Young Children's Use of Graphs for Arithmetic

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Introduction

- Mathematics standards now recommend graphing experiences during the early childhood years (Clements, 2001; NCTM, 2000).
- Still, basic research on young children's understanding of graphs is limited.
- Converging evidence suggests that preschoolers are competent with some aspects of graphing and arithmetic.
  - Solomon (2003) explored various graph formats and reported that preschoolers understand discrete graphs as representations of numerosity based on one-to-one correspondence.
  - Classroom observations (Gelman & Brenneman, 2004) revealed surprising competence when mathematical activities were situated in purposeful contexts.
  - Similarly, the arithmetic literature emphasizes the important roles of motivation and context in successful outcomes (e.g. Bjorklund & Rosenblum, 2001; Zur & Gelman, 2004).
- The current study grew from the basic literature in graphing and arithmetic *and* from our observations of children engaged in graphing activities.
- Translational research of this sort, in which basic research and classroom practice inspire and inform each other, is critical to the creation of ecologically valid classroom experiences and to a fuller description of cognitive development.

Method

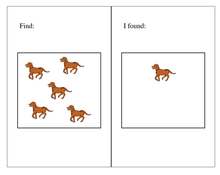
Participants

Younger group: n = 18, *M* = 4;9 (range = 4;1 - 5;3)
Older group: n = 20, *M* = 5;11 (range = 5;4 - 6;11)

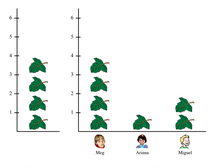
Procedure

- Counting and number pretest
- Graphs
  - Presented within the context of a scavenger hunt in which characters needed to find the target number of items
  - Served as a record of the target number of items and each character's progress at an interim point
- Formats
  - Book with Discrete Items
    - Randomly arranged sets
    - 5 sets of pages
  - Discrete Graph
    - Bars of individual objects
    - 2 graphs
  - Continuous Graph
    - Continuous bars
    - 2 graphs
  - Order of format presentation and numerical combinations varied.
  - Each child viewed all three formats.

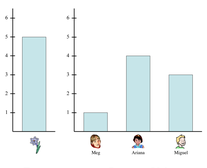
Discrete Book



Discrete Graph



Continuous Graph



- Four Types of Questions
  - **How many?** (cardinal value)
  - **Is he still looking?** (comparison of two cardinal values)
  - **How many more?** (arithmetic problem)
  - **Who found the most?** (summary question involving comparison)

- Question Sequence

Experimenter: **How many** leaves does each child need to find?

- ***Child: [correct target number]***
- ***Child: [incorrect number]*** E: Let's count together. E & *C: 1, 2, 3, …*

E: Okay, so everyone needed to find [target number] leaves.
E: **How many** leaves did [Meg / Ariana / Miguel] find?
C: [progress number]
E: Is [Meg / Ariana / Miguel] **still looking**?

Repeats once per character

- ***C: yes*** E: **How many more** leaves does [she/he] need to find? ***C: [numerical difference]***
- ***C: no***

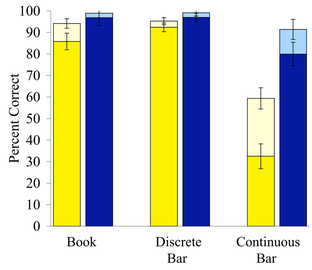
E: **Who found the most** leaves?
C: [say name or point]

Results

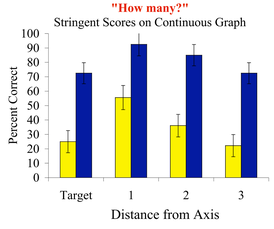
"How many?"

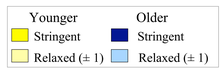
Overall:
- Book = Discrete > Continuous
- Older > Younger on Continuous

Discrete Formats:
- High accuracy at both ages
- Children generally counted



"How many?"
Stringent Scores on Continuous Graph

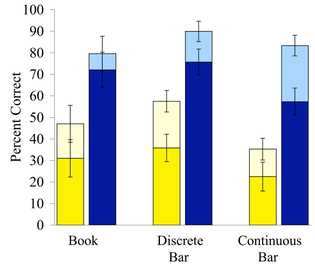




Using the Axis: Decreasing accuracy with increasing distance from the axis only on Continuous Bar Graphs with stringent coding

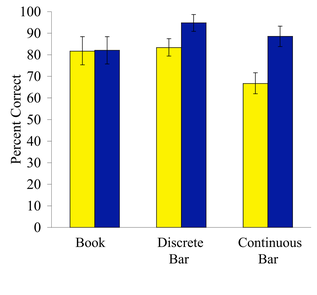
"How many more?"

