

The Physical Presence of a Robot Tutor Increases Cognitive Learning Gains

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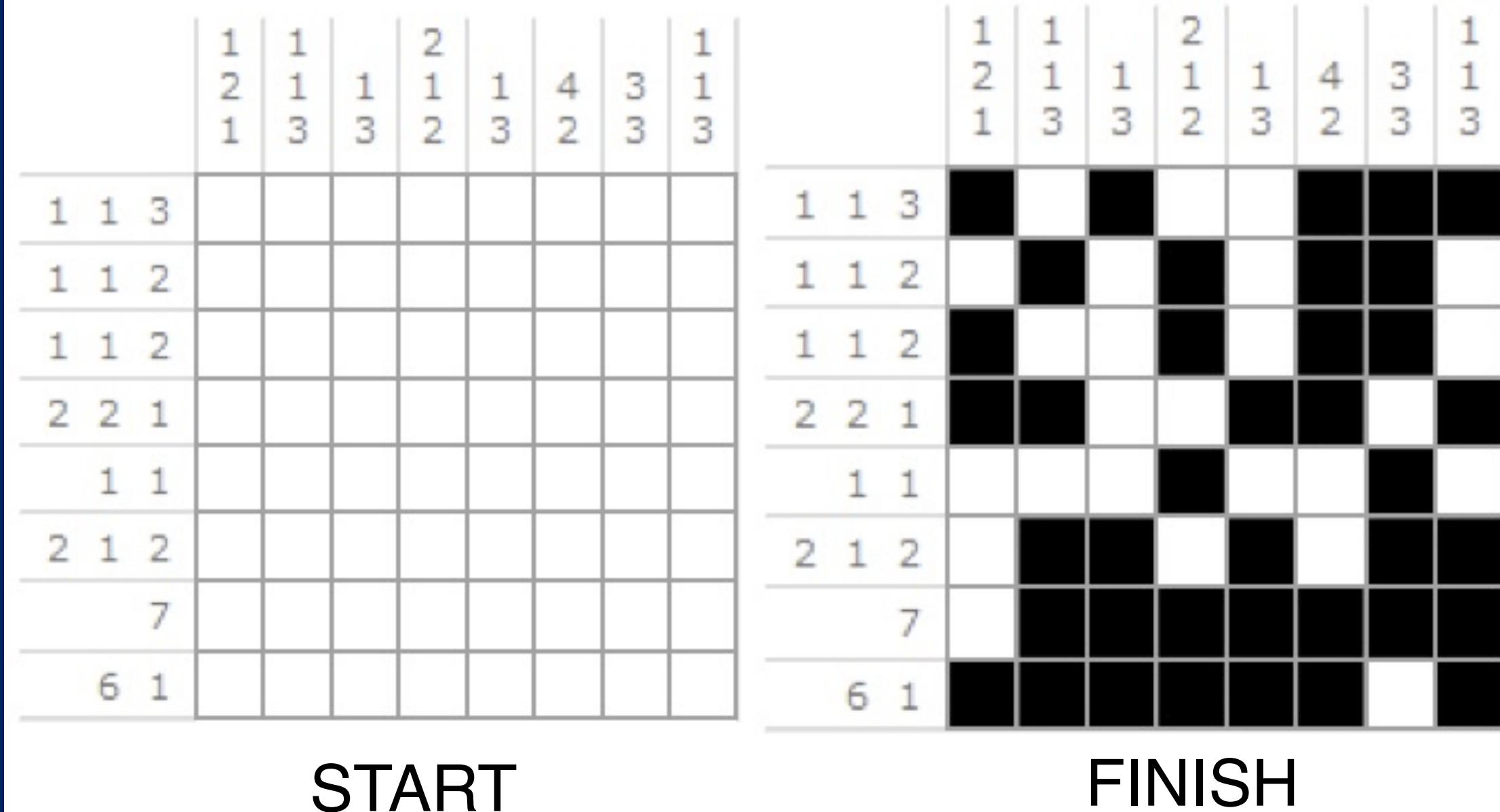
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Abstract

