Thinking During Play

Micah B. Goldwater, PhD
University of Sydney

Readings

- Quick commentaries online to see the debate on play-based education

http://www.scholastic.com/teachers/article/early-childhood-today-interviews-dr-herb-ginsburg-math-education-young-children

http://preschoolmatters.org/2014/03/03/play-mathematics-and-false-dichotomies/

http://www.salon.com/2013/08/26/school_is_a_prison_and_damaging_our_kids/

Readings

- Legare (2014) *Child Development Perspectives*
- Siegler, R. S. (2009). *Child Development Perspectives,*

Outline

- General importance of play
- Scientific thinking in play
- Logical thinking in play
- Mathematical thinking in play
- How can we use play to improve early education?

Play is important and is(was) in decline

- Children play, and it is good for them
- Wenner (2009) reviews in Scientific American
- Evidence that play reduces stress and anxiety
  - Anxious kids much less anxious after imaginative play
- Improves social skills
  - After free play, kids given social conflicts to reason about, offer better solutions
- Improves creativity
  - After playing with tools, kids generate more creative uses for them
- Increases self-regulation, lowers impulsivity

Play is important and is(was) in decline

- "According to a paper published in 2005 in the Archives of Pediatrics & Adolescent Medicine, children's free-play time dropped by a quarter between 1981 and 1997. Concerned about getting their kids into the right colleges, parents are sacrificing playtime for more structured activities. As early as preschool, youngsters' after-school hours are now being filled with music lessons and sports—reducing time for the type of imaginative and rambunctious cavorting that fosters creativity and cooperation."

- Peter Gray surveys evidence suggests kids are less creative on the whole than they were
  - See this new paper Gray, P., Lancy, D. F., & Bjorklund, D. F. (2023). Decline in Independent Activity as a Cause of Decline in Children's Mental Well-being: Summary of the Evidence. *The Journal of Pediatrics*, *260*.
  - Already criticisms e.g., comparing mental health across decades is confounded with diagnostic criteria, etc.

What is play like?

- Sensorimotor play
  - learning and repeating action sequences
  - 50% of play up to 2 years of age
- Symbolic/pretend play: multiple kinds
- Constructive play
  - Building/making stuff
  - 50% of play of 4 – 6 year olds
- Dramatic play
  - Imaginary situations and role playing in such situations
  - 2-3 years old often engage in parallel play
  - 3 – 5 more group play
- Games with rules
  - Can be culturally pre-existing games with established rules, or kids can make up their own rules. More structured than dramatic play.
  - Grows dramatically from 4 -7

Thinking in play?

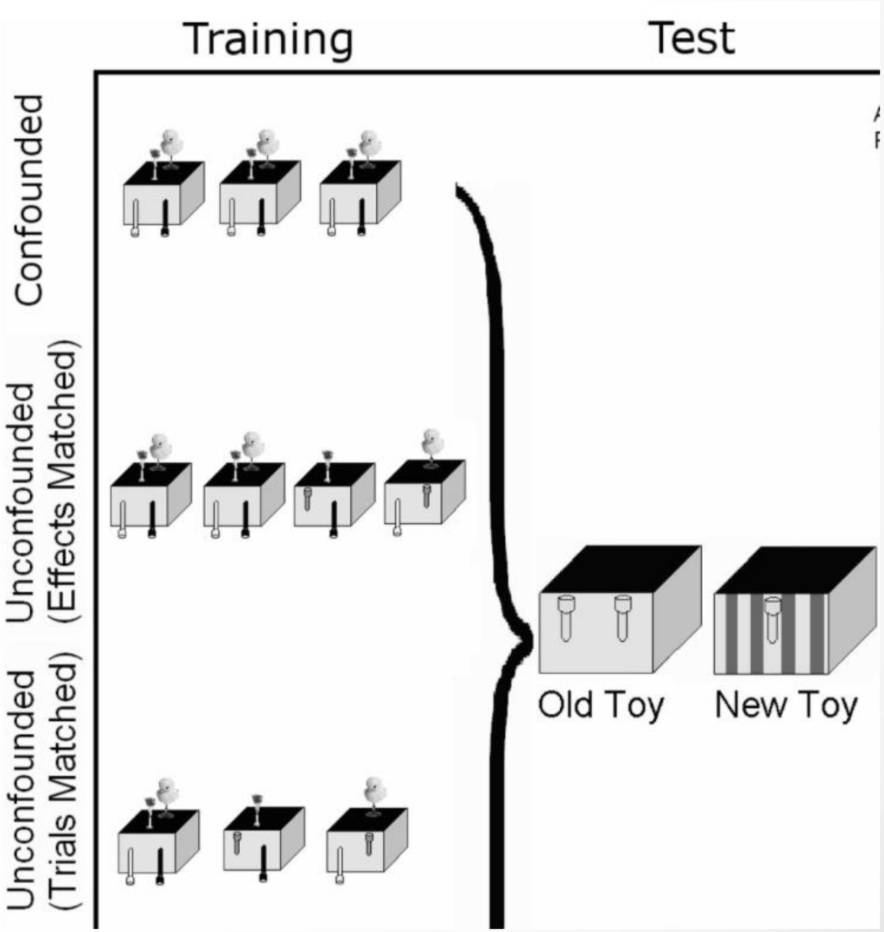
- Often when surveying teachers/parents about how much sophisticated reasoning is in play they say little
- Deny children can think mathematically, logically, and scientifically
  - “preoperational child”
- “it’s just child’s play”
- Recent research has showed just how sophisticated this thinking is

