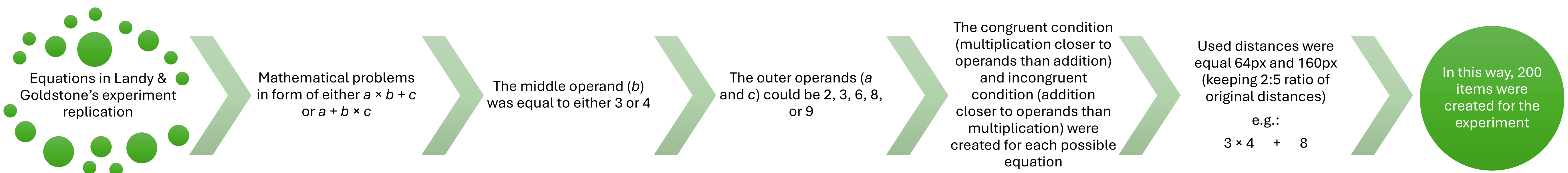


Spatial Biases in Arithmetic: The Effect of Operation Order and Visual Spacing on Calculations

Michał Obidziński^{1*}, Martyna Sroka¹, Krzysztof Cipora^{1,2}, & Mateusz Hohol²
¹Jagiellonian University in Kraków; ²Loughborough University; *michal.obidzinski@uj.edu.pl <https://mcll.edu.pl>



Conceptual replication of the third experiment of Landy & Goldstone (2010) – conducted online	Key changes to the procedure: forced-choice test instead of open tasks; smaller, more natural spacing between operands and operators
SHORT OVERVIEW	
Math4Speed test was used to investigate relationship between overall mathematical performance and congruency/incongruency effect	There are significant differences between congruent (C) and incongruent (I) stimuli: RTs are faster, and accuracy is significantly better for C vs I



Procedure in Landy & Goldstone's replication:	Math4Speed:
<ul style="list-style-type: none">Stimuli: mathematical problemsPresented with 4 possible answers (similar to a school test)Among the four options: one is correct, one reflects an operation-order error, and two are ± 2 from the former twoExample: for $3 \times 4 + 8$, the options could be 20, 36, 18, and 38Responses were given using the computer keyboard (D, F, J, and K keys)A short training session preceded the main task	<ul style="list-style-type: none">Speeded arithmetic task involving the four basic operations: addition, subtraction, multiplication, and division (Loenneker et al., 2024)There were 4 separate sections for operationsEach section consisted of 50 items and ended after a 2-minute deadline or when all equations had been answeredAnswers were given in an open format

Participants			
N = 201 after excluding 20 participants		N = 176 after exclusion of outliers	
17 due to poor performance: overall accuracy below 25% and/or consistently short reaction times (less than 500 ms in at least 15% of responses)	3 due to duplicate participation	Participants who scored below 25% accuracy in any condition	All analyses were conducted separately with and without outlier participants

Results – ANOVA for Congruency (2) × Operation Order (2), and Correlation			
Accuracy	Reaction Time	Error type	Correlation with Math4Speed
Overall <ul style="list-style-type: none">Congruency, $F(1, 200) = 22.85$, $p < .001$, $\eta^2_p = .1$Both, main effect of Order ($p = .099$) and Interaction ($p = .331$) are not significant	Overall <ul style="list-style-type: none">Congruency, $F(1, 185) = 75.27$, $p < .001$, $\eta^2_p = .29$No significant effect of Order ($p = .088$)Interaction effect, $F(1, 185) = 13.18$, $p < .001$, $\eta^2_p = .07$	Overall <ul style="list-style-type: none">Congruency: $F(1, 200) = 25.74$, $p < .001$, $\eta^2_p = .11$Order: $F(1, 200) = 5.54$, $p = .020$, $\eta^2_p = .03$No significant Interaction ($p = .912$)	Overall <ul style="list-style-type: none">M4S x Accuracy: $r = .21$, $p = .002$M4S x RT: $r = -.64$, $p < .001$
Without outliers <ul style="list-style-type: none">There is no significant effect	Without outliers <ul style="list-style-type: none">Congruency: $F(1, 175) = 126.85$, $p < .001$, $\eta^2_p = .42$Order: $F(1, 175) = 8.74$, $p = .005$, $\eta^2_p = .04$Interaction: $F(1, 175) = 8.77$, $p = .004$, $\eta^2_p = .05$	Without outliers <ul style="list-style-type: none">Congruency: $F(1, 175) = 11.37$, $p < .001$, $\eta^2_p = .06$No significant effect of Order ($p = .240$)No significant interaction ($p = .850$)	Without outliers <ul style="list-style-type: none">M4S x Accuracy: $r = .16$, $p = .04$M4S x RT: $r = -.65$, $p < .001$