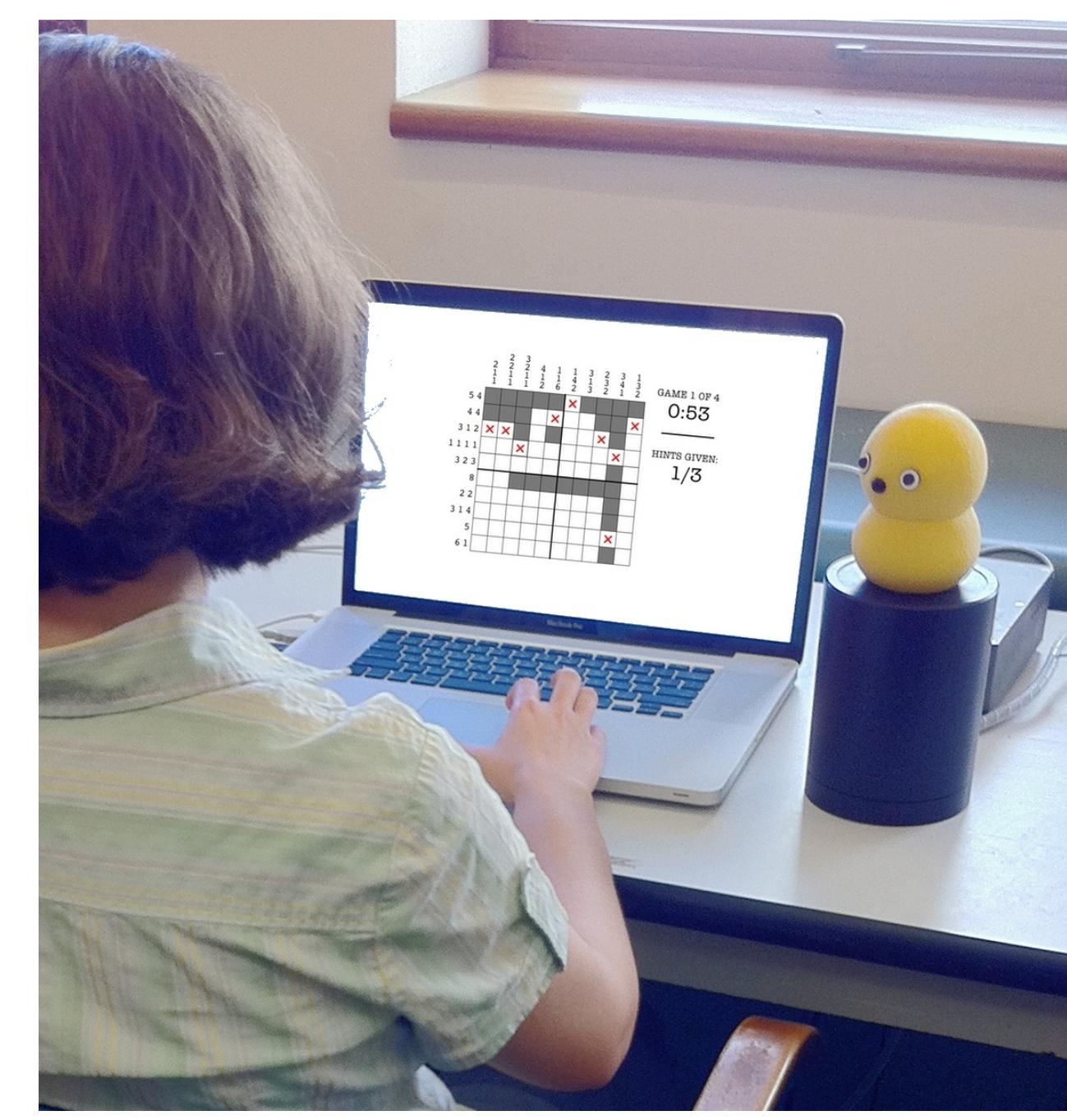
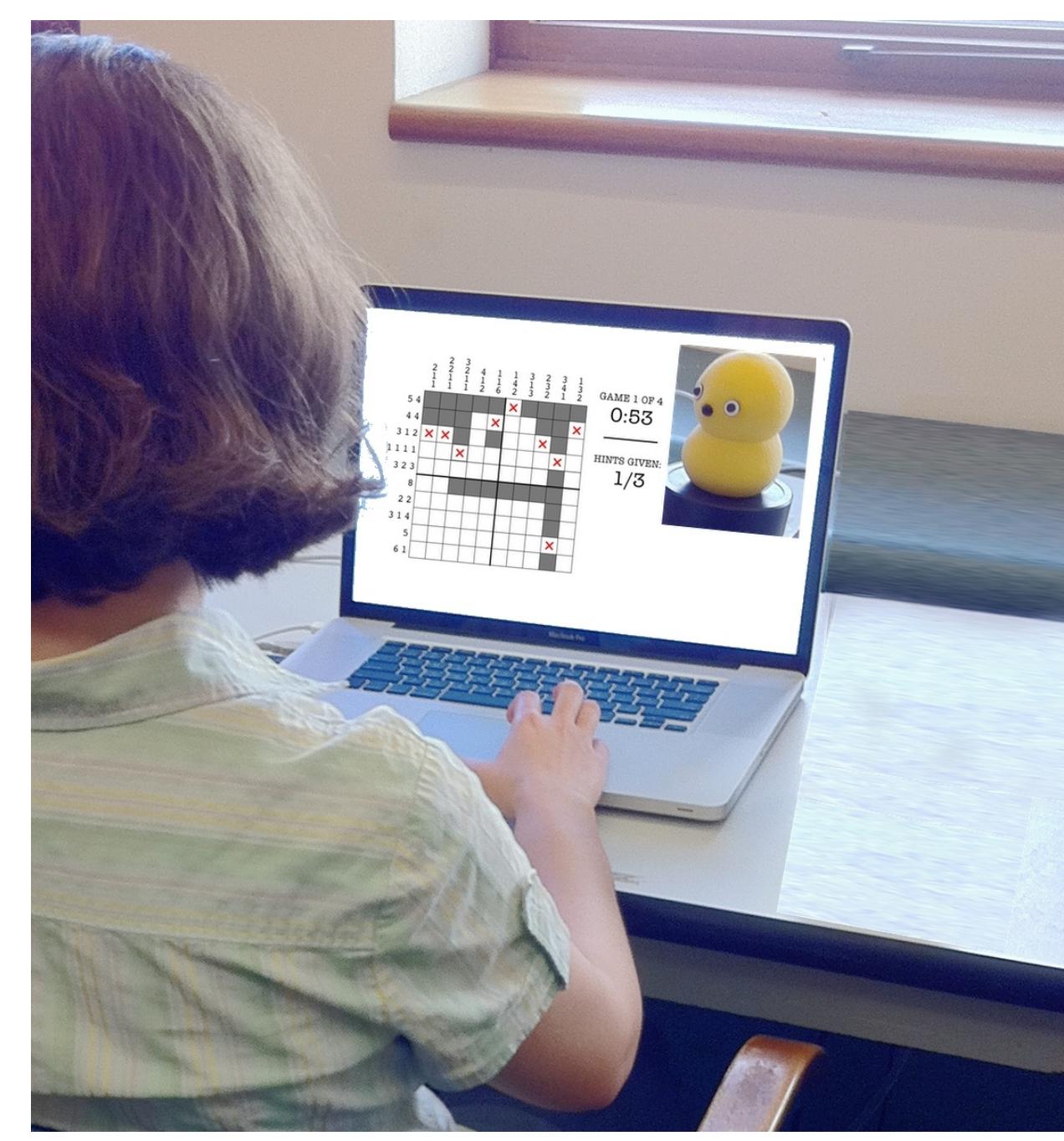
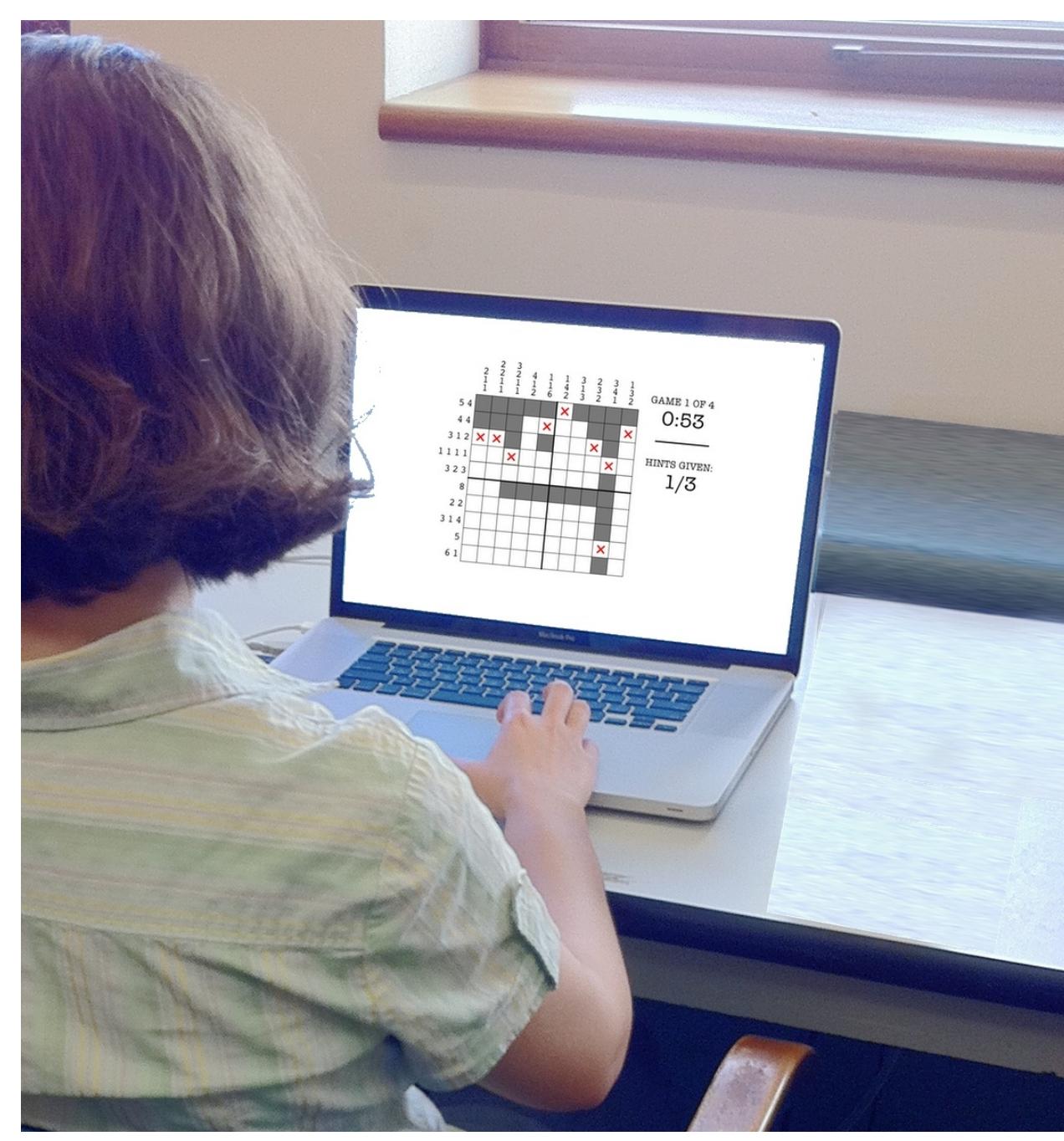
We present the results of a **100 participant study** on the role of a **robot's physical presence** in a robot tutoring task. Participants were asked to solve a set of Sudoku-like puzzles while being provided occasional gameplay advice by one of three automated tutors: physical robot, video of a robot, or robot voice only. Participants in the **physical robot group solved puzzles faster** on average and improved their same-puzzle solving time significantly more than participants in any other group. We conclude that the physical embodiment of a robot can produce measurable learning gains.

