIQUID QUANTITY	 "Do they have the same amount of orange drink or a different amount?"	 "Now watch what I do" (pouring contents of one glass).	 "Now, do they have the same amount of orange drink or a different amount?"

Liquid Quantity Problem

Conservation Concepts

CONSERVATION OF SOLID QUANTITY	 "Do they have the same amount of clay or a different amount?"	 "Now watch what I do" (stretching one piece of clay).	 "Now, do they have the same amount of clay or a different amount?"

Conservation of Number

CONSERVATION OF NUMBER	 "Is there the same number or a different number?"	 "Now watch what I do" (spreading one row).	 "Now, is there the same number or a different number?"

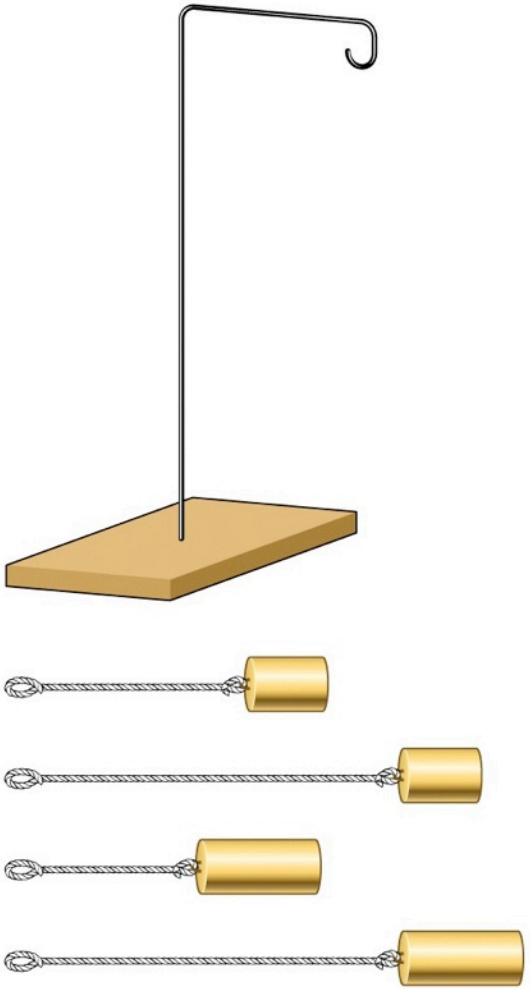
Numeric Quantity Problem

Piaget's Formal Operations Stage

- **Ability to think abstractly and reason hypothetically.**
- **Ability to engage in scientific thinking.**

Pendulum Problem

- **What influences how long it will take for the pendulum to complete an arc?**



Empirical Evaluation

- **Very greatly underestimated children's abilities**
  - Sensorimotor child is a myth
    - Perception of occluded objects and events indicates enduring representations exist long before a child's first birthday (e.g., Johnson & Aslin, 1996)

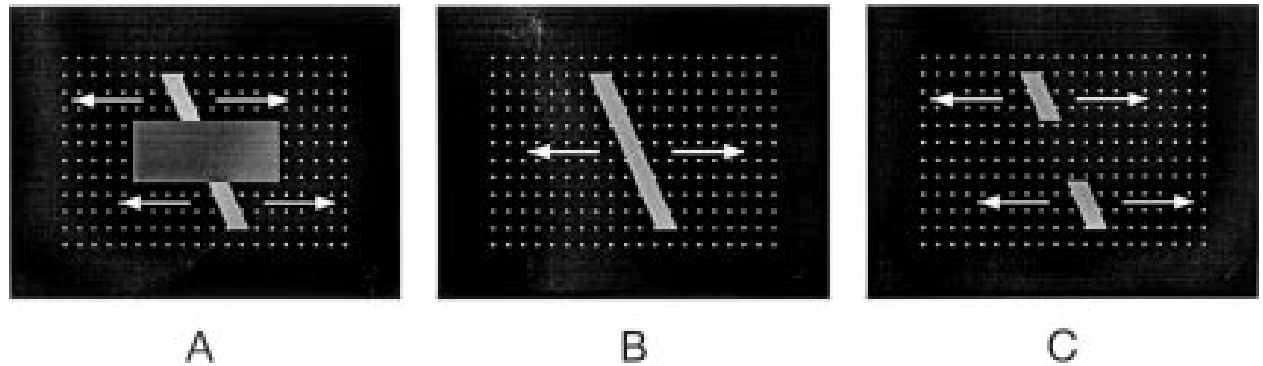


FIG. 1. Displays employed in past research to investigate young infants' perception of partly occluded objects (adapted from Johnson & Aslin, 1996). (A) A partly occluded rod, with aligned edges, moves relative to a stationary occluder. (B) A complete rod. (C) A broken rod. After habituation to the partly occluded rod display, infants showed a preference for the broken rod relative to the complete rod, indicating perception of the rod's unity during habituation. A control group preferred neither test display.

Empirical Evaluation

- **Very greatly underestimated children's abilities**
  - Preoperational child is a myth (Gelman, 1978)
    - Class inclusions are represented by preschoolers (Markman, 1990)
    - *Conservation* errors are almost universally *conversational* maxims (Mehler & Bever, 1968)

Empirical Evaluation

- **Between-concept changes not stage-like**
  - Successful conservation of liquid, solid, and numeric quantity do not rise (or fall) together as if they were part of a general pattern of thinking (Siegler, 1981)
  - Characteristic errors on one type of conservation (e.g., liquid) do not reliably predict types of errors on other types of conservation (e.g., number)

Empirical Evaluation

- **Within-concept changes not stage-like**
  - Even within a particular conservation task (e.g., numeric quantity), children's errors do not follow a set sequence
    - regressions are common
    - "stages" are skipped
    - frequency of correct responses often emerge gradually

Empirical Evaluation

- **No progress in understanding basic mechanisms of change**
  - "For 40 years now we have had assimilation and accommodation, the mysterious and shadowy forces of equilibration, the Batman and Robin of the developmental processes. What are they? How do they do their thing? Why is it after all this time, we know more about them than when they first sprang on the scene? What we need is a way to get beyond vague verbal statements of the nature of the developmental processes" (Klahr, 1982)

Empirical Evaluation

- **Children are terrible experimenters; they do not learn to control variables systematically on their own (Klahr, 2004)**

