# Neural variability quenching during decision-making: Neural individuality and its prestimulus complexity

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## Introduction

Variability in brain activity between participants has long been treated as meaningless noise or measurement error [1]. This neural variability, especially in task-evoked responses, however, has recently been shown to explain the behavioral and perceptual differences of individual participants [1,2], thus challenging this view.

It has been shown that prestimulus and resting state activity influence trial-to-trial variability (TTV), which suggests that TTV is partly due to internal - prestimulus - rather than external - stimulus-related - sources. The influence of the two implies that TTV is a hybrid of the impact of both internal prestimulus activity levels and external stimulus-related effects.

The operational distinction between internal and external effects can, on a psychological level, be studied comparing internally-guided (IDM) and externally-guided decision-making (EDM). In IDM, no correct answer based on external criteria exist; participants respond based on their own internal preferences – this reflects individuality on a psychological level.

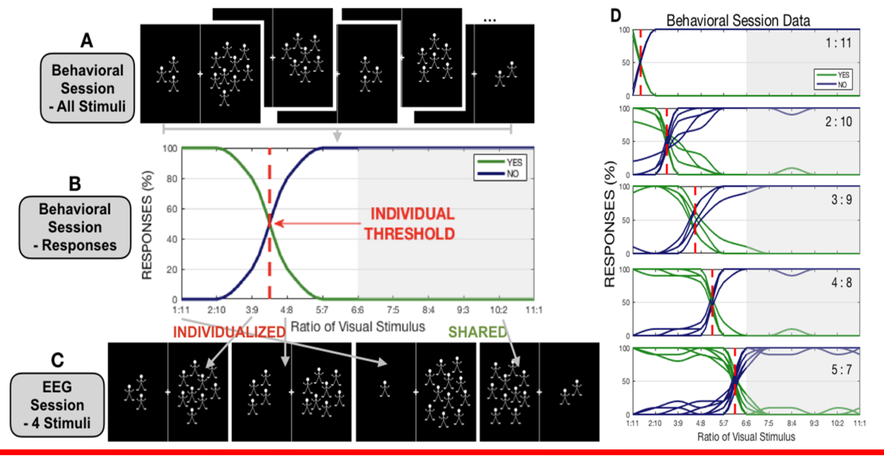


**Fig 1:** Study threshold determination and behavioral session results. **A)** Determination of threshold in behavioral session. After reading a scenario, participants were presented with 10 repetitions of each stimulus. **B)** Based on the responses, the threshold was calculated. **C)** The individualized stimuli and the shared stimuli were presented to participants in the EEG session. D) Response results from the behavioral session for all participants.

In contrast, in EDM there is one correct answer based on external criteria as would be the case if given two words and asked which was longer.

We therefore asked the following question: is poststimulus TTV also mediated by the information complexity of prestimulus activity? In a first step, we investigated the complexity - through the measurement of Lempel-Ziv Complexity - of both prestimulus and poststimulus activity in two 500ms intervals.

LZC, and thus complexity, was significant higher in the prestimulus period in both individualized and shared stimuli. While new by itself, this higher prestimulus complexity is in accordance with the above cited findings related to increased prestimulus activity levels or variance preceding poststimulus TTV. Together, both suggest that the higher amplitude/variance prior to stimulus onset represents a higher information complexity, which decreases after the stimulus is presented. Such a stimulus-related difference in information complexity appears to be a basic, general neural mechanism since no differences between conditions (IDM and EDM) were found.

