Telling People About the Left Digit Effect in Number Line Estimation Still Does Not Reduce the Effect

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Introduction

Number line estimation (NLE) tasks are widely used as assessment tools and as reliable predictors of math outcomes.[1] On a typical task, participants are asked to estimate the location of Arabic numerals on a bounded number line.

Recent evidence[2] reveals a novel source of error in NLE performance:

Left digit effect: Numbers with nearly identical magnitudes but different leftmost digits are estimated farther apart than their magnitudes alone would predict.

E.g., "602" is placed too far to the right of "599" on a 0-1000 line, despite their magnitudes being indistinguishable on the scale.

Studies have demonstrated a strong left digit effect following NLE interventions, including direct instruction about the effect, but the latter study was limited as it did not test whether the participants attended to and understood the instruction.[3]

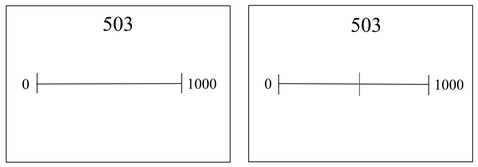
Here, we again provide direct instruction, but we also assess participants understanding of the effect following the instruction, offering a more stringent test of whether the left digit effect might be reduced with direct instruction.

Study Methods

Participants: Adults (N = 143, ages 18-70, Prolific internet sample) were randomly assigned to one of the following two conditions.

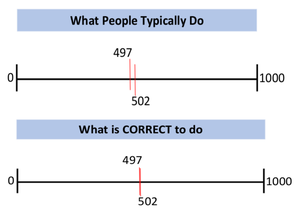
No-Instruction Condition (n = 67, two blocks of 60 trials each):

"On each trial, you will see a number line labeled from 0 to 1000 and will be asked where you think some number should go on the line. Click on the line to indicate where the number should go."



Instruction Condition (n = 76, same except with instruction between blocks):

Between-block instructions: *"In this task, people often exhibit what is called a left digit effect. This means they tend to place numbers of similar magnitude but different leftmost digits (like 497 & 502) farther apart on the number line than they should. They do not do this for numbers of similar magnitude with the same left digit (like 502 & 507)."*



Participants in the instruction condition who did not correctly answer two multiple choice comprehension questions within three tries (n = 1) were excluded. Additionally, participants were excluded from final analyses if more than three hundred pairs were missing (i.e., were removed as outliers; n = 7).

After block 2, in both conditions (to assess intervention-related changes), we collected:

- Self-reported level of effort for each block
- Definition of the left digit effect (or participants were told it)
- Participants' self-assessed likelihood that they showed a left digit effect
- Reported strategies used (of interest in instruction condition)

Response times (RTs) were also collected for each block.

Target numerals were grouped (for analyses) into one of the following:

- **Hundreds pairs**: numerals falling around 100's boundary (e.g., 498, 501)
- **Fifties pairs**: numerals falling around 50's boundary (e.g., 348, 353)
- Non-boundary values (e.g., 725)

Hundreds pairs were critical trials for assessing left digit effect, and fifties pairs served as controls; non-boundary values were used to compute overall error. Numerals were in a different random order for each block and participant.

Preregistered Measures and Predictions

Left Digit Effect

For each pair of target numerals, we calculated an individual difference score: *(placement of larger numeral – placement of smaller numeral).* We then calculated one average hundreds difference score and one average fifties difference score per participant.

hundreds difference score > 0 indicates a left digit effect

- **If instruction reduces the left digit effect** → Across blocks, hundreds difference scores will decrease more in the instruction than in the no-instruction condition.
- **If instruction *does not* reduce the left digit effect**. → Any decrease in hundreds difference scores across blocks will be the same in both conditions.

Overall Error

To measure overall error, we calculated percent absolute error (PAE): |*placement of numeral – correct location*|*/1000.* A smaller PAE indicates lower overall error.

- **If instruction reduces overall error** → Across blocks, PAE will decrease more in the instruction than in the no-instruction condition.
- **If instruction *does not* reduce overall error** → Any decrease in PAE across blocks will be the same in both conditions.

Demographic Variables

Is the hundreds difference score or PAE related to age, gender, education, or income?

