Old Wine In A New Bottle?

Problem-Size Effect Re-examined With Multilevel Modelling

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Introduction

Analysis of variance (ANOVA) is widely used in analyzing the problem size effect, a dominant behavioural pattern in arithmetic problem solving. Despite its popularity, ANOVA is not ideally suited to capture either inter- or intra-individual variabilities in data obtained from experiments on mental arithmetic.

We applied ANOVA along with two other statistical approaches – two-step regression and multilevel modelling (MLM) – to an archival dataset (LeFevre & Liu, 1997), and compared patterns of the problem-size effect resulting from each approach.

Description of the dataset

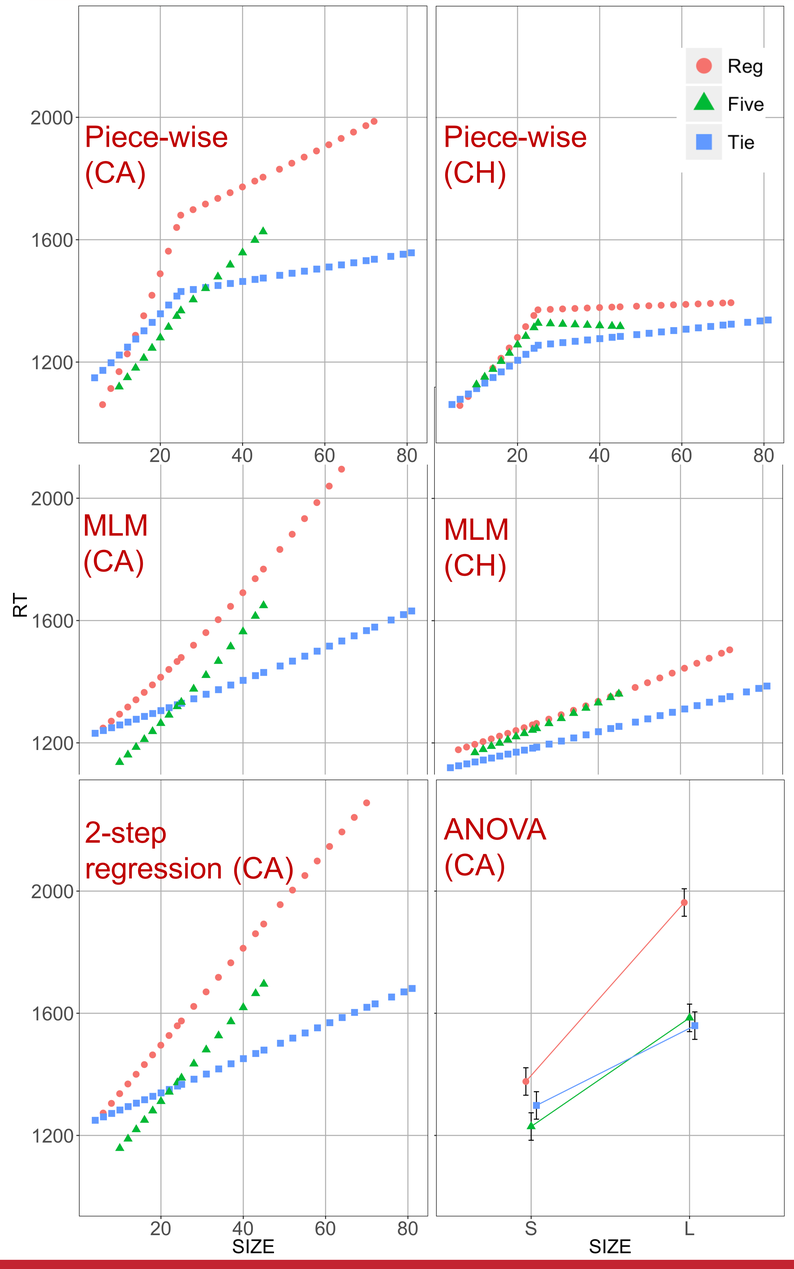
Twenty Canadian (CA) and twenty Chinese (CH) participants, each solved 192 single-digit multiplication problems.

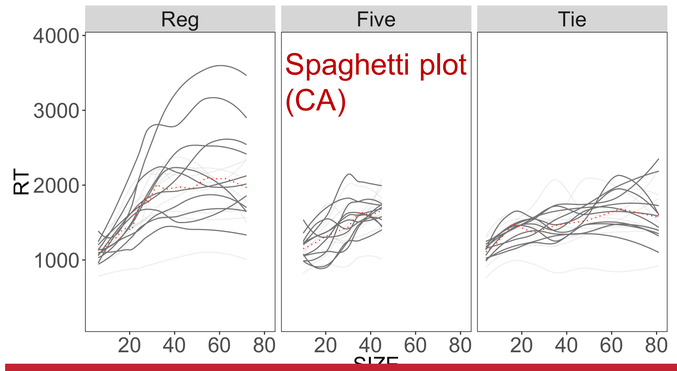
Problem types include five (e.g., 5x7), tie (e.g., 4x4), and regular (any problem that is not five or tie, nor has 0 or 1 in the operands).

Statistical Approaches

ANOVA	DV - Latency IV - educational background (between; CA, CH), problem size (within; Small, Large), problem type (within; Regular, Five, Tie).	
Two-step regression	Latency was regressed on problem size & type for each individual; regression coefficients were then compared across culture groups (i.e., CA vs. CH) using *t*-test. This "slopes-as-outcomes" approach was adopted in the original study.	
MLM	At level-1, latency of each individual problem is a function of its size and type. At level-2, person's education background is a predictor for intercept and all slopes. Problem size effect was allowed to vary across individuals.	
	Piece-wise	A variation of the base MLM in which the problem size effect was allowed to take different trajectories on small *vs*. large problems.

Results





Conclusion

Piece-wise model is by far the most accurate among the four, judging by its similarity to the spaghetti plot of the raw data. Two-step regression and multi-level modelling gave almost identical results in this dataset.

Using piece-wise model, the problem-size effect is much smaller on large *vs*. small problems. This transition is most noticeable among Chinese participants, for whom the large problems were almost interchangeable.

Using ANOVA, predicted latencies on the large Five and large Tie problems become indistinguishable among Canadian participants. However, a difference between the two are unmistakable based on regression-like approaches.

Unlike previously assumed, response time slows down unevenly rather than steadily as problem becomes larger. Multilevel modelling is more suitable than ANOVA for analyzing the problem size effect and affords the opportunity to more versatile models such as a piece-wise one.

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