Scientific thinking in play

- Science is about finding out the causes of natural phenomena
- Children also appear very concerned with what causes things
- They generate causal explanations and explore the world to test their hypotheses

Scientific thinking in play

- Schultz & Bonawitz (2007): Play is about discovering causal structure



Scientific thinking in play

- Schultz & Bonawitz (2007): Play is about discovering causal structure
- Jack-in-the-box type toy with 2 levers, 2 toys pop out (e.g., a donkey and a tiger)
  - One lever causes one toy, the other the other.
- Adult and pre-school child each pull a lever
- Confounded (i.e. ambiguous) condition: adult & child pull both levers at the same time and both toys pop up.
- Unconfounded (i.e. clear) condition condition: adult & child pull levers sequentially and each toy pops up in corresponding sequence
- Then child given option to play with this toy or a new toy
- They choose new toy in unconfounded, old when confounded
- Confounded condition needs more play to figure out how it works.

Causal Reasoning in Play is Abstract: Covered last lecture

- Alison Gopnik has been promoting a position wherein children reason abstractly from quite early on, specifically when engaging in causal reasoning
- Remember: kids are willing to entertain hypotheses that adults may be biased against

Scientific thinking in play

- Despite foundations of scientific thinking, school-aged children and non-scientist adults need instruction to control for variables when testing hypotheses.
  - David Klahr's work.
  - Lennart Schalk and colleagues in Switzerland show that "inquiry-based" primary school physics education improves both COV strategies and physics concepts understanding

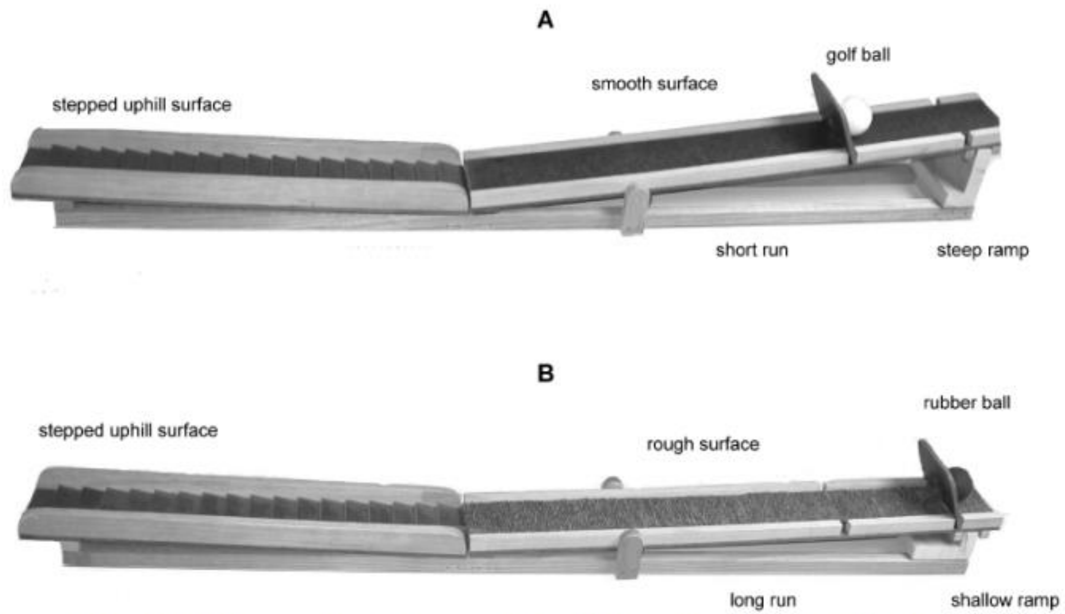


Fig. 1. The ramps used during the exploration and assessment phases. On each of the two ramps, children could vary the steepness, surface, and length of the ramp, as well as the type of ball. The confounded experiment depicted here contrasts (a) a golf ball on a steep, smooth, short ramp with (b) a rubber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