David Klahr and Milena Nigam

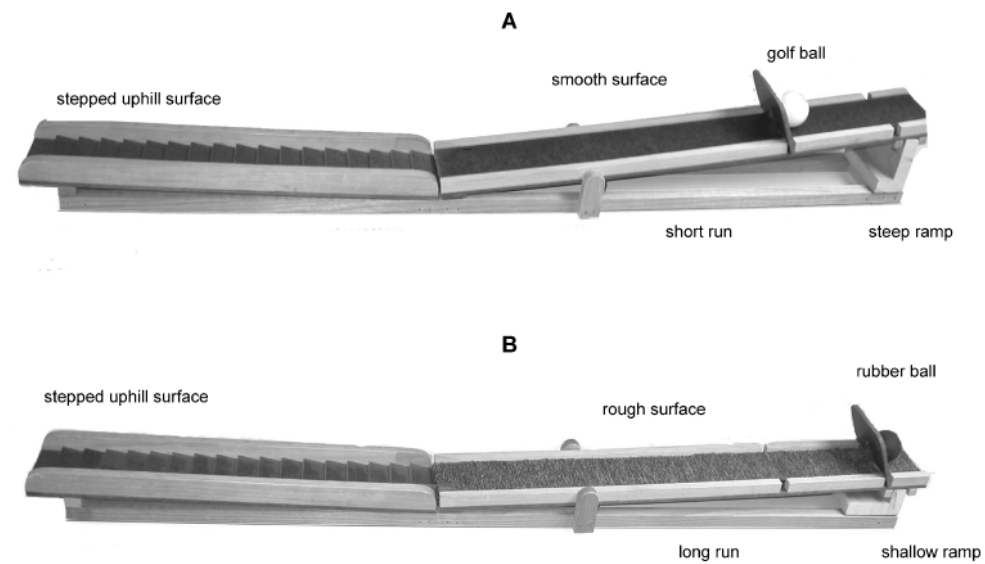


Fig. 1. The ramps used during the exploration and assessment phases. On each of the two ramps, children could vary the steepness, surface, and length of the ramp, as well as the type of ball. The confounded experiment depicted here contrasts (a) a golf ball on a steep, smooth, short ramp with (b) a rubber ball on a shallow, rough, long ramp.

Empirical Evaluation

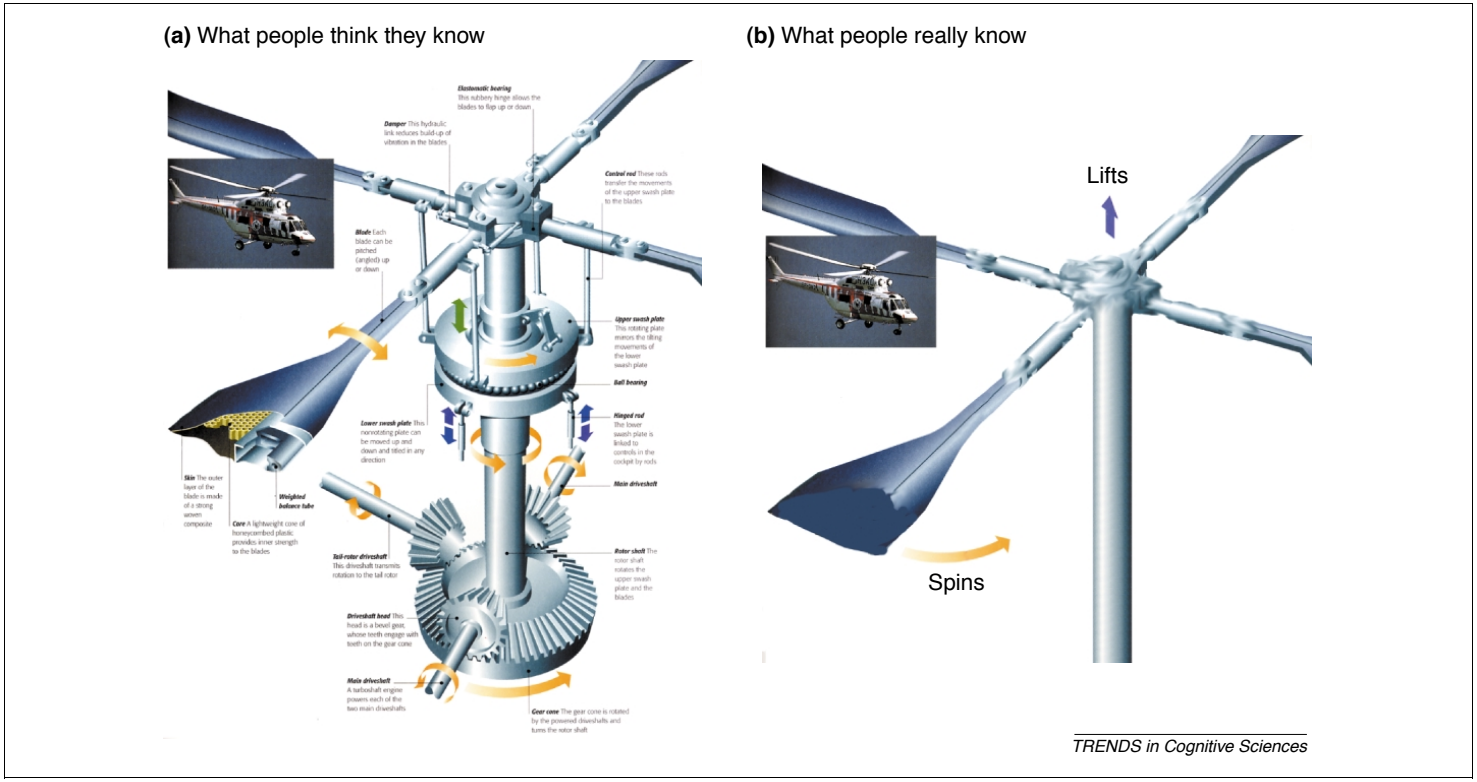


Fig. 1. When people estimate how deeply they understand the workings of various systems, they tend to think they know for more depth of detail than they actually do. When asked how a helicopter works, they seem to think they have knowledge approximating a detailed annotated drawing, but actually have a much coarser understanding corresponding to little more than the sense of a thing with blades that turn and provide lift. This illusion is quite specific to explanatory kinds of knowledge. People estimate the depth of their knowledge of procedures, facts and narratives much more accurately. Adapted with permission from [51].

- **Children are very seldom interested in attaining detailed causal understanding (though they do believe it exists)**

Criticisms of Piaget's Theory

- **Sociocultural approach:**
  - Children's thinking is affected by social interactions
- **Core Knowledge approach:**
  - Infants and young children have and use a lot of innate mental machinery for complex abstract thought
- **Information processing approach:**
  - Children's thinking is a computational process
  - Children's thinking is not as consistent as the stages suggest.

Sociocultural Approach

- **Russian psychologist Lev Vygotsky portrayed children as social beings intertwined with other people who were eager to help them learn and gain skills.**

Sociocultural Approach

- **Child as apprentice**
  - Some of children's abilities are culturally-dependent
  - Some cognitive change originates in social interaction
  - Children are both learners and teachers.

Some Important Social Interactions

- **Sharing our thoughts**
  - Joint attention: Infants and social partners focus on common referent.
  - Social referencing: Children look to social partners for guidance about how to respond to unfamiliar events.
- **Social scaffolding:**
  - More competent people provide temporary frameworks that lead children to higher-order thinking.
- **Zone of proximal development:**
  - The range between what children can do unsupported and what they can do with optimal social support.

