By Way of Comparison: Scientific Reasoning in Preschool and Early Elementary School Children

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Many researchers study whether and when children can construct experiments and control confounding variables. We ask somewhat simpler questions: Do young children recognize that a comparison is more informative than a demonstration to answer a "find out" question? To what extent do they know that the method of difference is a key first step in designing an experiment? How does age relate to this knowledge?

STUDY 1

Participants were 27 first- (*mean age = 87.1, range = 80-97 mos., 15 girls*) and 24 second-graders (*mean = 101.2, range = 87 - 119 mos., 10 girls*) from a lower-income, predominantly African-American neighborhood in West Philadelphia.

Children listened to stories, supplemented with photos. In each story, a character faces a specific problem and decides to design a test to get relevant information. Three stories were framed as competitions or races (e.g., Which toy car goes faster?), and three varied a key step in a process to find out if it affected the outcome (e.g., Does adding vinegar to dye affect the color of eggs?). Samples are shown in Figure 1. After each story, children answered questions that tapped understanding. Once understanding was established, participants identified the test that would allow the story character to obtain the desired information and justified their response.

RACE STORIES - Studies 1 & 2

Q: Remember, he wants to find out if one of the cars, the blue or the yellow, goes faster. If you had to find that out, which way would you do it? This way or that way?

PROCESS STORIES - Study 2

Q: Remember she wants to find out whether adding vinegar to the dye will make the color of the egg lighter or darker. If you had to find that out…(as above).

Comparative - Method of difference **Non-comparative**

Figure 1: Sample Test Questions and Stimuli

Findings

Figure 2 shows that, overall, second graders' choices were marginally better than first graders', *F (1,49) = 3.271, p = .077*. Both groups reasoned more accurately on race tasks than on process tasks, *F (1,40) = 43.972, p < .001*; this item effect was more pronounced in the Grade 1 sample, *F (1,49) = 4.170, p = 0.047*.

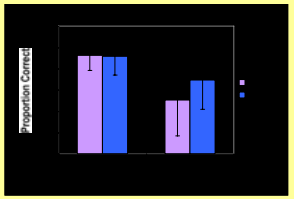


Figure 2: Proportion Correct by Story Type and Grade

Children's justifications of their choices were scored for whether they referred to the need to use a *comparative* test to answer a "find out" question. Examples of these are provided in Figure 4. Children found it easier to justify race scenario choices. As shown in Figure 4, the proportion of correct test choices that were followed by a good justification was .63 for first graders and .76 for second graders for race stories. For process stories, these figures were .32 and .28, respectively.

Discussion & Study 2 Rationale

We suspect that race stories yielded better performance than process stories because the schema for competitive situations is simpler and more familiar. While both story types require the use of controlled comparisons, they differ in that the outcome of a competition directly answers the question of which contestant is superior; process situations, in contrast, pose the question of whether an added element affects a process which in turn affects an outcome. These items likely involved additional causal reasoning and may have increased verbal load.

Still, first graders' above chance performance indicates that relevant reasoning skill emerges at even earlier ages for some learners. Study 2 explores the roots of this capacity using simple comparative (i.e., race-type) scenarios to explore the range of performance among 4- and 5-year-olds.

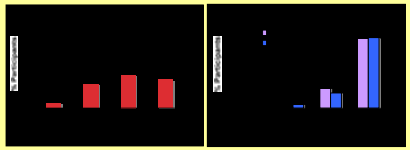
STUDY 2

Participants were 19 preschoolers (*mean = 57.7, range = 51-62 months, 12 girls*) from two schools in central New Jersey - one that serves ethnically diverse, middle income families and one that serves lower income, predominantly Hispanic families.

We generated 6 simple stories with photographs. Like the Study 1 race scenarios, all had the goal of finding a "superior" contestant: cream that heals boo-boos faster; sponge that cleans up more juice; toy car that goes faster; wind-up toy that travels farther; glove that keeps hands warmer; and ball that bounces higher. Memory probes were asked and stories repeated as necessary to support comprehension. Children were asked to justify their test choices.

Findings

Each child received a score (out of 6) for the number of times s/he chose a comparative test. Not unexpectedly, the mean proportion correct did not exceed chance, *mean = .58, t (18) = 1.12, p = .28*. Our prediction that some preschoolers would be able to identify proper comparative tests was borne out. As shown in Figure 3, a third of the sample showed a robust tendency to choose the proper test (5 or 6 correct). To illustrate developmental growth, the right side of the figure shows the scores (out of 3) for Study 1 participants for race stories.



PreK Grades 1 & 2

Figure 3: Percentage of Each Age Group at Each Score Level For Race Stories

Preschoolers were less able than older children to generate a scientific explanation for their choice of a comparative test. They did so after 20% of their correct test choices. These results are shown in Figure 4, along with findings for Study 2 participants for race scenarios only.

Examples of "Good" Justifications

- To see how fast each one would go. But these two are the same, so you wouldn't see how fast the blue car would go. So I would do it like this so you would see how fast these two would go (preK).
- Because I wanted to see if the yellow or the blue would go faster (preK).
- If she do it this way (non-comparative), she wouldn't know if the green one is faster (Gr. 1).
- If you want to find out which car of those two go faster, you can't have two of the same car (Gr. 2).

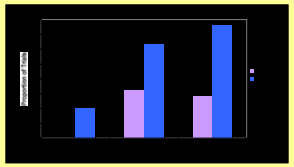


Figure 4: Comparative Test Choices Followed by a "Good" Justification

Discussion

Together these studies provide insight about a possible learning pathway for scientific reasoning skills associated with the notion of a variable. The race scenarios, especially, exemplify simple comparisons from which children might build further understandings of experimental design. These include reasoning about the difference between an example and a test and understanding the importance of controlling variables to create fair tests. The simple race stories are also easier for children to talk about, providing supportive opportunities for them to begin to reflect on and discuss their own scientific thinking. The Study 2 preschoolers are currently participating in a longitudinal training study. It is meant to inform us about likely learning trajectories for scientific reasoning as well as the design of educational experiences most likely to support growth towards more complex understandings.

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