## Results

### 1. Less TTV quenching in Indiv stims in alpha and beta bands

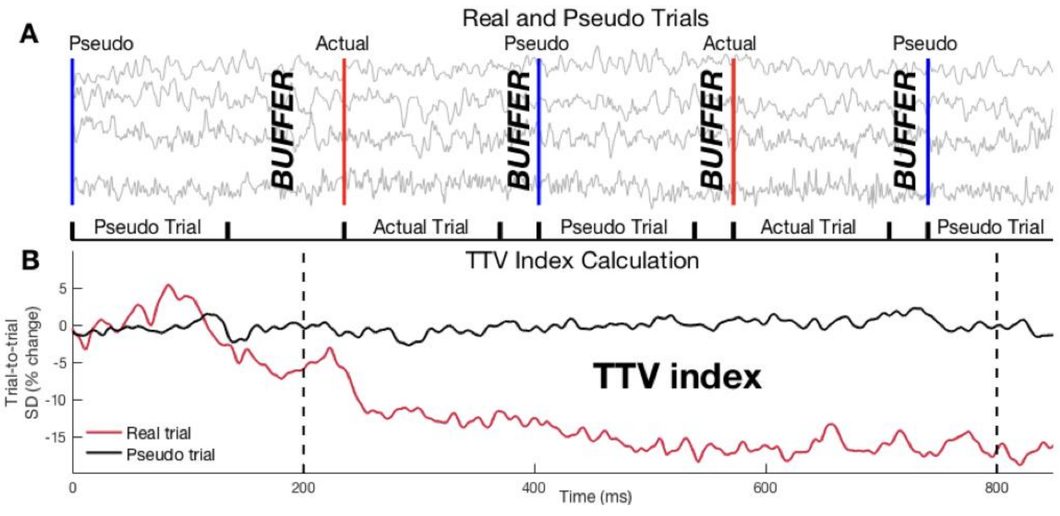


**Fig 2**: Pseudotrial placement and trial-to-trial variability (TTV) index calculation. **A)** Pseudotrials are calculated from periods of the intertrial intervals (ITIs) in which a virtual stimulus was inserted. Before this, a 1s buffer between the actual trial and the pseudotrial was taken. From the pseudotrials, TTV of this pseudo stimulus was then calculated. **B)** To account for the change in variability specifically related to the stimulus itself, the pseudotrial TTV was subtracted from the actual trial TTV from 200 to 800ms poststimulus. The mean was then calculated yielding one value, the TTV index.

