Theories of Cognitive Development

Psychology of Childhood
Cognitive Development

- Age-related changes in children’s knowledge and thinking
  - learning and memory
  - causal knowledge
  - language
  - concepts
  - mental abilities related to academic skills
Theories of Cognitive Development

- Why do we bother with theories of cognitive development
  - Organize understanding of many individual cognitive changes
  - Raise crucial questions about human nature
  - Motivate new research
Influential Theories of Cognitive Development

- Piaget’s theory
- Sociocultural theories
- Core-knowledge theories
- Information-processing theories
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 stages of cognitive development, with the following properties.
  - **Qualitative change**: Children of different ages (and at different stages) think in different ways.
  - **Broad applicability**: The type of thinking at each stage pervades topic and content areas.
  - **Brief transitions**: Transitions to higher stages of thinking are not necessarily continuous.
  - **Invariant sequence**: 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): Reflexive Activity**
  - Building knowledge through reflexes (grasping, sucking).
  - No attempt to locate objects that have disappeared.

- **Substage 2 (1 to 4 months): Primary Circular Reactions**
  - 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): Secondary Circular Reactions**
  - 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): Coordination of Secondary Reactions**
  - 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): Tertiary Circular Reactions**
  - 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): Symbolic Thought**
  - 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 in Spatial Reasoning
Egocentrism in Language

My dad is a policeman...

I have a real big dog...

He caught a robber once...

He licks my face all the time...
Seriation cases of seriation, thinking about classes, and conservation. Piaget suggested. Consider, for example, the difficulties to explain if the children truly lacked certain cognitive structures. Younger children typically still make errors. But in many cases, the patterns of failures and successes on Piaget's tasks suggests that young children had failed at Piagetian tasks.

In Piaget's seriation task, the child is asked to arrange a set of rods in order from shortest to longest. Doing so correctly requires careful attention to the way each rod's length relates to the others. If you can remember all those relationships, you will quickly know that if rod A is longer than rod B, and rod B is longer than rod C, then rod A is also longer than rod C. You must also remember to look at both ends of the rods and arrange them along the tops if the bottoms are also changing relative to each other.

If the younger child truly lacks the ability to use transitive reasoning, then it should be possible to show clear differences when they attempt seriation tasks (Halford et al., 1998). Piaget's original seriation task because of problems with memory or young children typically fail at this task because of the tasks' memory demands. But consider for a moment how carefully designed experiments can tease apart the reasons children fail at Piagetian tasks.

In the studies designed to test the alternative explanations, researchers found that children younger than around 7 years of age (for example, to understand that if Adam is taller than Bill, then Adam also must be taller than Chris). Piaget claimed that preoperational children's cognitive structures do not allow them to use transitive reasoning (for example, D>B). In this scenario, in which they were not be swayed by what looks like constant length increases requires careful attention to the way each rod's length relates to the others. If you can remember all those relationships, you will quickly know that if rod A is longer than rod B, and rod B is longer than rod C, then rod A is also longer than rod C. You must also remember to look at both ends of the rods and arrange them along the tops if the bottoms are also changing relative to each other.

Piaget's development of classic seriation tasks, in which children are asked to arrange a group of objects must be ordered according to a shared property, such as size or height. One of these tasks is to order rods according to their length, which is difficult for children younger than roughly 7 years of age (see Figure 9.10). Their inability to correctly report size inequalities when just looking at the rods inserted in the box. They were then asked about several new inequalities. This finding suggests that young children had failed at the novel inequalities. Which is greater, B or D? I know that E>D, D>C, B>A, so D must be greater than B. Which is greater, C or B? Using the setup shown in Figure 9.11, Bryant and Trabasso extensively trained young children to compare pairs of rods inserted in the box. They were then asked about several new inequalities. This study clearly illustrates how carefully designed experiments can tease apart the reasons children fail at Piagetian tasks.
**Centration in Class inclusion**

When asked, "Are there more daffodils or more flowers?" the child responds, "There are more daffodils."
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

<table>
<thead>
<tr>
<th>Conservation of Liquid Quantity</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>“Do they have the same amount of orange drink or a different amount?”</td>
<td>“Now watch what I do” (pouring contents of one glass).</td>
<td>“Now, do they have the same amount of orange drink or a different amount?”</td>
</tr>
</tbody>
</table>
Liquid Quantity Problem
Conservation Concepts

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conservation of Solid Quantity</td>
<td>“Do they have the same amount of clay or a different amount?”</td>
</tr>
<tr>
<td></td>
<td>“Now watch what I do” (stretching one piece of clay).</td>
</tr>
<tr>
<td></td>
<td>“Now, do they have the same amount of clay or a different amount?”</td>
</tr>
</tbody>
</table>
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?
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.
Empirical Evaluation

- Piaget 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 errors (Mehler & Bever, 1968; McGarrigle & Donaldson, 1974)
Class inclusion

Piaget’s question: More blue circles or more circles all together?

Markman’s question: More baby circles or more circles in the family?
Fig. 1. The length of the rows in (a) was 7 inches (18 cm) for M & M’s and 8 inches (20 cm) for clay pellets; in (b) 7 and 3 inches (18 and 8 cm) for M & M’s and 8 and 5 inches (20 and 13 cm) for clay pellets. There was a 1½-inch (3-cm) space between each of the four clay pellets and a 2-inch (5-cm) space between each of the four M & M’s. The clay pellets were ½ inch (1.3 cm) in diameter. The M & M candies were all of the same color.