Empirical Evaluation

- **Social support is often a necessary but insufficient condition for cognitive development (Siegler & Liebert, 1983)**
- **Effect of language on thought is still hotly debated**
- **ZPD almost impossible to falsify**

Core-Knowledge Approach

- **Child as Primate Scientist**
  - Children have innate cognitive capabilities that are the product of human evolutionary processes.
  - Focus on human universals (e.g., language, social cognition, biological categorization, using numbers)
  - Children are much more advanced in their thinking than Piaget suggested.

Core Knowledge Approach to Infant Cognition

- **Elizabeth Spelke: "If children are endowed with abilities to perceive objects, persons, sets, and places, then they may use their perceptual experience to learn about the properties and behavior of such entities...."**

Core-Knowledge Approach

- **Principles of core-knowledge theories**
  - Children have innate cognitive capabilities that are the product of human evolutionary processes.
    - Children are much more advanced in their thinking than Piaget suggested.
  - Focus on universally adaptive aspects of human cognition
    - arise early in infancy
    - have neurophysiological correlates
    - cross-culturally uniform
    - basis of more complex understandings

Core-Knowledge Theories

- **Children's core knowledge:**
  - basic physics (the object concept, support, containment)
  - animate/inanimate distinction
  - numerical representation
  - language
  - biological categorization

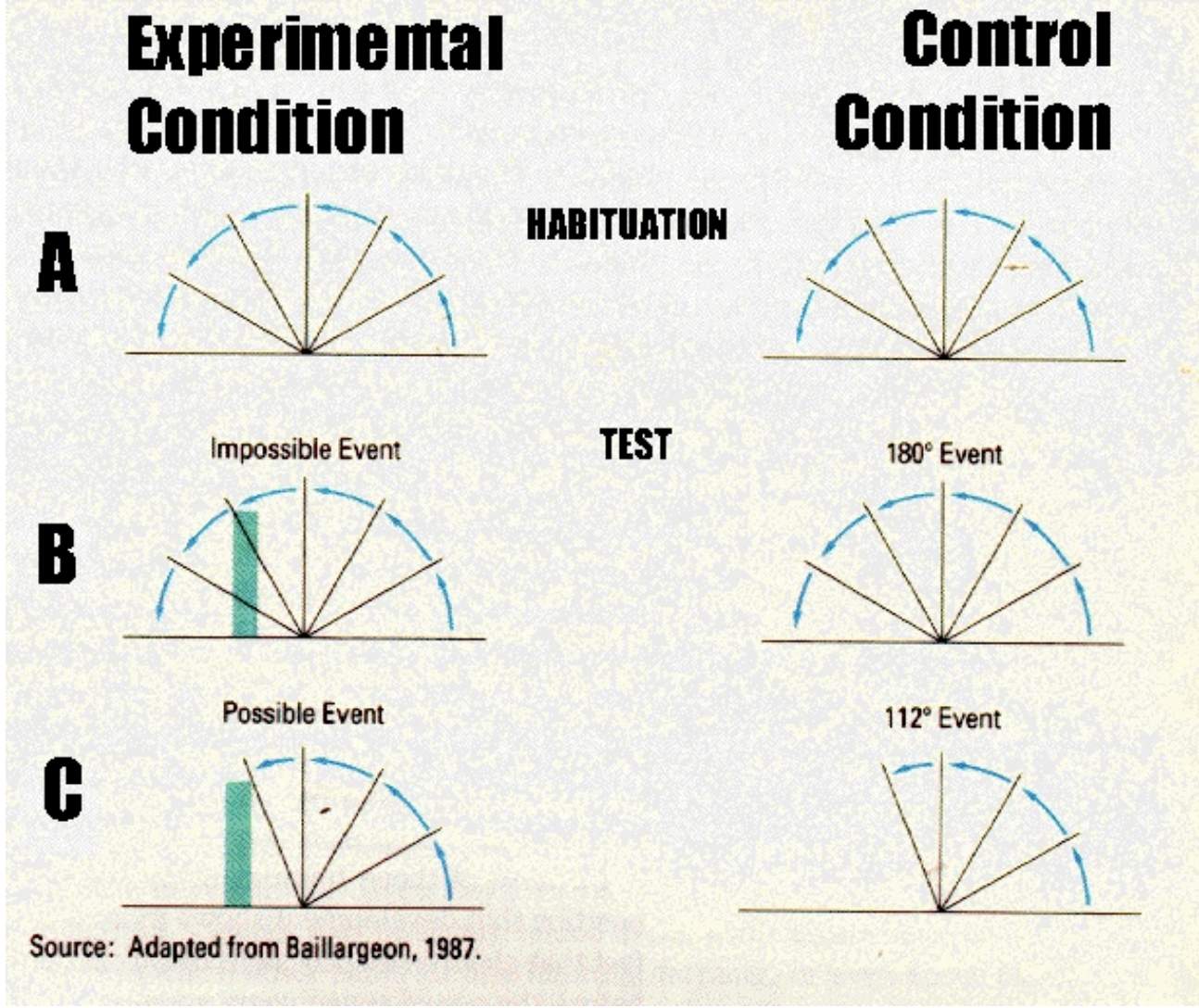
Object concept

- **The developmental sequence that Piaget described has been replicated in many different studies**
  - Piaget's task also replicates well
  - But what about his explanation?
  - For the infant, does out-of-sight = out-of-mind?

Maybe not

Baillargeon (1987):

