A Multimodal Interface for Solving Equations

Phase I: Evaluation of Multimodal Input for Entering Mathematical Equations on the Computer

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Project Goal

o Develop a **multimodal intelligent tutoring system**
o Allow students to use natural input (**handwriting and speech**) to solve mathematics equations online
o Paper-like interface should be more natural and **reduce cognitive load** of student
o Achieve **better learning** and increased transfer of equation-solving skills

Project Phases (Year 1)

Phase I: Input Modalities study
o Test speed, user error, and user preferences for various modalities when entering mathematical equations
o Completed

Phase II: Data Analysis, Recognition Engine Testing
o Analysis of corpus from Study 1 for design recommendations
o Testing recognition engines on corpus from Study 1
o Training recognition engines on samples of real student handwriting and speech
o Prototype implementation

Phase III: Prototype Usability study
o Test usability of prototype system
o Multimodal versus unimodal equation entry (handwriting and/or speech)
o Test both with and without active machine recognition of input
o Learning gains within Cognitive Tutor lesson on equation solving

Current Findings

o Handwriting **faster**, **more efficient**, and **more enjoyable** to novice users than standard keyboard-and-mouse
o **Handwriting-plus-speech faster and better liked** than keyboard-and-mouse
o Handwriting-plus-speech not much worse than handwriting alone, so **multimodal may be a winner**

Phase I Method

| Condition	Description
Keyboard-and-mouse	Used keyboard and mouse with Microsoft Equation Editor.
Handwriting-only	Wrote on TabletPC Journal program; without recognition.
Speech only	Dictated into microphone; without recognition or visual feedback.
Handwriting-plus-speech	Both spoke and wrote either in series or in parallel (user choice).

Sample Stimuli and User Input

| Condition	Typeset Version	User Input
Keyboard-and-mouse	$\dfrac{1}{|x|+1} - \dfrac{x^2}{2} \le y$	$\dfrac{1}{/1/+1} - \dfrac{x^2}{2} \le y$
Handwriting only	$f(x) = 5(y_1 - y_2)$	$f(x) = 5(y_2 - y_1)$
Speech only	$\dfrac{y-4}{y^2 - 5y + 4} = 9$	"y minus four over y squared minus five y plus four equals nine"
Handwriting-plus-speaking (in parallel)	$\sum \left[c_k^2 - 2c_k - 10 \right]$	$\sum \left(c_k^2 - 2c_k - 10 \right)$ "sum of c subscript k squared minus two c subscript k minus ten close parentheses"