Apparatus

"NONOGRAMS"



Sample "nonogram" game, a grid-based fill-in-the-blanks constraint-satisfaction puzzle game resembling crossword puzzles or Sudoku.



Experiment apparatus varied by condition. There were two control conditions: no advice given (A) and random advice with robot (C). There were three experimental conditions: personalized advice via disembodied voice (A), on-screen video of robot (B), or physically present robot (C).

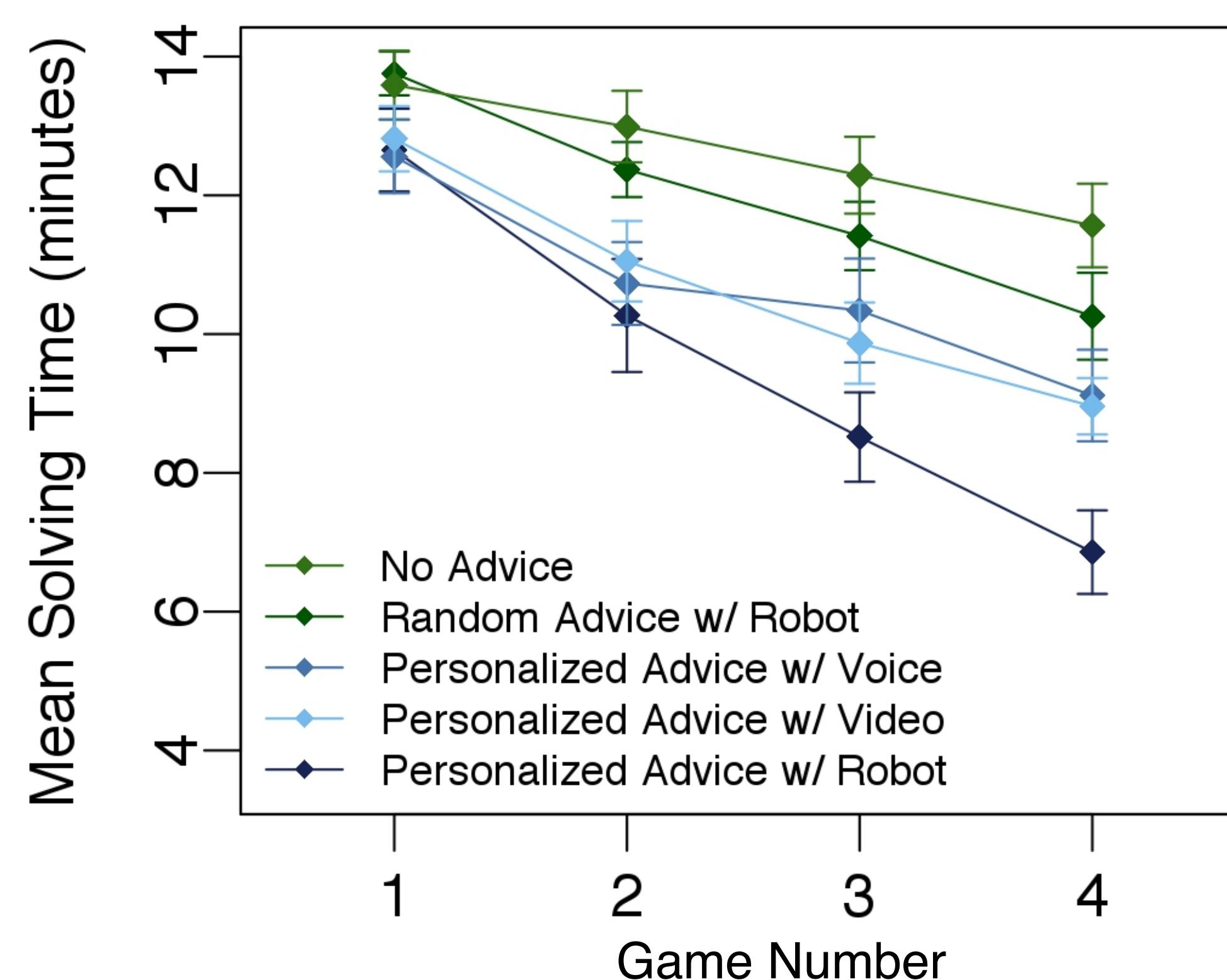
Results

ROBOT GROUP SOLVED PUZZLES FASTEST

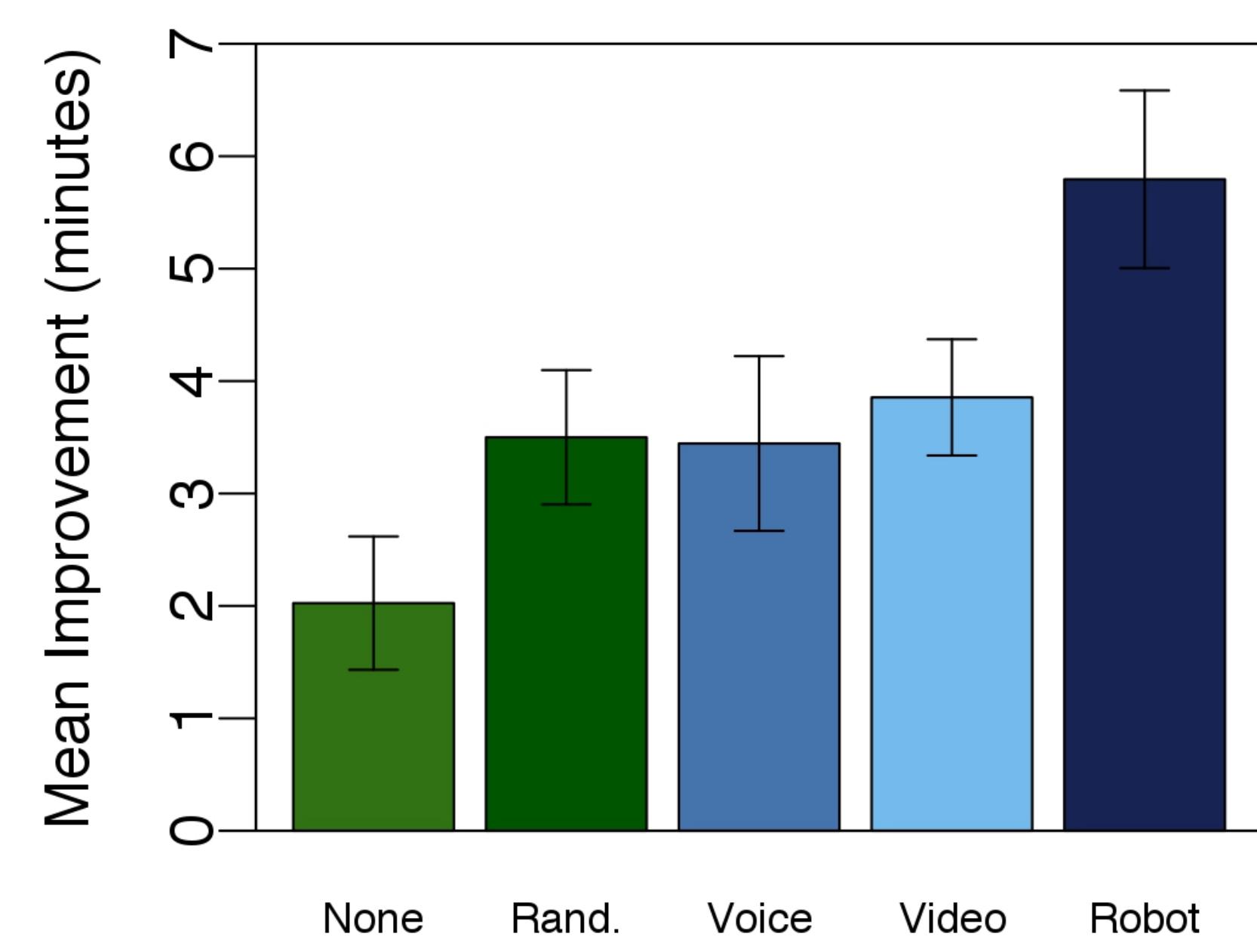
Mean Solving Time (minutes)