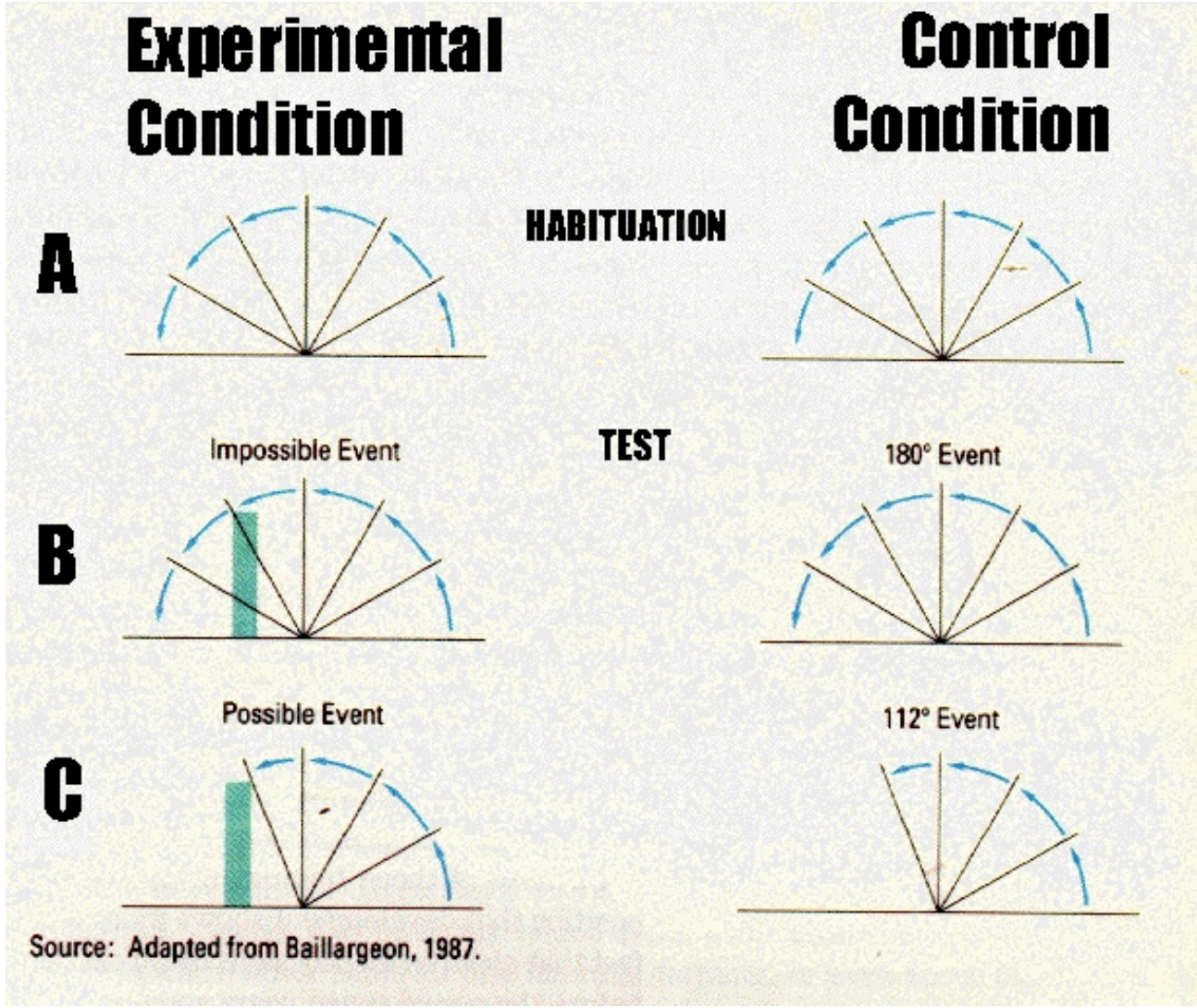
- **Do infants understand that unseen objects continue to exist and have certain properties?**



Source: Adapted from Baillargeon, 1987.

Maybe not

Baillargeon (1987) found that 3.5 month old infants understand that unseen objects continue to exist and have certain properties.

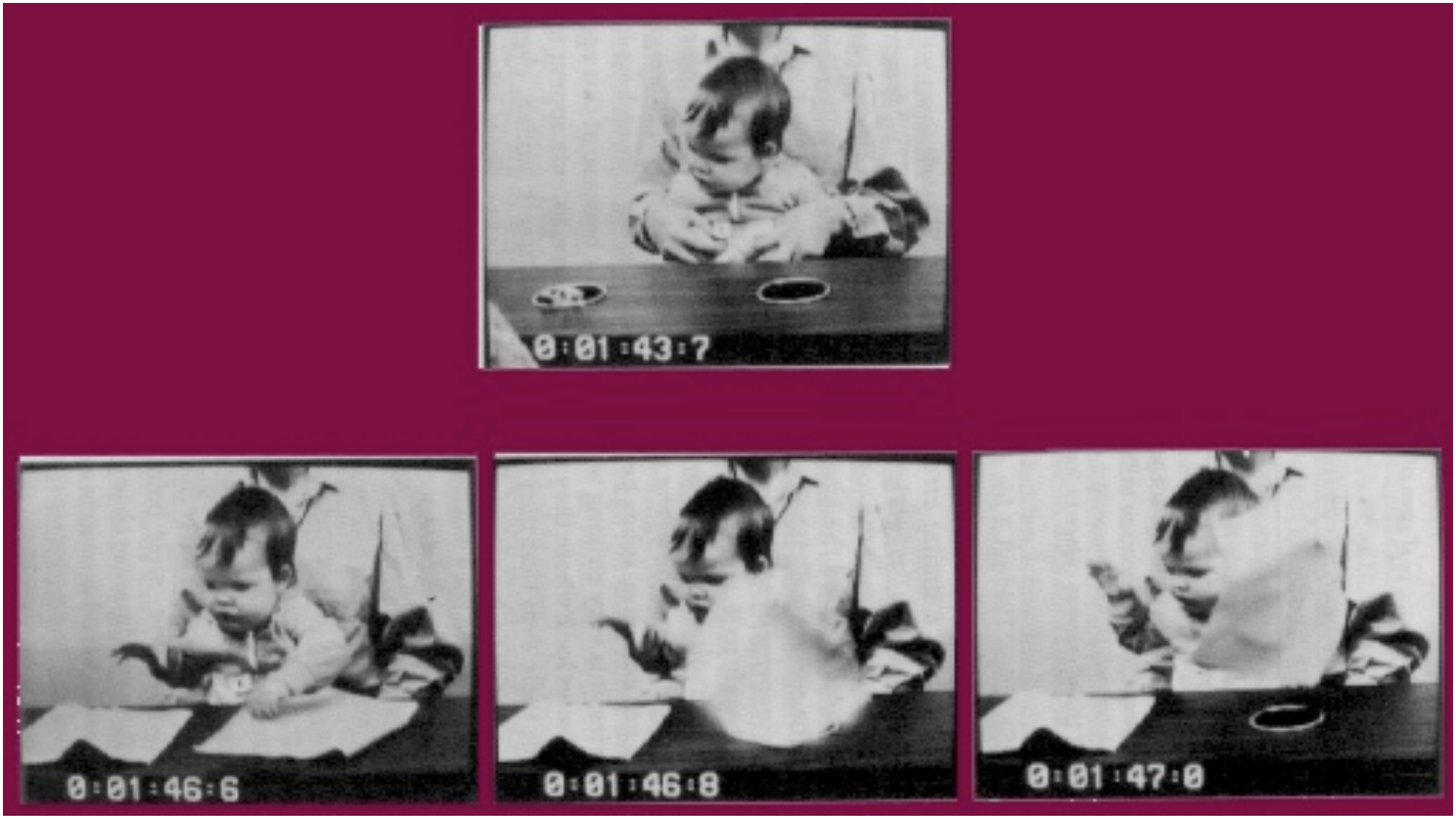


Source: Adapted from Baillargeon, 1987.

Object representation vs. Manual Search

- **Diamond (1987): Infants from 5 to 7 months understand that unseen objects continue to exist, but they make A-not-B errors due to ancillary deficits**
  - the inability to inhibit behavior (not suggested by Piaget) and
  - the failure to coordinate means-end behavior (suggested by Piaget).
- **Ancillary deficits are the result of a premature brain.**
  - The inability to inhibit prepotent responses is the result of a premature dorsolateral prefrontal cortex.
  - The inability to coordinate actions into means-end sequences is the result of few callosal connections between the supplementary motor areas of the left and right hemispheres.