Results

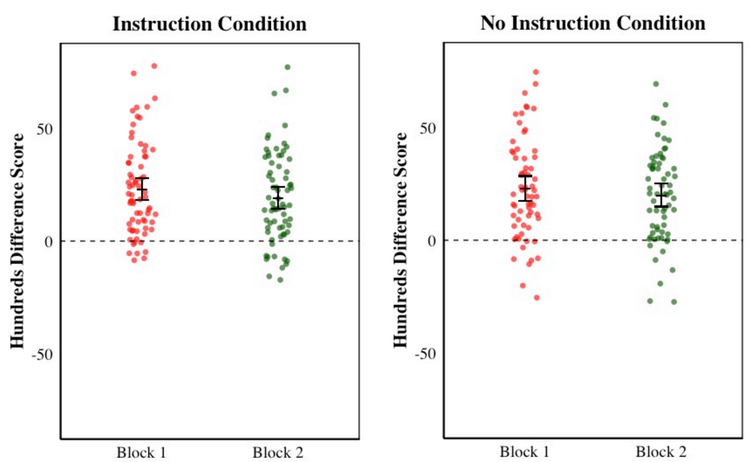
Left Digit Effect and Overall Error

A robust left digit effect was observed. Hundreds difference scores were different from 0 in each block of the no-instruction and instruction conditions (*t*s > 7, *p*s < .001). In contrast, also as predicted, fifties difference scores did not differ from 0 (*p*s > .20).

Instruction did not reduce the left digit effect. There was no condition by block interaction for the hundreds difference score (F(1, 133) = 0.04, MSE = 329.69, p = .847). There was no main effect of block or condition (*p*s > .90).

Instruction did not reduce overall error. There was no condition by block interaction for PAE (F(1, 133) = 1.06, MSE < 0.01, p = .306). There was a main effect of block (F(1, 133) = 4.42, MSE < 0.01, p = .037), but not condition (p > .90).

Figure 1. *Average Hundreds Difference Score by Condition and Block*



Results

Response Time and Effort

- Participants in the instruction condition decreased RT less across blocks than those in the no-instruction condition (F(1, 133) = 5.77, MSE = 133.00, p = .018).
- Participants in the instruction condition increased effort more across blocks than those in the no-instruction condition (F(1, 133) = 21.80, MSE = 0.73, p < .001).
- **Findings support that participants in the instruction condition understood the effect and were trying to reduce it.**

Definition and Confidence

- Participants who recalled the definition correctly, or partially correctly, at the end of the task did not show a pattern of improvement greater than those who remembered the definition incorrectly (F(1, 115) = 0.36, MSE = 303.692, p = .851)
- Participants in the instruction condition were more confident that they reduced their left digit effect (M = 5.69, SD = 1.95) than those in the no-instruction condition (M = 3.55, SD = 1.79), (t(133) = 6.62, p < .001).

Strategies Reported in the Instruction Condition

Descriptively, there were decreases in hundreds difference score between blocks with reported use of no strategy, rounding, number strategies, and effort, but not with dividing the line (as shown in Table 1).

Table 1. *Change in Hundreds Difference Scores Across Blocks of the Instruction Condition as a Function of Main Strategy Reported for Reducing the Left Digit Effect*

Strategy	Block 1	Block 2
No strategy (n = 12)	25.90 (23.68)	15.61 (15.56)
Dividing the line (n = 21)	19.03 (21.59)	22.23 (23.54)
Rounding (n = 9)	24.36 (24.22)	8.66 (17.73)
Number strategies (n = 20)	22.17 (14.95)	18.81 (17.06)
Effort (n = 6)	34.52 (22.08)	26.77 (27.33)
Other (n = 2)	16.00 (30.41)	39.85 (4.92)

Demographic Variables

As age increased, hundreds difference score decreased (r(131) = -.33, p < .01) and PAE decreased (r(133) = -.17, p =.044). No other relationships with demographic variables were statistically significant (*p*s > .057).

Discussion and Conclusions

- The left digit effect is robustly observed in adults' NLE: leftmost digits, not just the overall magnitudes of target numerals, influence estimates.
- The bias cannot be easily reduced,[4,5] even when participants understand the effect and are actively trying to reduce it.

References and Acknowledgments

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