Can evidence of non-retrieval procedure use be found in the shape of response time distributions?

Distributional analyses were performed using the ex-Gaussian model, which consists of a normally distributed leading edge component and an exponentially distributed tail. The ex-Gaussian model provides a good fit to response time data and allows three quantitative summary measures of distributional shape to be obtained:

- **Mu** (\(\mu\)) the mean of the normal component
- **Sigma** (\(\sigma\)) the standard deviation of the normal component, and
- **Tau** (\(\tau\)) the mean of the exponential tail.

We evaluated the position of Penner-Wilger, Leth-Steen & LeFevre (2002) that non-retrieval procedure use is reflected in tau. Self-reports were collected in order to provide a crucial check against an existing measure of procedure use. If tau does index procedure use, then individuals using a greater proportion of procedures should have more positively skewed response time distributions, reflected in larger tau values.

**Method**

Adult participants solved 288 single-digit addition problems ranging from 2 + 2 to 9 + 9. Problems were presented on a computer screen and participants responded verbally. After each problem participants gave self-reports of their solution method from the following list: Transform (if knowledge of another problem was used), Count (if a strategy based on counting was used), Remember (i.e. retrieval, if the answer came to them without any steps or calculations), and Other (Campbell & Timm, 2000).

**Analyses**

Large problems were defined as products greater than 25, small problems as products less than or equal to 25. Participants were divided into groups based on percentage of retrieval use reported: Retrievers (9 participants) reported retrieval on 99% of small problems and 98% of large problems. Procedure users (8 participants) reported retrieval on 40% of small problems and 30% of large problems.

Traditional measures including mean response time (RT), standard deviation (SD), percent error, and the three ex-Gaussian parameters, obtained by fitting the ex-Gaussian distribution to the individual participant data in each of the four conditions, were analyzed in a series of 2 (problem size: small, large) x 2 (group: retrievers, procedure users) repeated-measure ANOVAs.

**Results**

Traditional analysis (Figure 1, left panel).

Participants were slower, their response times more variable, and more errors were made on large problems than on small problems. Procedure users were slower to solve problems than retrievers and their response times were more variable. Mean RT and SD showed a Problem size x Group interaction such that retrievers did not show a problem-size effect whereas procedure users did.

Ex-Gaussian analysis (Figure 1, right panel).

Tau was larger for large problems than small problems. Mu and tau were both larger for procedure users than retrievers. The Problem size x Group interaction evident in RT and SD is evident only in tau such that retrievers did not show a problem-size effect whereas procedure users did. As mean RT = mu + tau, and variance = sigma^2 + tau^2, the effects evident in mean RT and SD result from the effect in tau.

But mean RT and SD show the same pattern as tau, so why not just use mean RT and forget about tau? Increases in RT (or SD) can result either from an increase in tau, or mu (or sigma), or both. It is also possible to get a tradeoff between tau and mu (or sigma) such that no effect is evident in traditional measures. Tau isolates the effect of interest and ensures it is not obscured.

**Conclusion**

Evidence of procedure use can be found in tau, the mean of the exponential tail of response time distributions, as posited by Penner-Wilger et al. (2002). Tau successfully distinguishes between groups of retrievers and procedure users for single-digit addition. Thus, tau shows promise as an additional, objective tool for exploring phenomena in mathematical cognition within the framework of individual differences in solution procedures.

**References**


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