Timing errors in sequence experiments: Implications for models of temporal processing

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From the execution of complex motor plans to the perception and generation of speech, our brain depends on reliable representations of time. Currently, it is not easy to decide which of the many existing theories and models describes best the neural processes underlying these representations. We have conducted psychophysical experiments in combination with detailed computational modeling in order to critically evaluate existing theories and to find a neuronal model which is in accordance with the psychophysical results.

One testable prediction that seperates two different classes of models is about the influence of context information on timing errors. If participants are presented with a sequence of intervals of constant length (CI), followed by an interval of a slightly varied length (VI), one might expect that this interval is easier to detect the more CIs are previously presented. However, evidence for this effect is ambiguous and there are both models that predict an augmented discrimination and those which deny such an effect.

In our experiments, the participants listened to sequences of isochronous tone intervals and had to detect a temporally deviating interval VI that could occur at different positions within the sequence. We found that the position of the VI influencenced the discrimination threshold, so we could rule out the class of models that do not predict an adaptation effect. The results also question models based on oscillatory processes, as phase information did not effect the performance. Furthermore, we varied both the duration of the standard intervals and the number of presented intervals in the sequence. While the discrimination threshold increases with the duration of the intervals, indicating impaired performance, the number of intervals has no effects. This implies that the sequence is not processed as a whole. In this case, additional intervals would increase the total length of the sequence and decrease the performance, just as changing the length of the intervals does. Thus, we conclude that each interval must be processed individually in a first stage and the effects of the context information can be separated from those of the interval duration.

Finally, we present a computational model of the stage that is directly concerned with temporal processing and which explains the dependence of temporal variability on the length of the intervals. While it is known that timing errors increase monotonically with the duration of the interval to be processed, current theories also postulate that they obey Weber’s law, which states that this increase is linear. This view is challenged by recent experimental findings which report deviations from linearity at longer intervals. Our model, which is based on a set of synfire chains with different speeds of transmission, explains the complete form of the error course as the optimal solution under limited resources. Furthermore, we discuss a mechanism based on spike-timing dependant plasticity which implements the neuronal selection of the optimal chain for each given interval of time. This mechanism also integrates the output from the various chains into a unique representation of time, and provides an explanation for training effects on temporal processing.

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