| | Puzzle 1 | Puzzle 2 | Puzzle 3 | Puzzle 4 |
|-------|------------|------------|------------|------------|
| None | 13.6 ± 2.2 | 13.0 ± 2.3 | 12.3 ± 2.5 | 11.6 ± 2.7 |
| Rand. | 13.8 ± 1.4 | 12.5 ± 2.0 | 11.4 ± 2.3 | 10.3 ± 2.9 |
| Voice | 12.6 ± 2.4 | 10.7 ± 2.7 | 10.3 ± 3.3 | 9.1 ± 3.0 |
| Video | 12.8 ± 2.1 | 11.1 ± 2.6 | 9.9 ± 2.6 | 8.7 ± 2.4 |
| Robot | 12.7 ± 2.6 | 10.0 ± 3.5 | 9.4 ± 3.0 | 7.6 ± 3.1 |

Mean solving time per puzzle. Participants in the robot condition solved each puzzle faster than participants in any other condition. In the fourth puzzle, significantly faster, $p \leq 0.03$.



ROBOT GROUP IMPROVED MOST



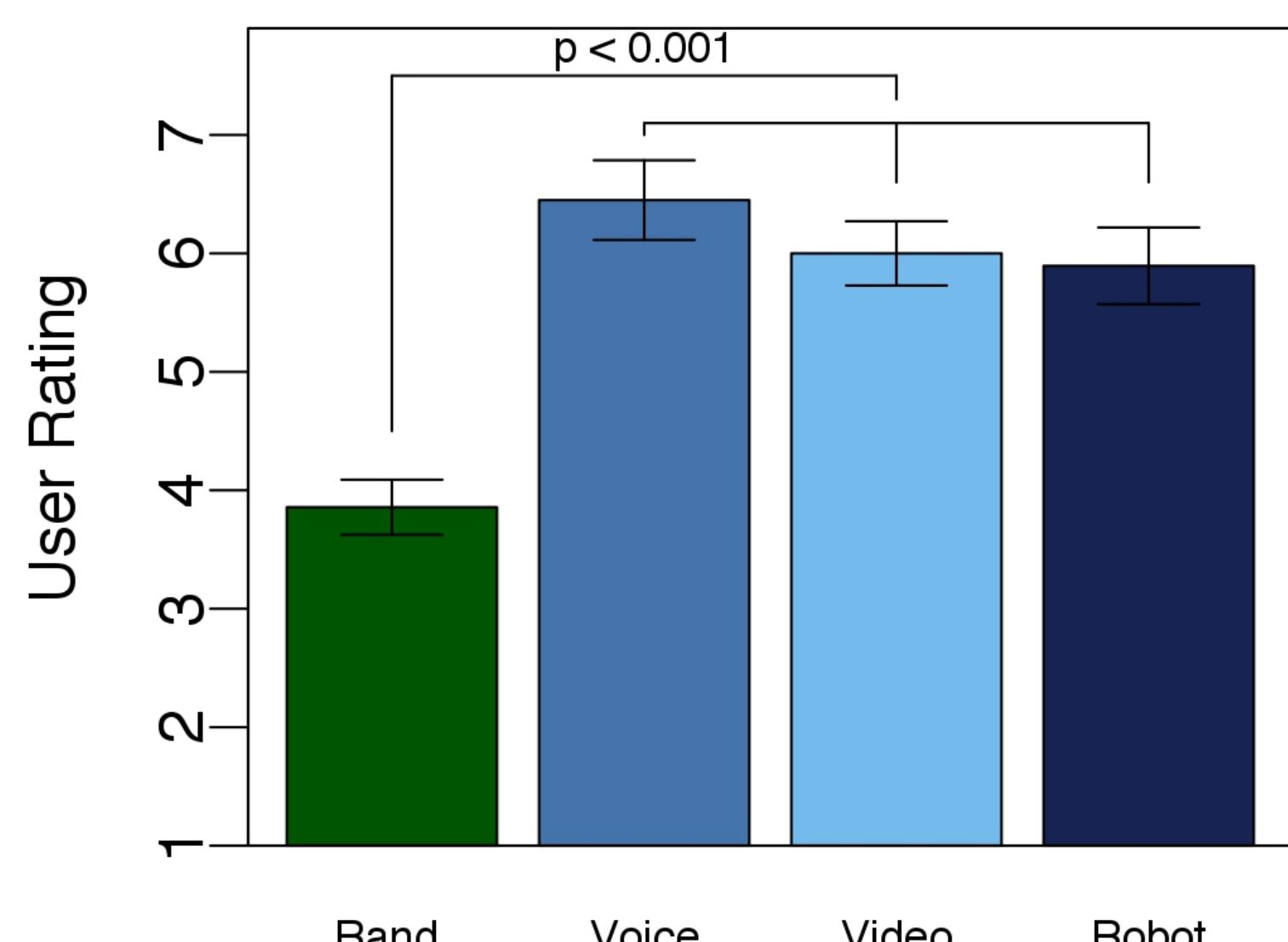
The first and last puzzles were **variations of the same gameboard**, disguised by a 90° rotation. Participants in the robot condition improved their **same-puzzle** solving time significantly more than other groups, $p < 0.05$.