Scientific thinking in play

- Kids will try all sorts of stuff, not systematically control for variables when many are involved.
- Don't have abstract representation for control-for-variables strategy
- In addition
- Domain-knowledge is critical: what are the relevant variables to control for?
  - Think about how different theories tell you which variables are important.
  - When professional scientists don't control for a variable, it's not because they don't have this understanding

- https://twitter.com/C_Hendrick/status/1432405330785443846 discussing

Joseph, G. M., & Patel, V. L. (1990). Domain knowledge and hypothesis generation in diagnostic reasoning. *Medical Decision Making*, *10*(1), 31-44.

Outline

- Logical thinking in play

Logical thinking in play

- Pretend play is often about establishing hypothetical situations and reasoning from the premises of these hypothetical situations
  - Deductive reasoning
- “If we are in a world like X, therefore Y follows, but if it were like A then B follows”
  - Counterfactual reasoning

Logical thinking in play

- Harris (2001): Can children think logically about hypotheticals that contradict their experience?
- “All cats bark. Rex is a cat, does Rex bark?”
- Ask 4 – 6 year olds.
- They say no. Rex is a cat, cats don’t bark. Refuse to reason from the false premise. Concrete thinking?
- But simply prompt the question with “Imagine a world where cats bark…”
- Or even “think about how things would be if…”
- Then 4 – 6 year olds could do it no problem.
- Potentially contradicts classic work by collaborators of Vygotsky that abstract logical reasoning was only supported by cultural institutions like schools.

Logical thinking in play

- Buchsbaum et al. (2012). Pretense and counterfactual reasoning
- 3 and 4 year old children are shown a toy that lights up and sings “happy birthday.”
- They are shown two objects, a zando and a non-zando. Zandos makes the box play, non-zandos do not. This is demonstrated
- Children are asked “what if the non-zando was a zando, then would the box play?” and vice-versa (counter-factuals)

Logical thinking in play

- Buchsbaum et al. (2012). Pretense and counterfactual reasoning
- Then another experimenter comes in and takes the box and the toys.
- It's a stuffed monkeys birthday, but now they don't have the birthday singing toy. So, the experimenter takes out just some other objects and tells the kid to pretend it's a birthday singing box and that there is a zando and a non-zando.
- Kid is then supposed to reason that the pretend zando can make the pretend toy sing "happy birthday" while the non-zando would not.
- Ability to reason correctly about the pretend zando was correlated with the ability to reason counterfactually earlier.

Logical thinking in play

- Buchsbaum et al. (2012) & Harris (2001) show how children can go beyond their perceptual experience, inhibit the most obvious response about known objects and reason logically

Outline

- Mathematical thinking in play
- How can we use play to improve early education?

Mathematical thinking in play

- Many teachers do not attempt to teach children under 6-7 math beyond simple counting games and using a clock because they don't think kids can think mathematically.
    - And they often hate maths themselves
- Many pre-school teachers (perhaps over-reacting to need for play research) say that teaching is bad for young kids and they just need to play freely to develop properly
- Seo & Ginsburg (2004) catalogue mathematical thinking during play in 4 year-olds to show how much more children are capable of

Mathematical thinking in play

- From Seo & Ginsburg (2004) via Sarama & Clements (2009)
- *Classification*
- This category includes grouping, sorting, or categorizing by attributes. A child cleaned up the blocks on the rug, for example, by taking one block at a time and placing it in a box that contained the same size and shape of blocks. Also a girl took all the plastic bugs out of the container and sorted them by type of bug and then by color. They were classifying.

Mathematical thinking in play

- From Seo & Ginsburg (2004) via Sarama & Clements (2009)
- *Pattern and Shape*
- This category includes identifying or creating patterns or shapes or exploring geometric properties. In one example, a child made a bead necklace, creating a yellow-red color pattern. In another, a boy put a double-unit block on the rug, two unit blocks on the double-unit block, and triangular blocks in the middle, building a symmetrical structure. These children were playing with pattern and shape.

