Multilevel Models for Single-Case Data: Using Virtual Manipulatives for Students With Disabilities

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Abstract

The purpose of this study was to synthesize the effects of using virtual manipulatives to increase the mathematical accuracy of students with disabilities over the last 20 years of research. By applying three-level multilevel modeling, the research team analyzed both immediate effects and trends during the intervention phase. The current manuscript was submitted for publication (Shin et al., 2021).

Introduction & Method

- Multilevel models for individual case data allow for flexibility and can address methodological considerations within SCD studies, such as changes in levels and trends between baseline and intervention phases (Baek et al., 2020), variability in intervention effects through moderators at both the case and study levels (Moeyaert et al., 2020), and within-group errors that can be autocorrelated (Petit-Bois et al., 2016).
- The four inclusion criteria for the selection of studies were as follows: (a) studies included students with disabilities in grades K–12; (b) the research designs of the studies were single-case designs; (c) the independent variable was the use of virtual manipulatives; and (d) the dependent variable was mathematical accuracy.
- The research team extracted a total of 1,797 raw data points from 114 cases across 35 single-case studies published between January 2000 and September 2020.
- Single-case design data are hierarchically structured and can be displayed as three-level multilevel modeling (e.g., Moeyaert et al., 2020), repeated measurement occasions (Level 1), nested within cases (Level 2), and cases nested within studies (Level 3).

Method (continued)

- We applied a piecewise linear regression approach (Level 1) by separately modeling time trends in the baseline and intervention phases (Singer & Willett, 2003).

$$y_{ijk} = \beta_{00jk} + \beta_{01jk} Intervention_{ijk} + \beta_{02jk} Intervention_{ijk} \times Time_{ijk} + e_{ijk},$$

where y_{ijk} is the mathematical accuracy at the measurement occasion, i^{th} (i = 0, 1,…I), for the j^{th} case (j = 1, 2,…J) in study k when β_{00jk} is the baseline level, β_{01jk} is the change in level when the intervention phase starts (immediate effect), β_{02jk} is the change in slope between the baseline and the intervention phase (trend during the use of virtual manipulatives), and e_{ijk} is an error term that is assumed to be independent and is normally distributed with a mean of 0 and variance of σ^2. $Intervention_{jk}$ was dummy coded (0 for baseline phase, 1 for intervention phase); and $Time_{ijk}$ was centered at the first measurement occasion in the intervention phase.

Empirical Results

Table 1. *Parameters for the Three-Level Multilevel Model Without Moderators*

Parameter	Model 1
Fixed Effects	
Immediate effect (γ_{0100})	71.75*** (3.69)
Trend during intervention (γ_{0200})	1.68*** (0.40)
Random Effects	
Between-study variance	
Immediate effect ($\sigma^2_{v_1}$)	423.39* (115.91)
Trend during intervention ($\sigma^2_{v_2}$)	2.95* (1.35)
Between-case variance	
Immediate effect ($\sigma^2_{u_1}$)	95.57* (33.46)
Trend during intervention ($\sigma^2_{u_2}$)	1.59* (0.98)

Note. Standard errors are in parentheses. The means and variances of the intercept (baseline level) are not presented.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Empirical Results & Implications

- The average immediate effect and trend during the intervention were statistically significant.
- The average immediate effect varied significantly by student grade, disability type, developer, device, type of virtual manipulative, and visual model embedded in virtual manipulatives.
- The visual model embedded in virtual manipulatives significantly influenced the average trend during the use of virtual manipulatives.
- The findings of the present study highlighted favorable effects on students' growth over time, as well as increased mathematical accuracy through the use of virtual manipulatives.
- Virtual manipulatives can be flexibly used to fit the various sizes, colors, and unlimited objects provided during mathematics instruction.

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References

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