- Older > Younger
- Book = Discrete > Continuous



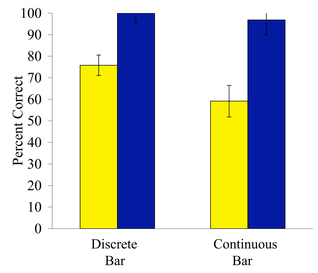
"Is he still looking?"

- Book > Discrete > Continuous
- Medians 10 – 15% above mean
- Average performance > 80% for all formats except on continuous graphs with book first, continuous graph first



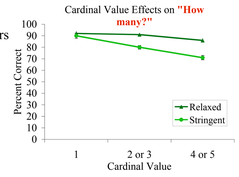
"Who found the most?"

- Older > Younger
- Easiest question



Accuracy Levels Based on Numerosity

- While numerosity has an effect, children's successes are not only on the smallest numbers
- Effects of numerosity were not affected by age.



	"Still looking?"	"How many more?" [a]
Total (Target + Progress)		
3 and 4	**94%**	**60%**
5 - 7	**83%**	**50%**
7 - 9	**80%**	**49%**
Difference (Target - Progress)		
0 "All done"	**72%**	**-**
1	**84%**	**59%**
2 or 3	**86%**	**43%**
4	**87%**	**41%**

Notes. [a] Relaxed coding resulted in accuracies that were 15-20 percentage points higher for all values.

Order Effects

- More frequently found on continuous graph format
- Possibility of carryover effects after adoption of a counting procedure
  - Difficult to start with discrete and then switch to continuous
  - Sufficient experience with the discrete materials can overcome this

Discussion

- Older children were more accurate than younger children, with a few exceptions.
- Performance was generally better for discrete formats than for continuous formats. The addition of a graph format for the discrete graph did not impair performance compared to the book with discrete items.
- Overall, children performed better than in previous studies involving a more traditional graphing set-up (Solomon, 2003; pilot work in our lab). Why?
  - ***Did the example and correction on the target value help?*** **Yes.**
    - Unlike the present study, our pilot work did not include an example or correction, and children's responses to the continuous graph were often 1. Further, with only one graph per format, children had no opportunity to practice or improve.
    - In the current study,
      - Accuracy was lower on target values (which were then corrected) than on the progress amounts for the continuous graphs.
      - Children transferred the correction counting procedure to the progress values (both accurately and inaccurately).
      - Children frequently anticipated the upcoming questions and proceeded independently.
  - ***Did context help?*** **Yes.**
    - Previous studies offered a less motivating context (reporting information versus assessing the progress of a scavenger hunt). Further, they provided no direct lead-in to the subtraction question. Children in the present study were better able to answer "How many more?" than were our pilot subjects.
    - The familiar context of a scavenger hunt motivated the children's attention and effort by providing a compelling reason to use their mathematical knowledge.

Conclusions & Implications

- Graphs are appropriate educational tools in the early childhood classroom.
  - While performance does vary, preschoolers can interpret graphs and use that information to solve arithmetic problems.
  - Success with various cardinal values and difference sizes suggests that understanding could transfer to larger set sizes.
  - Overall, young children show a strong emerging understanding of abstract representations.
  - High overall performance suggests that early understanding of graphs could transfer to other graphical forms (i.e. more complex bar graphs or line graphs) once children are on the relevant learning path.
- Future work will build on the current design and results.
  - A second test session with a subset of participants three weeks later revealed considerable performance gains. This promising result will be explored further.
  - We continue to look at the role of instruction and experience in children's ability to construct and interpret graphs.
  - We look forward to discovering new applications for the translational approach to the study of learning and development.

References

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Acknowledgments

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