Mathematical thinking in play

- From Seo & Ginsburg (2004) via Sarama & Clements (2009)
- *Magnitude*
- *Enumeration*
- *Dynamics*
- *Spatial relations*

Failures in mathematical thinking

- Why are people so terrible in maths on the whole?
- New York Times magazine recently described a case from the 1980's US where a 1/3 lb burger was marketing to compete with MacDonald's 1/4 lb burger. It failed because people thought 1/4 was bigger than 1/3
- 4 year-olds carefully use symmetry in their block building, but then fail to understand it formally in maths class years later.

Failures in mathematical thinking

- Huge socio-economic class disparities
  - High rates of numerical illiteracy in US lower classes. Can't have a job that requires the use of a cash register
- Already major differences in formal maths reasoning by the start of primary school between SES groups, and numerical competence during childhood predicts longitudinal outcomes.
- Why the early difference?
- No difference between classes in mathematical play
- Large disparities in verbal mathematical reasoning
- But large disparities in quantity and quality of language input/conversation in high vs. low SES groups.
- Low SES kids have less opportunity to reflect on their play and make concepts explicit

Improving mathematical thinking

- Kids show foundations of maths thinking
- This is different than explicit formal reasoning ability
- There needs to be intentional instruction encouraging reflection, explicit thought, and systematic application of mathematical ideas to novel situations

Improving mathematical thinking

- Not recommending to take time away from play to then give 4 year-olds a lecture
- Clements and Sarama say: Educators need to understand what children's thinking is like, and build curricula building on what the children can already do and then formally *mathematicize* their implicit knowledge
- Siegler has a slightly different angle: what is critical to understand what are the key representations, and design games to target those.
    - Rather than gamifying the entire curriculum, you can be more targeted

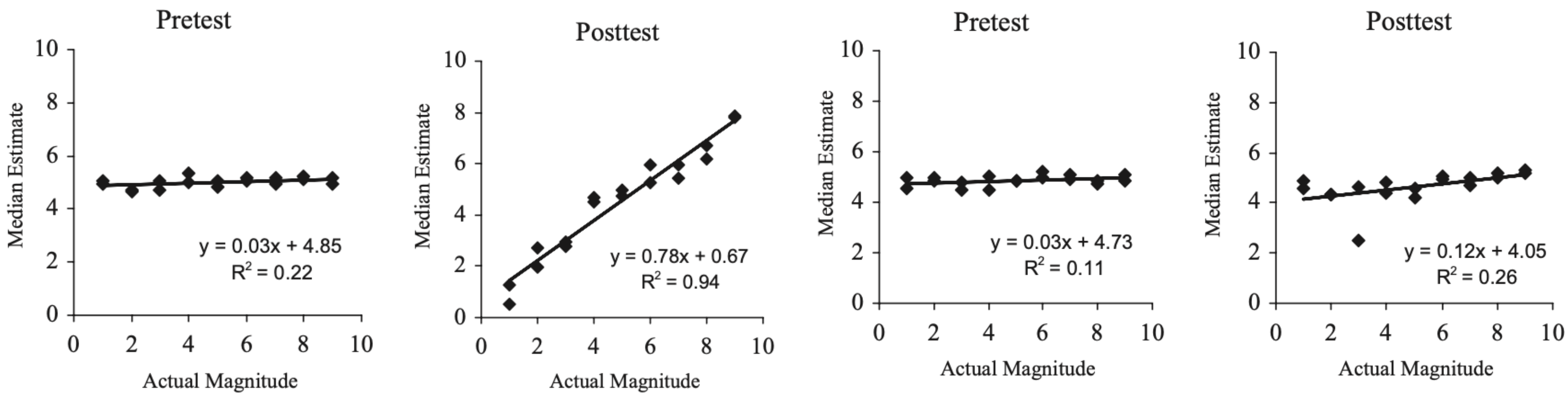
Improving mathematical thinking

- Robert Siegler's "The Great Race" Game
- Number line representations are critical
- Improves numeracy for low SES children, some evidence that complete closes the preschool SES numeracy gap
- Across papers, different control conditions- counting activities, circular version of the game, or a linear game with just the colors, not numbers

Improving mathematical thinking

- Pre-test and post-test measures:
  - number line estimation, 1-10
  - Magnitude comparison “what is more, six cookies or one cookie?”
  - Single digit arithmetic. At post-test, corrective feedback and opportunities to learn more.
- Four 15 minute sessions over two weeks (for linear number game and the controls) and a post-test session later
    - Post-tests: between one week and nine weeks later
- Game play is simply, spin a spinner that lands on a number, move ahead that number of places. First to the end wins

Improving mathematical thinking



Linear board game

Circular game

- Median place on the number line for a condition. At pre-test, median for every number is where 5 should go.
- Only linear number condition significantly improves. Median becomes accurate. Other controls look like circular game.
- Magnitude comparison and arithmetic improves for linear game.
- Little or no improvement on any measure for other conditions.

