Telling People about the Left Digit Effect in Number Line Estimation 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 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 the robustness of the left digit effect and its generality across a variety of NLE interventions, including competitive feedback, summary feedback, and trial-by-trial accuracy feedback.

We recently asked whether the left digit effect might be reduced under with more knowledge of the left digit effect. Here, we go one step further and give participants the definition of the left digit effect and a direct representation of what it looks like in the context of the task.

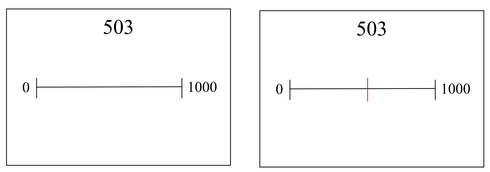
Research Question: Does NLE performance improve when one is informed about the left digit effect (LDE)?

Study Methods

Participants: A total of 131 adults (plus 5 excluded for incomplete data) were assigned to either a No Feedback or a Feedback condition:

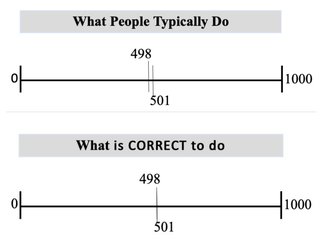
No Feedback Condition: (n = 66, two blocks of 60 trials each, with a control screen in between blocks):

"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."



Feedback Condition: (n = 65, same, except feedback was given between blocks):

Participants were given the following definition of the LDE: "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 498 & 501) 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 501 & 503)."



Target numerals were grouped 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 accuracy.

Numerals were in a different random order for each block and participant.

Preregistered Measures and Predictions

Difference Scores

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 feedback reduces the left digit effect** → Across blocks, hundreds difference scores will decrease more in the Feedback than the No Feedback Condition.
- **If feedback *does not* reduce the left digit effect**. → Any improvement in hundreds difference scores across blocks will be the same in both conditions.

Overall Accuracy

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

- **If feedback leads to improvements in overall accuracy** → Across blocks, PAE will decrease more in the Feedback than in the No Feedback Condition.
- **If feedback *does not* lead to improvements in overall accuracy** → Any decrease in PAE across blocks will be the same in both conditions.

Demographic Information

We looked for correlations between demographic variables including age, gender, education level, and income.

Results

Difference Scores

A robust left digit effect was observed. Hundreds difference scores were different from 0 in each block of the No Feedback and Feedback Conditions (ts > 7, ps < .001). In contrast, also as predicted, fifties difference scores did not differ from 0 (ps > .05).

The feedback intervention did not reduce the left digit effect. There was no condition by block interaction for hundreds difference scores (F(1, 129) = 0.32, MSE = 264.64, p = .572). There was also no main effect of either condition or block (ps > .45).

Overall Accuracy

Direct feedback did not reduce overall error. There was no condition by block interaction for PAE (F(1, 129) = 0.72, MSE < 0.01, p = .397). There was also no main effect of condition (F(1, 129) = 0.81, MSE < 0.01, p = .370) or block F(1, 129) = 1.35 , MSE < 0.01, p = .247) on PAE.

Demographic Information

There were no significant correlations between the left digit effect and gender, income, or education. However, there was a significant correlation between the left digit effect and age (r(131) = -3.25, p < 0.01).

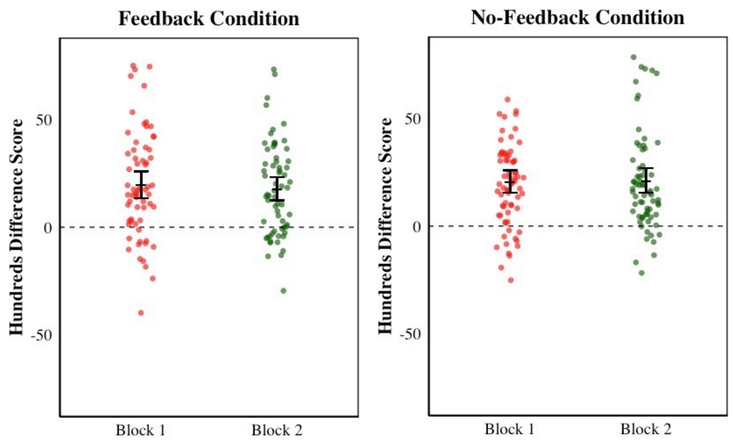
Table 1. *NLE Performance Measures by Condition and Block*

		Block 1	Block 2
No Feedback (n = 66)	100s	20.67 (21.69)	20.46 (23.11)
	50s	-1.93 (19.85)	-3.71 (16.35)
	PAE	4.12 (1.45)	3.91 (1.57)
Feedback (n = 65)	100s	19.25 (25.06)	16.76 (20.57)
	50s	-2.20 (18.28)	3.14 (14.91)
	PAE	3.82 (1.38)	3.79 (1.34)

PAEs are represented as percentages in table; *SDs* are in parentheses

Results

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



Key findings: A direct feedback intervention does not reduce the left digit effect. Additionally, no increases in overall accuracy across blocks were observed in both conditions. Considering demographic information, there was a negative significant correlation between the left digit effect and age, meaning the left digit effect decreases with age.

Conclusions

The left digit effect is robustly observed in adults' NLE performance: leftmost digits, not just the magnitudes of target numerals, influence estimates.

In comparison to our previous findings with other forms of feedback, direct feedback does not improve NLE performance:

- Similar to previous findings, the left digit effect is not reduced following feedback.
- Unlike previous findings, overall accuracy does not improve following feedback. However, previous studies includes 3 blocks of 120 trials each, indicating that more practice may contribute to overall accuracy.

This work replicates previous findings of the left digit effect[2] and provides further evidence that the bias cannot be easily reduced or eliminated.[3,4]

Future Questions

- Are there individual difference measures (e.g., math skills) that predict the extent to which one is more (or less) susceptible to left digit effects?
- What experimental circumstances lead to overall changes in accuracy in the NLE task?
- Does the magnitude of one's left digit effect in number line estimation predict similar bias in more complex judgment tasks?

References and Acknowledgments

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