Fig. 2. The proportion by age of responses choosing the row with more members in the situation shown in Fig. 1b. Numbers inside bars indicate total number of subjects of that age.
McGarrigle & Donaldson (1974)

“Oh look! It’s naughty teddy! He’s going to spoil the game!”
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

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

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.
Children are very seldom interested in attaining detailed causal understanding (though they do believe it exists)
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)
Piaget’s Theory

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 Theory

Counter-evidence

1. Piaget generally underestimated preschoolers’ cognitive abilities by using needlessly misleading tasks
2. Even using Piaget’s tasks, changes in performance were not stage-like
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.
Vygotsky on Piaget

- Vygotsky, unlike Piaget, thought that abstract thinking could not develop on its own, but required language and Western schooling.
  - To test this, Vygotsky tested peasants in Uzbekistan, varying in age, sex, and exposure to the new schools that had been established.
  - Of these variables, only schooling correlated with abstract thinking.
Unschooled Adult Peasant

*Cotton can grow only where it is hot and dry. In England it is cold and damp. Can cotton grow there?*

I don’t know

*Think about it.*

I’ve only been in the Kashgar country; I don’t know beyond that . . .

*But on the basis of what I said to you, can cotton grow there?*

If the land is good, cotton will grow there, but if it is damp and poor, it won’t grow. If it’s like the Kashgar country, it will grow there too. If the soil is loose, it can grow there too. Of course.
All bears are white where there is always snow; in Zovaya Zemlya there is always snow; what color are the bears there?

I have seen only black bears and I do not talk of what I have not seen.

What do my words imply?

If a person has not been there he can not say anything on the basis of words. If a man was 60 or 80 and had seen a white bear there and told me about it, he could be believed.
What do a chicken and a dog have in common?

They are not alike. A chicken has two legs, a dog has four. A chicken has wings but a dog doesn't. A dog has big ears and a chicken's are small.

Is there one word you could use for them both?

No, of course not.

Would the word "animal" fit?

Yes.
What do a fish and a crow have in common?

A fish — it lives in water. A crow flies. If the fish just lies on top of the water, the crow could peck at it. A crow can eat a fish but a fish can't eat a crow.

Could you use one word for them both?

If you call them "animals", that wouldn't be right. A fish isn't an animal and a crow isn't either. A crow can eat a fish but a fish can't eat a bird. A person can eat fish but not a crow.
Syllogistic Reasoning

"If Juan and Jose drink a lot of beer, the mayor of the town gets angry. Juan and Jose are drinking a lot of beer now. Do you think the mayor is angry with them? Kpelle woman: "No - so many men drink beer, why should the mayor get angry?"
Types of Social Interactions

- **Indirect Social Supports**
  - **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)
Peers can be terrible teachers because their confidence outweighs their competence (Levin & Druyan, 1993)
Empirical Evaluation

Counter-factual Syllogism

If Juan and Jose drink a lot of beer, the mayor of the town gets angry.
Juan and Jose are drinking a lot of beer now.
Do you think the mayor is angry with them?

Ordinary Syllogism

If the horse is well fed, it cannot work very well.
Today, Rama’s horse was well fed.
Can it work very well today?

Dash & Das, 1987
Vygotsky’s Theory

- **Counter-evidence**
  1. Social interactions aren’t as supportive as hypothesized
  2. Peers can be terrible teachers
  3. Some forms of syllogistic reasoning seem to be universal and not require schooling
Classical Theories

- The developmental theories of Vygotsky and Piaget continue to influence children’s schooling
  - Piaget: School readiness
  - Piaget: Hands-on science
  - Vygotsky: Peer tutoring
- Whether this influence has been good or bad will probably require further testing.
Modern theories of cognitive development differ from classical theories

- No heroic theorists
- No canonical texts
- Family resemblance structure
- Still evaluating...
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)
Scene: Daughter and father in the yard. A playmate rides in on a bike.

Child: Daddy, would you unlock the basement door?
Father: Why?
Child: Cause I want to ride my bike.
Father: Your bike is in the garage.
Child: But my socks are in the dryer!
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?

- **Speed 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

(a) Visual Search

(b) Mental Rotation

(c) Mental Addition

(d) Tapping
Information-Processing Approach: What changes?

- **Rules and strategies**
  - Rules 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, predict balance; otherwise, 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

<table>
<thead>
<tr>
<th>Task</th>
<th>A. Dominant dimension</th>
<th>B. Subordinate dimension</th>
<th>C. Relation between A &amp; B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance scale</td>
<td>Weight</td>
<td>Distance from fulcrum</td>
<td>$C = A \times B$</td>
</tr>
<tr>
<td>Conservation of liquid</td>
<td>Height of liquid</td>
<td>cross-sectional area of liquid</td>
<td>$C = A \times B$</td>
</tr>
<tr>
<td>Conservation of number</td>
<td>Length of row</td>
<td>Density of objects in row</td>
<td>$C = A \times B$</td>
</tr>
</tbody>
</table>
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

- Strategy 1
- Strategy 2
- Strategy 3
- Strategy 4
- Strategy 5

Percent use vs. Age

More
Less
Younger
Older
Microgenetic
Moral Reasoning

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

- **Children’s domain-specific theories:**
  - Children actively organize their understanding into informal causal theories
    - psychology
    - biology
    - physics
Bottom Line

- Post-Piagetian theories deal with different aspects of development
  - sometimes conflict between approaches, sometimes greater conflict within an approach
- Most researchers view different approaches as complementary
- No Grand Unified Theory (yet)