The left digit effect in paper vs. computer number line estimation

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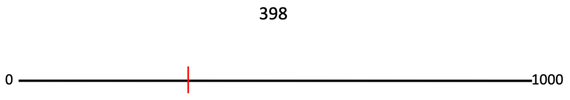
Introduction

- A cognitive phenomenon known as the **Left Digit Effect,** or the left digit bias, is present in many aspects of everyday life:
  - When deciding which products to buy, a price of $6.99 is perceived to be significantly lower in price than $7.00 despite being only one cent apart.[1]
  - A burger advertised as having 399 calories as opposed to 400 leaves people with lower levels of anticipated guilt.[2]
  - Physicians perceive patients in the weeks just after their 80th birthday as more at risk for heart complications and are less willing to give treatment to them as opposed to patients that are in the weeks just before their 80th birthday.[3]

- In a number line estimation task, people are asked to place target numerals on a number line (as shown below):



- These number line estimation tasks are commonly used to learn about how children and adults think about numbers and are even used to understand how numerical ability can contribute to mathematical achievement.[4] It is therefore important to know what is shaping people's performance in these tasks.

- The **Left Digit Effect** was found to be present in number line estimation tasks, showing that the left digit of a number strongly biases its placement on a number line:
  - People place target numerals on either side of a hundreds boundary significantly farther apart than they should be in number line estimation tasks, despite having similar magnitudes (e.g., 698 is placed too far to the left of 702).[5]

- The left-digit effect is present in computer-based formats for children and adults[5] and in paper-based formats with adults[6], but little information is available as to whether the left-digit effect is present with children in paper-based format.

- Small changes in task format are known to affect number line estimation in children and adults[7], but the difference in left-digit effect across paper-based and computer-based tasks has not been examined.

Research Questions

For children aged 9-12 and adults:

Is the left digit effect present in paper-based and computer-based number line estimation tasks?

Does the left digit effect differ across paper-based and computer-based tasks?

Methods

- Participants (N = 46 children aged 9-12, N = 42 adults) completed a number line estimation task on computer and paper with order counterbalanced.

- Each task included one block of 40 trials, each with the same target numerals presented in random orders.

- The following critical pairs were embedded within each block and were used to assess the left digit effect:

199/202, 298/301, 398/402, 499/502, 597/601, 699/703, 798/802, 899/901

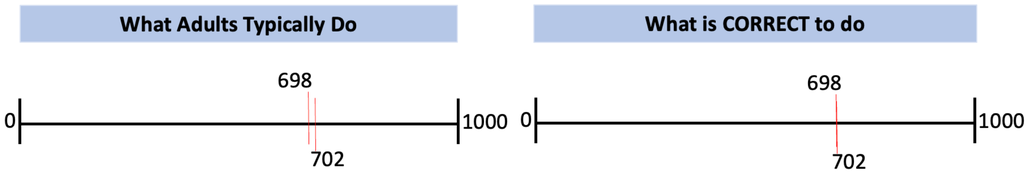
Measure of the Left Digit Effect:

- Hundreds difference scores = *larger numeral placement – smaller numeral placement – true difference between target numerals*.
  * Difference score > 0 indicates a left digit effect

Measure of Overall Error:

- Percent Absolute Error (PAE) = |*estimate – target numeral*|*/1000*
  - Higher PAE = lower accuracy