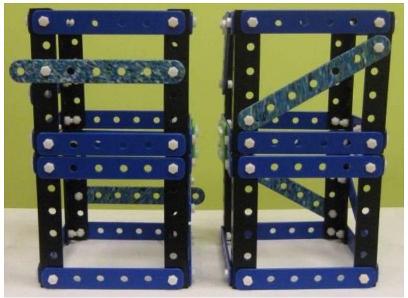
Learning geometric/physical principles in play: Principles of Stable Construction

Dedre Gentner et al., 2016

Collapsed Building

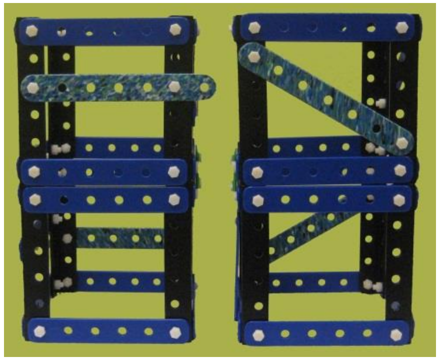
Children often fail in free construction tasks

Goal: teach children a key principle of stable construction: that *diagonal braces* confer stability

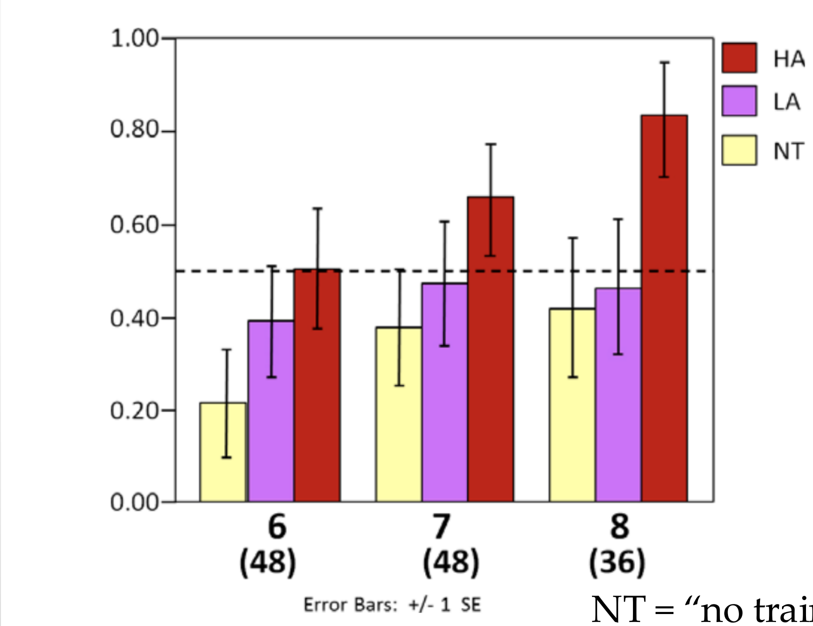


- Basic principle: The triangle is a stable polygon

Low Alignability High Alignability Test



Demonstration part of play session.



NT = "no training"

Follow up work shows that the word "brace" during learning helps even more
Zheng, Goldwater & Gentner (2025)

Improving formal thinking more generally

- If there is no well-designed learning game, you can at least support reflective thinking about their play
- Generally, (outside of maths as well), help children practice reflective reasoning, ask children “why did that happen? Why do you think that? How do you know?”

Thinking in play: Summary

- Free play helps social skills, creativity & reduces stress.
- Before entering primary school, children show sophisticated thinking skills during play
- They test hypotheses to determine cause and effect relationships
- They reason logically (deductively and counter-factually) about imaginary scenarios that conflict with their knowledge and experience
- They show a multitude of mathematical thinking strategies
- Formal scientific and mathematical thinking is still a great challenge
- Early educational curriculum needs to build on their abilities shown in play and make such knowledge the object of explicit reflection and reasoning.