Discussion

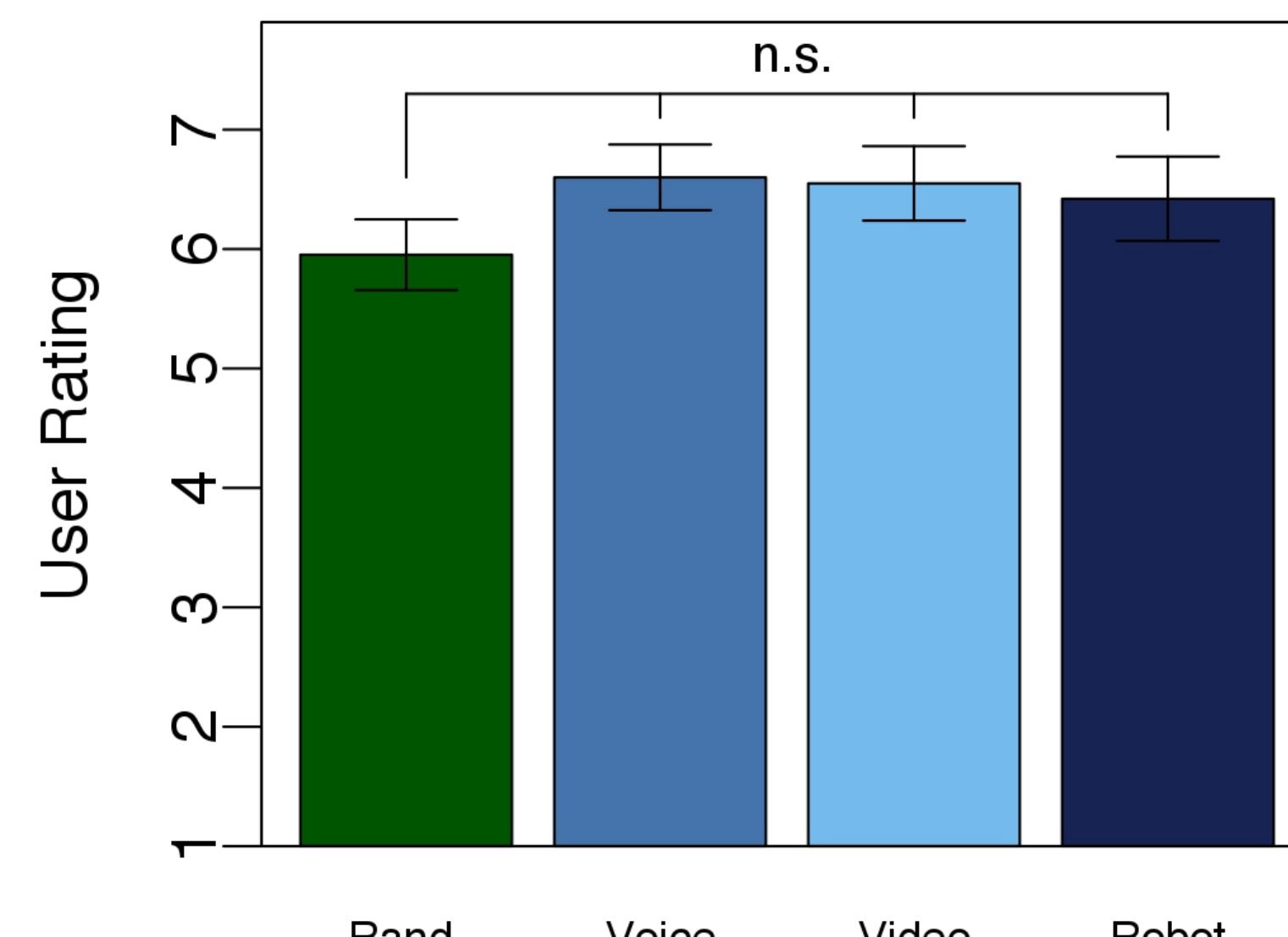
Why did the robot's physical presence lead to learning gains?