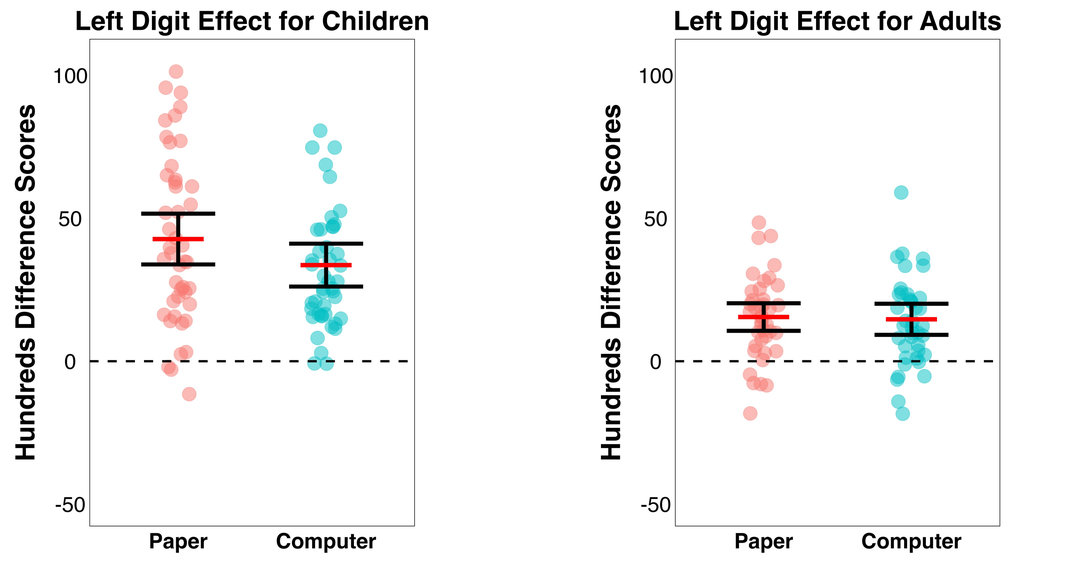
* analyses were preregistered unless otherwise noted



Results

Children

Adults



1. For both children and adults, there are large and significant left digit effects for both paper and computer tasks.

- Children: paper-based (M = 42.740, $t(44)$ = 9.696, p <.00, d = 1.445) and computer-based (M = 33.626, $t(44)$ = 9.037, p < .001, d = 1.347)
- Adults: paper-based (M = 15.139, $t(39)$ = 6.592, p < .001, d = 1.042) and computer-based (M = 13.781, $t(39)$ = 5.644, p < .001, d = 0.892) tasks.

2. Children had a higher left digit effect for the paper task than for the computer task; adults' left digit bias scores were not significantly different between the two types of tasks.

- Children: $F(1, 43)$ = 4.128, p = .048
- Adults: $F(1, 38)$ = .273, p = .604

3. For children, there was no interaction between task version and order; for adults, there was a higher left digit effect for the task that was completed first (i.e., adults who did the paper task first had higher left digit scores on the paper task).

- Children: $F(1, 43)$ = 0.039, p = .845
- Adults: $F(1,38)$ = 5.608, p = .023

4. Children had a significantly higher left digit effect than adults.

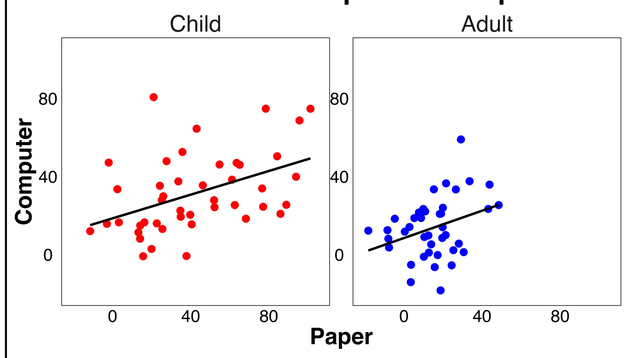
- $F(1, 82)$ = 34.119, p < .001

5. Percent Absolute Error for both children and adults was low.

- Children: paper-based (5.1%) and computer-based (5.2%)
- Adults: paper-based (2.8%) and computer-based (4.0%)

Results (cont.)

Correlation of Paper vs Computer



There was a positive correlation between the paper task and computer task left digit effects for both children and adults.

- Children: r = .412, p = .005
- Adults: r = .329, p = .038

Summary

- The strong left digit effects shown for children and adults in both task versions reinforces the idea that this left digit bias is prevalent in number line estimation.
  - This confirmation is important as number line estimation tasks on both computer and paper are used extensively to understand how people think about numbers.[4]
  - Understanding how these tasks are affected by the left digit effect prevents us from drawing incorrect conclusions about numeric ability and mathematic achievement.

- The significantly larger left-digit effect for children in the paper-based task over the computer-based task confirms the idea that changes in task format can have an impact on the way that children place numbers.

- The finding of a larger left-digit effect in adults for the task that was completed first might suggest that the switching of tasks led to practice effects, but this is unlikely based on past studies.[8]

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