Object representation vs. Manual Search



Infant 'Physics'

<u>Support vs. Containment</u>

- **Familiarization:**
  - screen is lowered to hide a portion of the display
  - ball is then dropped behind screen
  - screen is raised
  - *ball is seen resting on the floor of the display*
  - looking time to the event is measured

Infant Physics

<u>Support vs. Containment</u>

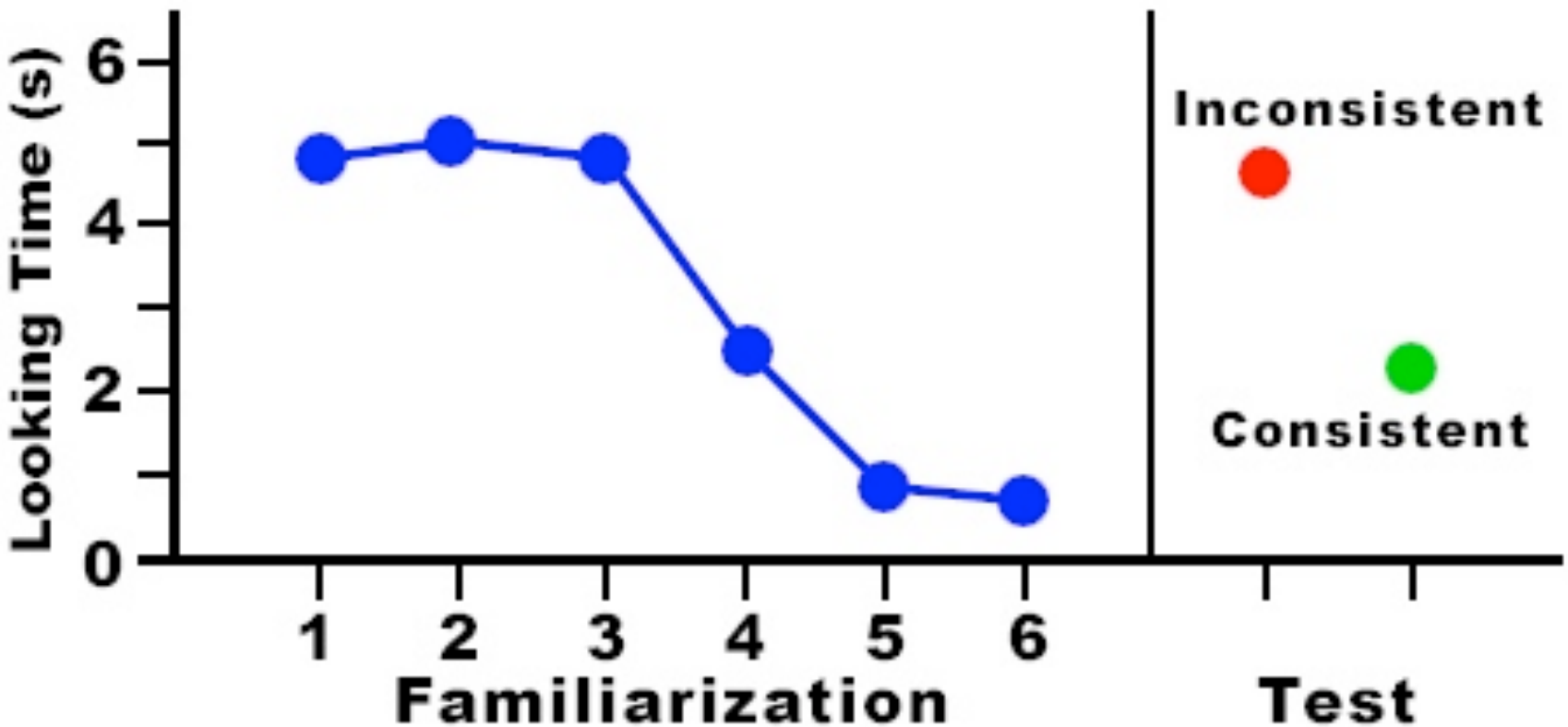
- **Test (Consistent Display):**
  - a platform is added above the floor
    the screen is lowered to hide both surfaces
  - a ball is then dropped behind the screen
  - the screen is raised
  - *the ball is seen resting on the raised platform*
  - looking time to the event is measured

Infant Physics

<u>Support vs. Containment</u>

- **Test (Inconsistent Display):**
  - a platform is added above the floor
    the screen is lowered to hide both surfaces
  - a ball is then dropped behind the screen
  - the screen is raised
  - *the ball is seen resting on the floor*
  - looking time to the event is measured

Infant Physics



Results: 4-month-olds look reliably longer at the Inconsistent event

Infant 'Physics'

<u>Solidity of Barriers</u>

- **Familiarization:**
  - a screen is lowered to hide a portion of the display
  - ball rolls behind screen
  - screen is raised
  - *<u>ball is seen resting against right hand wall</u>*
  - looking time to event is measured

Infant Physics

<u>Solidity of Barriers</u>

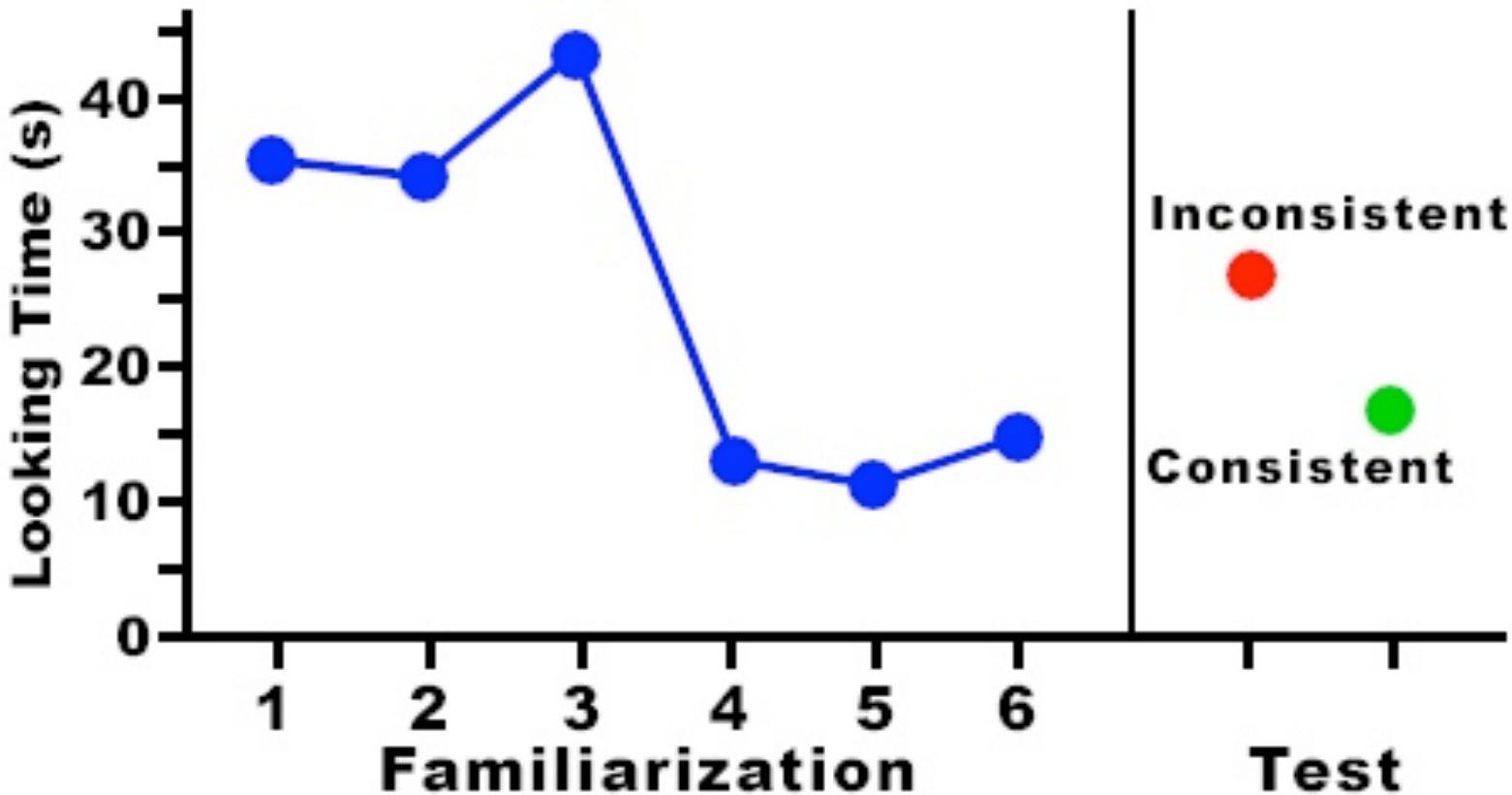
- **Test (Consistent Display):**
  - barrier is lowered to floor of display
  - screen is lowered to hide portion of display
  - ball rolls behind screeen
  - screen is raised
  - *<u>the ball is seen resting against barrier</u>*
  - looking time to the event is measured