Phase I Results
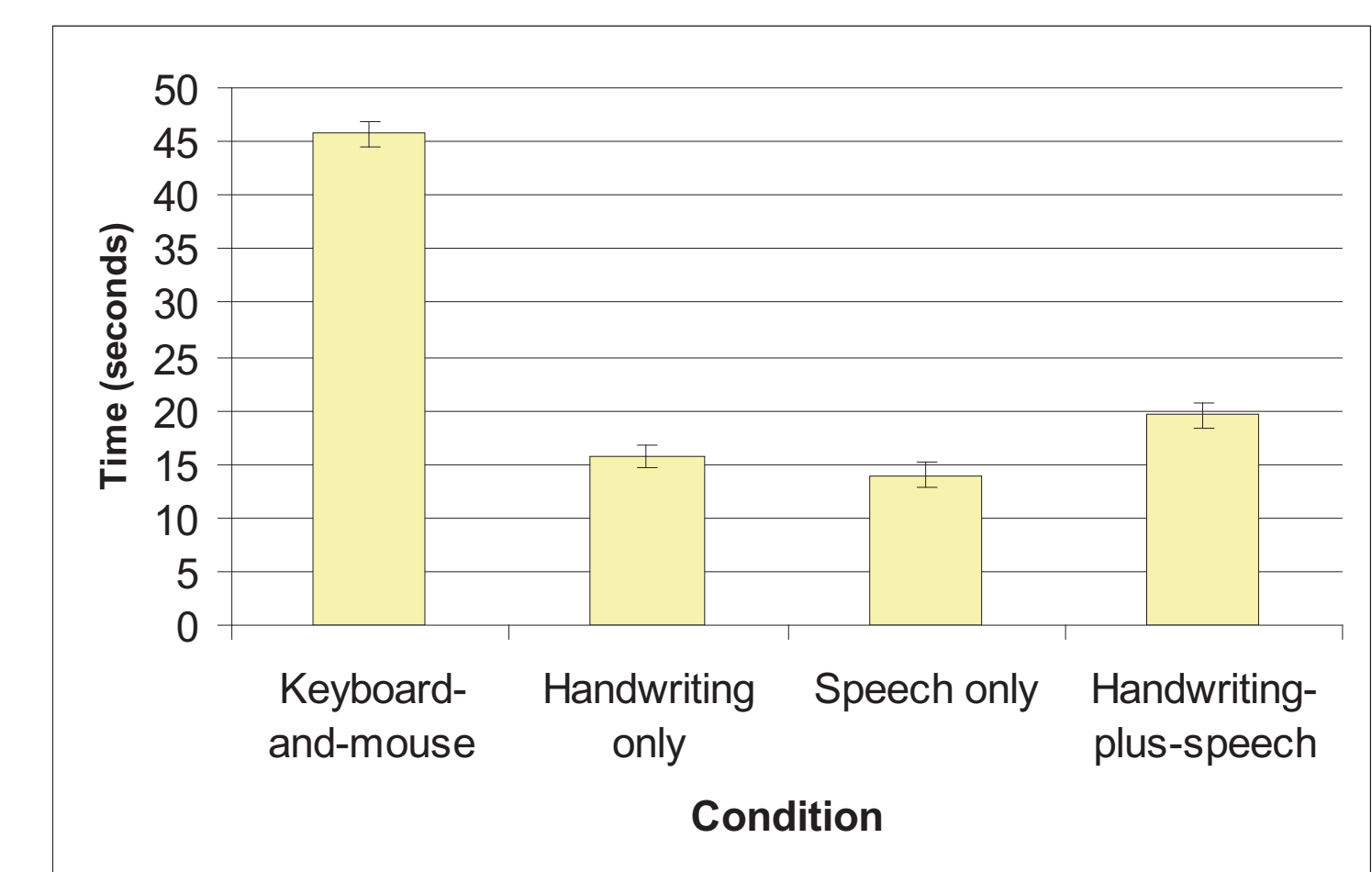
Average time in seconds per equation by condition. Error bars show 95% confidence interval (CI).
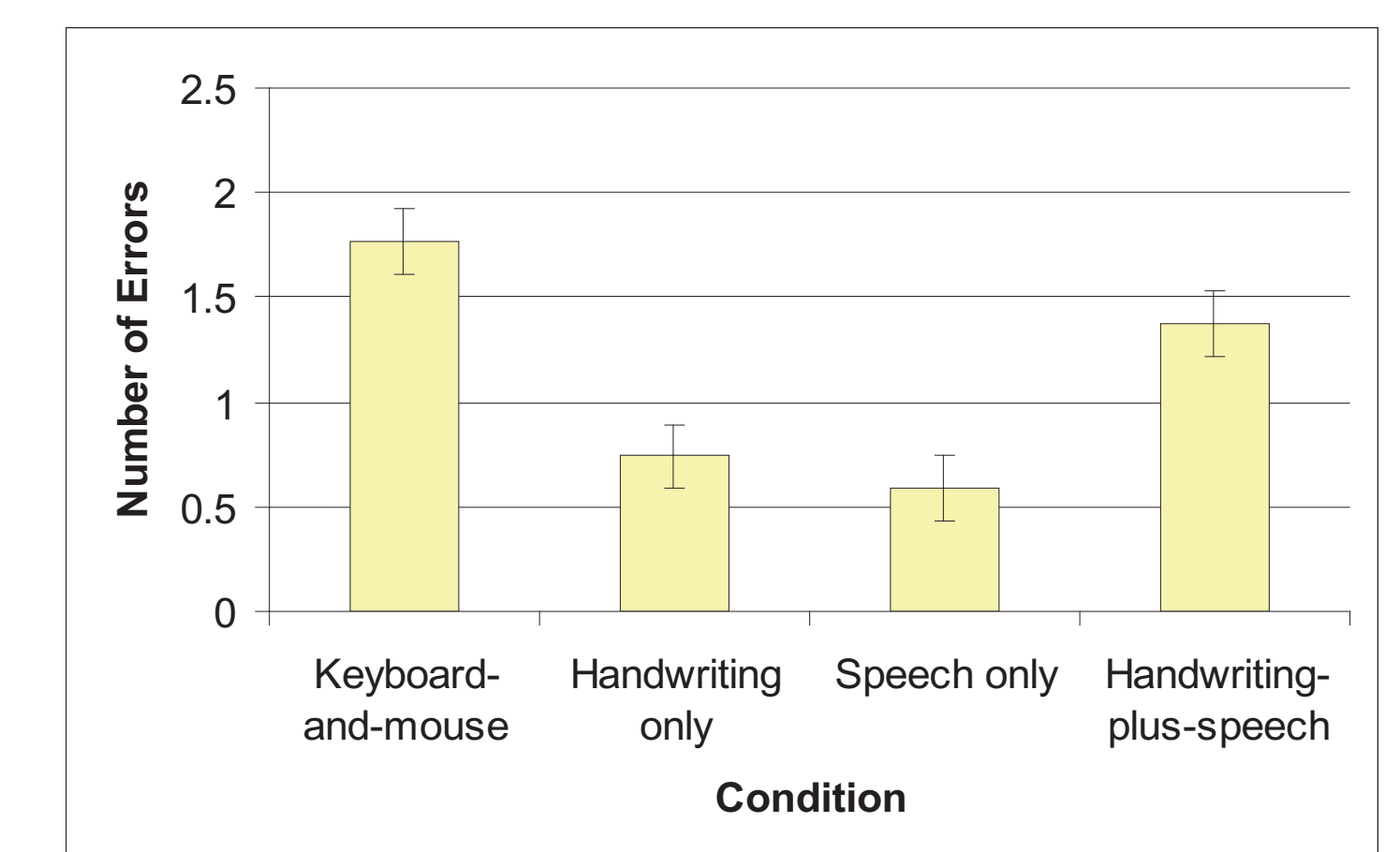