- Novelty:** New stimulus may have increased attention, but may also have a distraction.
 - Authority:** Physical presence may imbue a robot with more credibility.
 - Peer pressure:** Compliance with a physical agent may be greater than an on-screen agent.
- More investigation is needed. See paper for related work.

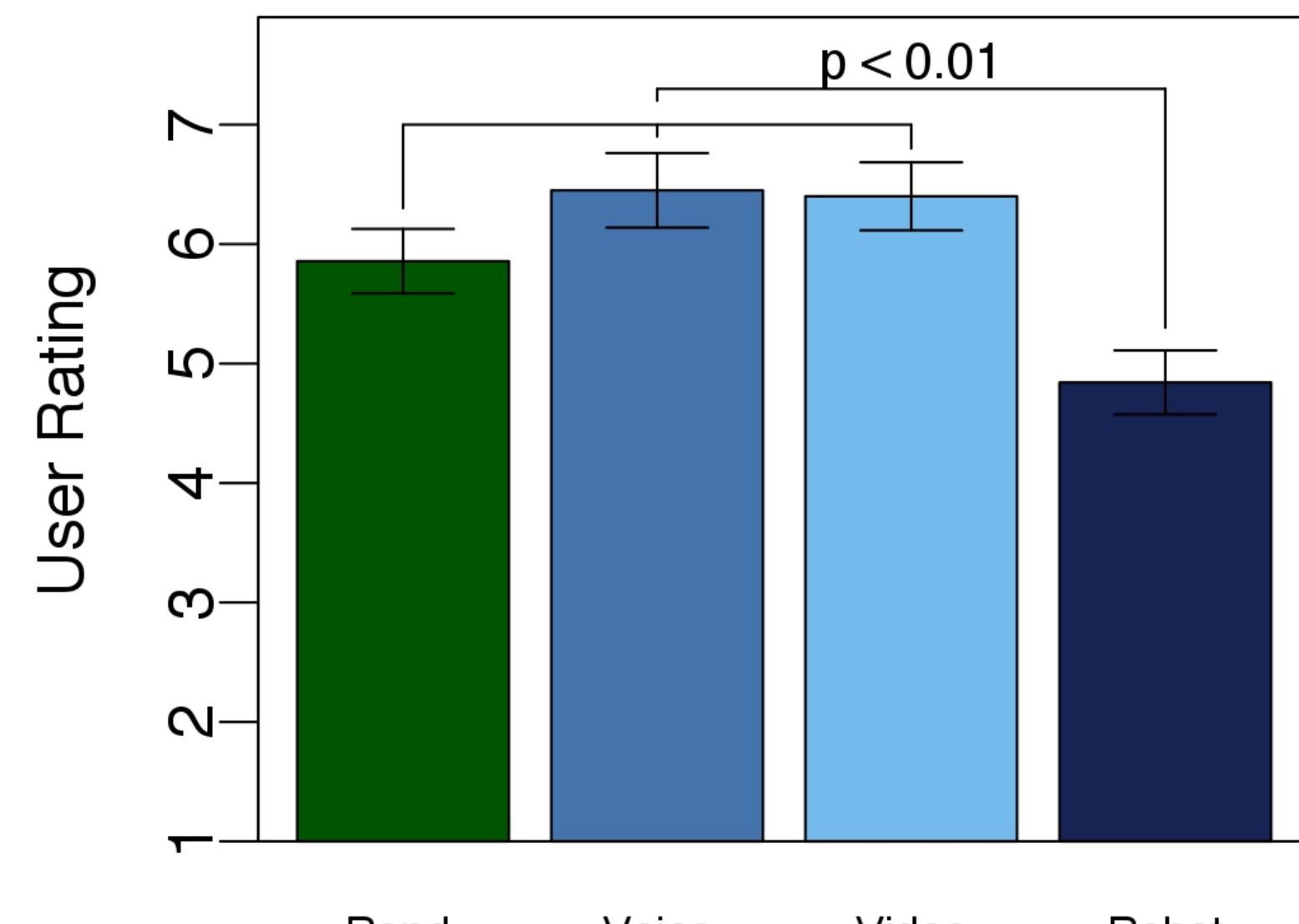
How relevant did the robot's hints seem to you?



How well did you understand the robot's hints?



How annoying/distracting did you find the robot to be?



Participants completed self-report Likert-scale questionnaires after the interaction. Participants in the three experimental conditions rated the hints as significantly more relevant to them than those in the random condition, but there was no significant difference between groups in the self-reported level of understanding of the hints. Participants in the robot group rated the robot as less "annoying/distracting" than participants in any other group.