Infant Physics

<u>Solidity of Barriers</u>

- **Test (Inconsistent Display):**
  - barrier is lowered to floor of display
  - screen is lowered to hide portion of display
  - ball rolls behind screeen
  - screen is raised
  - *<u>the ball is seen resting against right hand wall</u>*
  - looking time to the event is measured

Infant Physics



Results: 2.5-month-olds look reliably longer at the Inconsistent event

Information-Processing Approach

- **Child as Computer**
  - Concerned with the development of domain-general processes
    - learning,
    - memory, and
    - problem-solving skills.
  - Provides detailed description of the steps involved in thinking (like a computer program)

Conversation with a Child

- *Scene: Daughter and father in the yard. A playmate rides in on a bike.*
  - *Child*: Daddy, would you unlock the basement door?
  - *Father*: Why?
  - *C*: Cause I want to ride my bike.
  - *F*: Your bike is in the garage.
  - *C*: But my socks are in the dryer!

Information Processing Analysis

- **Top goal: I want to ride my bike.**
  - constraint: I need to shoes to ride comfortably.
  - fact: I'm barefoot.
    - Subgoal 1: Get my sneakers
    - Fact: The sneakers are in the yard.
    - Fact: Sneakers are uncomfortable on bare feet.
      - Subgoal 2. Get my socks.
      - Fact: The sock drawer was empty this morning.
      - Inference: The socks are probably in the dryer.
        - *Subgoal 3:* Get them from the dryer.
        - Fact: The dryer is in the basement.
          - Subgoal 4: Go to the basement.
          - Fact: It's quicker to go through the yard entrance.
          - Fact: The yard entrance is always locked.
            - Subgoal 5: Unlock the door to the basement.
            - Fact: Daddies have keys to everything.
              - Subgoal 6: Ask daddy to unlock the door.

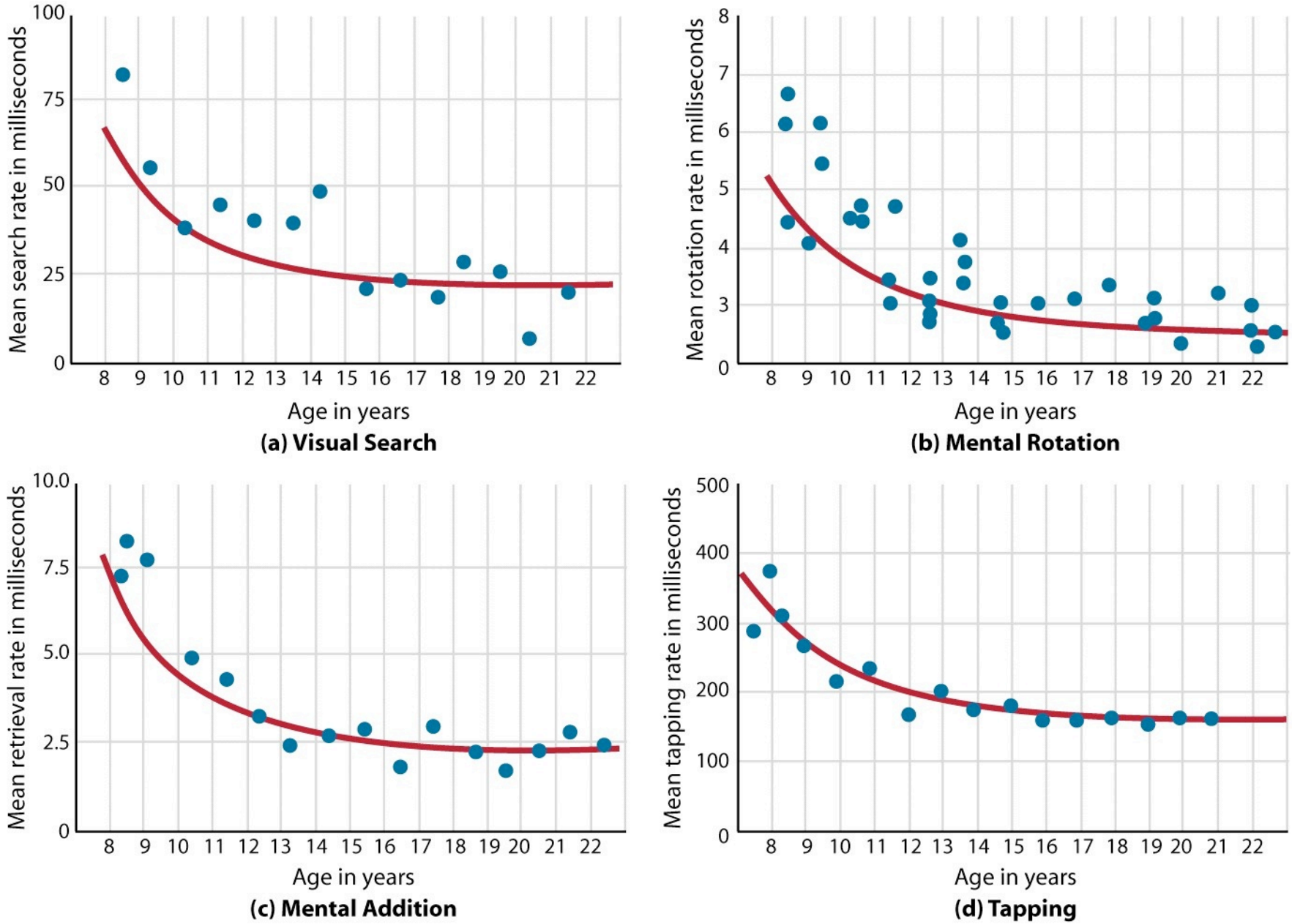
Information Processing Approach

- **Three major principles:**
  - Thinking is information processing.
  - Change is produced by a process of continuous self-modification.
  - The steps of change can be precisely specified by identifying mechanisms of change.

