

REJOINDER: COMBINING SPEED AND ACCURACY TO ASSESS ERROR-FREE
COGNITIVE PROCESSES

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We welcome Rouder's thoughtful comments, which provide valuable context for our work. We especially appreciate the amount of time that he has placed into examining features and properties of our model. Rouder points out the close connection of our modeling framework with the deadline model framework of Ollman and Billington (1972). In doing so, he explains some of the difficulties that have been discovered with deadline models, summarizing work by Ruthruff (1996) as well as his own with Ratcliff (Ratcliff and Rouder, 1998). Our response to Rouder's discussion allows us to clarify a bit further the assumptions underlying our model.

While Rouder is correct in noticing that our error-free statistical model is nearly identical to the deadline model of Ollman and Billington (1972), our model is, in fact, different in a crucial respect. The deadline model, like our error-free modeling framework, assumes a race between two processes. The process of interest, the discrimination process, infallibly produces correct responses. The model assumes that a participant's underlying discrimination time distribution depends only on the type of stimulus presented, so that it is not affected by the relative stress on speed versus accuracy. Meanwhile, the deadline time process is under control of the participant, and is manipulated by the individual according to the demands of a trial. In other words, the deadline time is set by a participant before a trial begins, and is meant to capture the relative demands on speed versus accuracy.

In our modeling framework, we also posit two processes that are in a race; one, the error-free process, which always produces correct responses, and the other, the guessing process, which randomly produces correct responses. But unlike the deadline model, our error-free modeling framework assumes that the two processes occur in parallel, and are meant to reflect all cognitive processes that are participant-specific for a fixed experimental condition. Thus, by contrast, our framework allows for the possibility that *both* processes can be affected by speed versus accuracy demands, not just one of the two processes (i.e., the guessing process). If speed or accuracy demands are experimentally manipulated (e.g., by asking the participant to be as accurate as possible rather than as quick as possible), then they can affect the error-free process insofar as changing speed or accuracy demands constitutes a change in the experimental condition. In our framework, all differences in an experimental setting, whether they are explicit changes in stress on speed versus accuracy, change in the difficulty of the task, change in induced emotion, etc., are

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incorporated as covariates in the models for both latent response time distributions. Even when difficulty of the task is randomized within block, as in Ratcliff and Rouder (1998), appropriate covariates and their effects can be included in the latent model distributions. Because our error-free distribution can be affected by speed stress versus accuracy stress, many of the criticisms raised against the Ollman and Billington's deadline model, including those criticisms derived from empirical failures to satisfy the deadline inequality, do not apply to our framework. In particular, Rouder's comment that the deadline cannot depend on stimulus difficulty does indeed apply to Ollman and Billington's model, but not ours.

If the error-free distribution can depend on the experimental instructions stressing accuracy versus speed, what is the error-free process measuring? It is very specifically measuring the distribution of times for a process that always produces correct responses, assuming that an amalgam of competing processes produces a correct response with a pre-specified probability (usually, but not always, corresponding to the reciprocal of the number of task choices). It is the prespecified probability of correctness for the guessing process that is the crux of our model. With this parameter fixed, our article shows that the distributions corresponding to the race between an error-free and guessing process are completely identifiable, and that any extra modeling assumptions are simply to gain precision in inferences. However, if it is believed that a guessing process operates on partial information, so that guesses have a greater than random chance of being correct, then our modeling assumptions will produce error-free inferences that are difficult to interpret.

To clarify the use of our model, suppose an experimenter constructs two sets of trials with similar stimuli, one in which accuracy is stressed, and the other in which speed is stressed. Following our approach, these sets of trials would be modeled separately, or at least modeled having some of the error-free distribution parameters be distinct from the guessing distribution parameters. If it turned out that the estimated parameters of the error-free distribution were statistically significantly different, then one conclusion that can be reached is that imposing speed versus accuracy stress on a participant is itself an experimental condition, so we should not be surprised to expect that the underlying error-free distributions would differ. For example, if the error-free time is greater, on average, for accuracy stress trials than for speed stress trials, then, under the assumptions of our model, instructing a participant to respond quickly results in quicker error-free responses.

Rouder also examined our model by producing simulated data based on a range of parameter values. Our modeling framework allows inference for the correct latent distributions, assuming that the modeler is willing to relax distributional assumptions sufficiently. This is both a blessing and a curse. On the one hand, any empirical distribution of reaction times corresponds to a set of identifiable error-free and guessing response time distributions. On the other hand, what class of distributions should one assume? Rouder illustrates that using Weibull models for the latent distributions results in simulated reaction time data that do not share characteristics of actual data. In adopting our framework, this suggests that perhaps a larger class of models, not just three-parameter Weibull models, should be considered. And, as suggested in our paper, model diagnostics (particularly graphical ones) can help to identify incorrect modeling assumptions. In this sense, we fully agree with Rouder that users of models such as ours need to be aware of the possibility of model misspecification, and its consequences.

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