Mean number of errors made per equation by condition. Error bars show 95% CI.
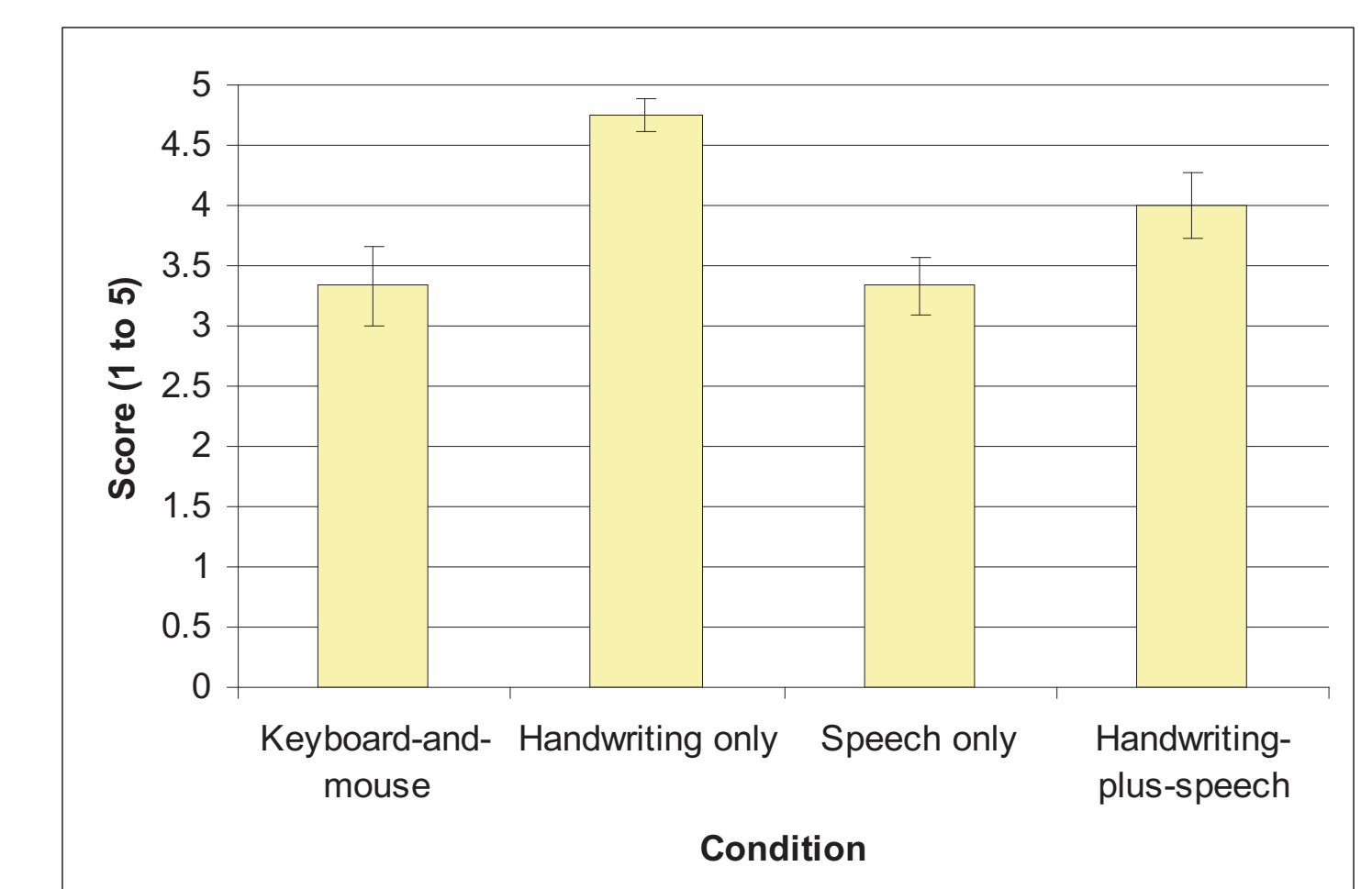
Post-test questionnaire rankings of each condition on a 5-point Likert scale. Error bars show 95% CI.