Information-Processing Approach: What changes?

- **<u>Speed</u> of memory processes change with practice**
  - Associating events with one another.
  - Recognizing objects as familiar.
  - Generalizing from one instance to another.
  - Encoding (representing features of objects and events in memory).

Increase in Processing Speed

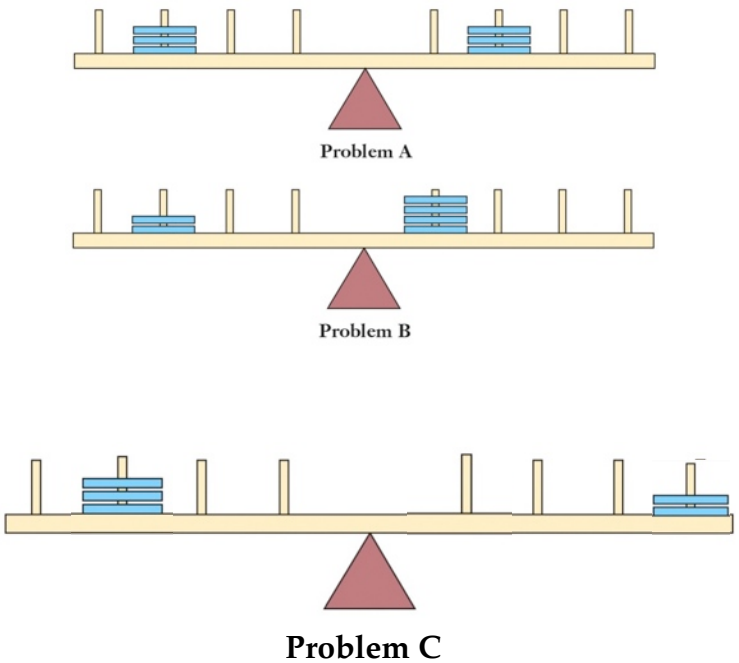


Information-Processing Approach: What changes?

- **Rules and strategies**
  - Rules are are like lines of code in a computer program; children add and subtract rules over development.

Information-Processing Approach: What changes?

- **Balance Scale Problem** (Siegler, 1976)
  - *Rule 1*: If the weight is same on both sides, side with more weight goes down.
  - *Rule 2*: If one side has more weight, predict it will go down. If weights on two sides are equal (Problem A), choose side with greater distance.
  - *Rule 3*: If both weight and distance are equal, predict balance. If one side has more weight or distance, and two side are equal on other dimension, predict that side with greater value on unequal dimension will go down. If one side has more weight and other more distance, guess (Problem B).
  - *Rule 4*: Multiply weight times distance (torque). Predict side with greater torque goes down.



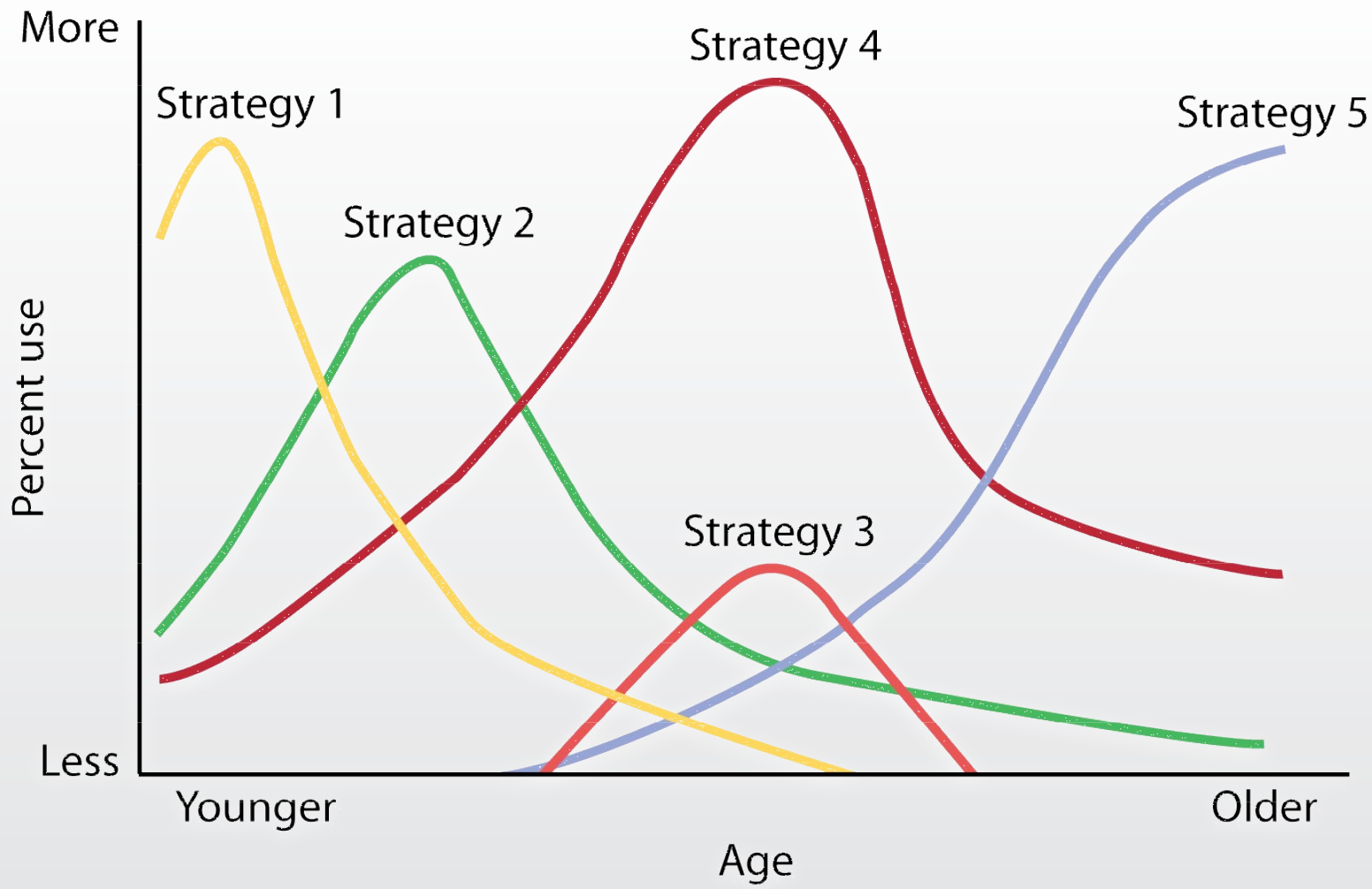
Anatomy of Piagetian problems

Task	A. Dominant dimension	B. Subordinate dimension	C. Relation between A & B
Balance scale	Weight	Distance from fulcrum	C = A x B
Conservation of liquid	Height of liquid	cross-sectional area of liquid	C = A x B
Conservation of number	Length of row	Density of objects in row	C = A x B

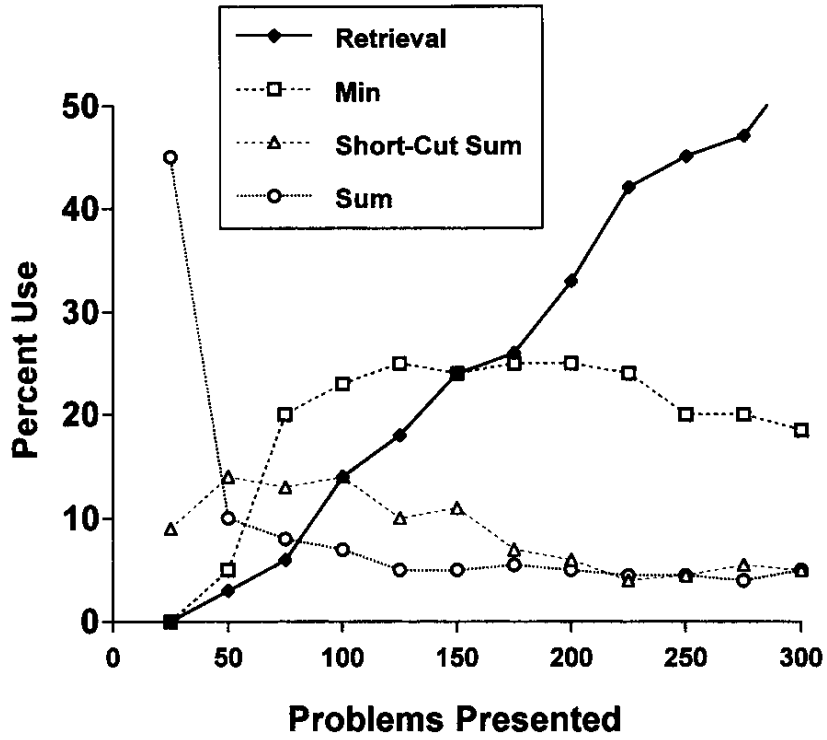
Information-Processing Approach: What changes?

- **Rules and strategies**
  - Strategies are flexible approaches to solving problems; strategies compete with another over development.
    - E.g., How would a computer solve the problem 7 + 6?

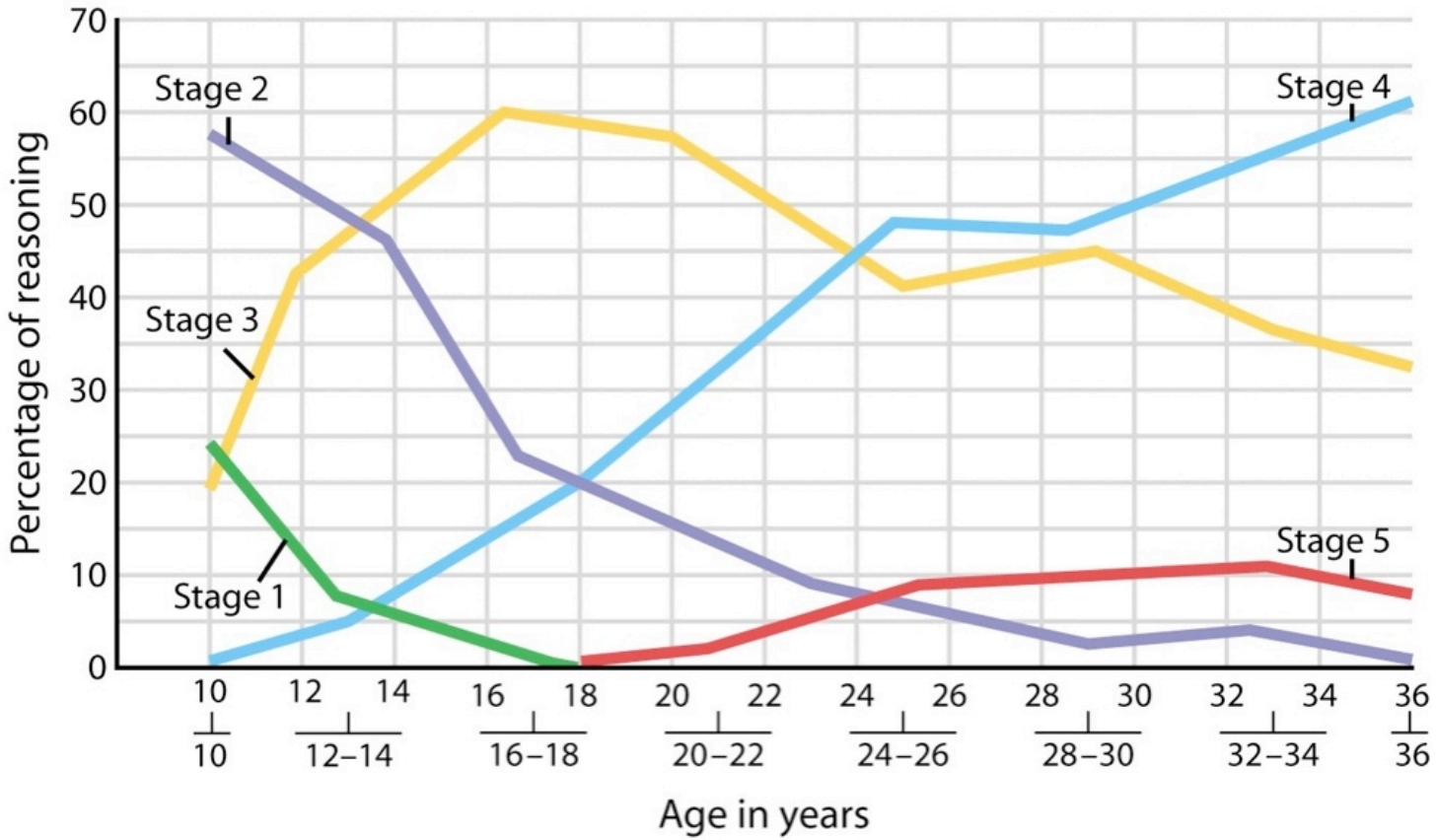
Overlapping-Waves Model of Information Processing



Microgenetic



Moral Reasoning



Stage 1: Blind Obedience
Stage 2: Fear of Punishment
Stage 3: Maintaining Relationships
Stage 4: Laws/Duties
Stage 5: Universal principles