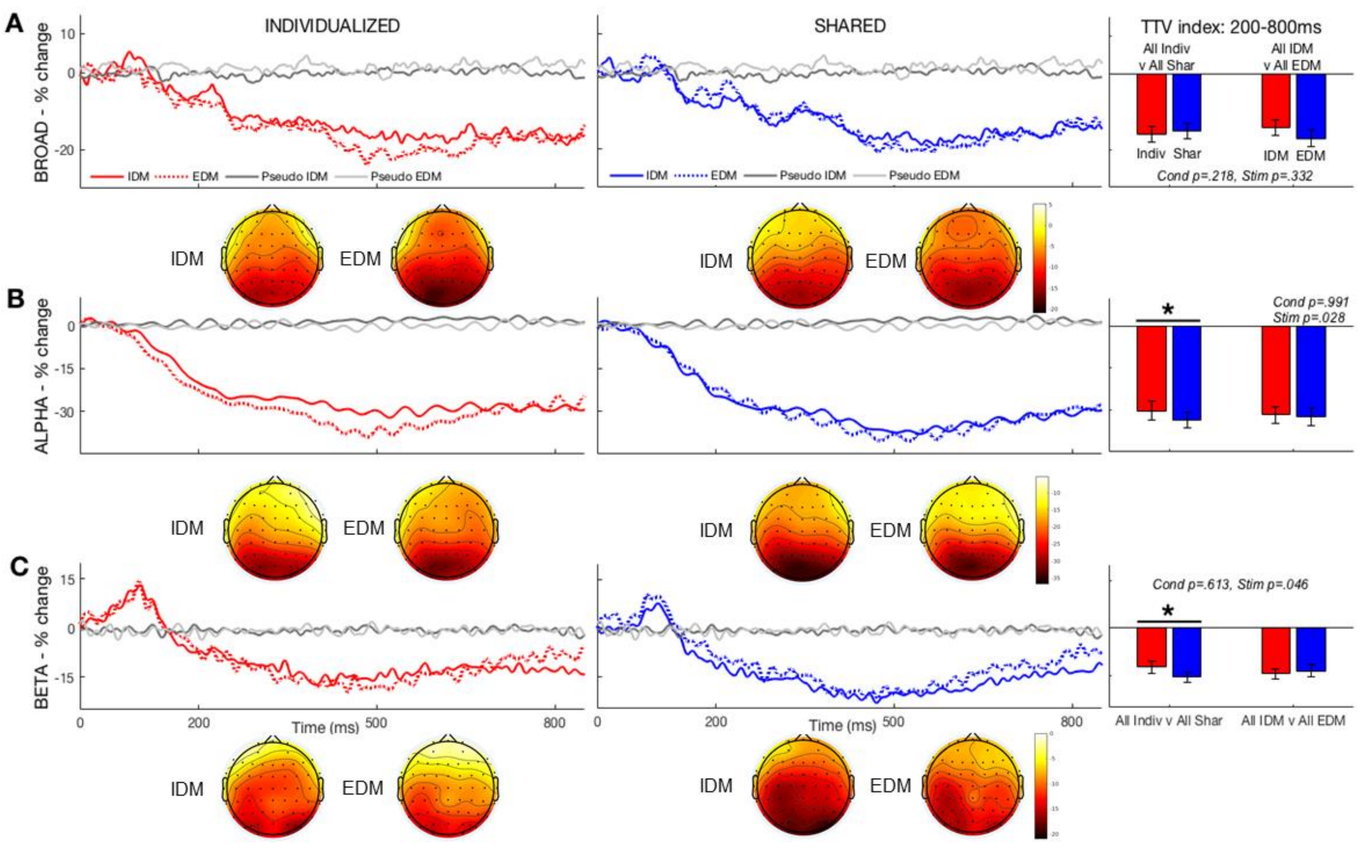


**Fig 3**: Trial-to-trial variability (TTV) index for both stimuli and conditions at Pz. **A)** TTV in the broadband (0.5-70Hz) grouped according to stimulus. Topographical maps for the broadband are below each TTV curve. **B)**, **C)** In a 2x2 repeated measures ANOVA, a significant effect of stimulus was found in the alpha (B) and beta (C) band

### 2. LZC decreases after stim onset while difference in IDM decrease between stims

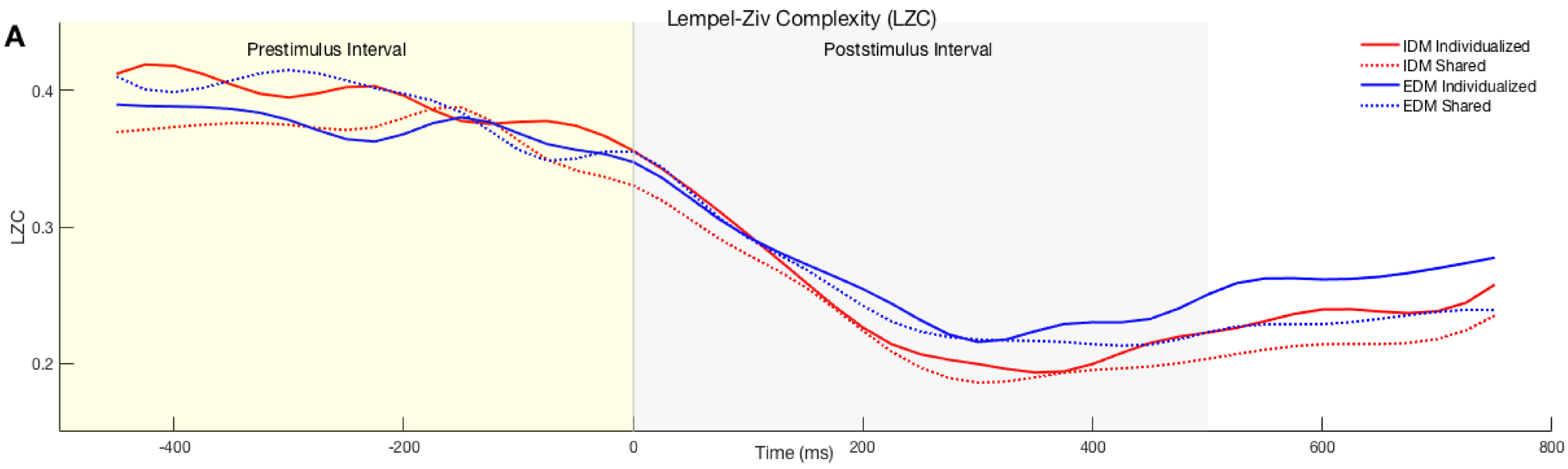


**Fig 4**: Lempel-Ziv complexity (LZC) in the peristimulus periods. **A**) To examine complexity as a mechanism for TTV, 500ms prior to and after stimulus onset were investigated for complexity using the LZC measure. In paired samples *t*-tests, it was found that stimulus onset had a significant effect on complexity in both groups of stimuli and conditions. **B)** Paired-samples *t*-tests compared the difference in LZC related to stimulus onset between the individualized and shared stimuli in both conditions. There was a significant effect of stimulus in the IDM condition, but not in the EDM condition.

### 3. Prestim LZC correlates with TTV index in alpha band for Indiv IDM stims

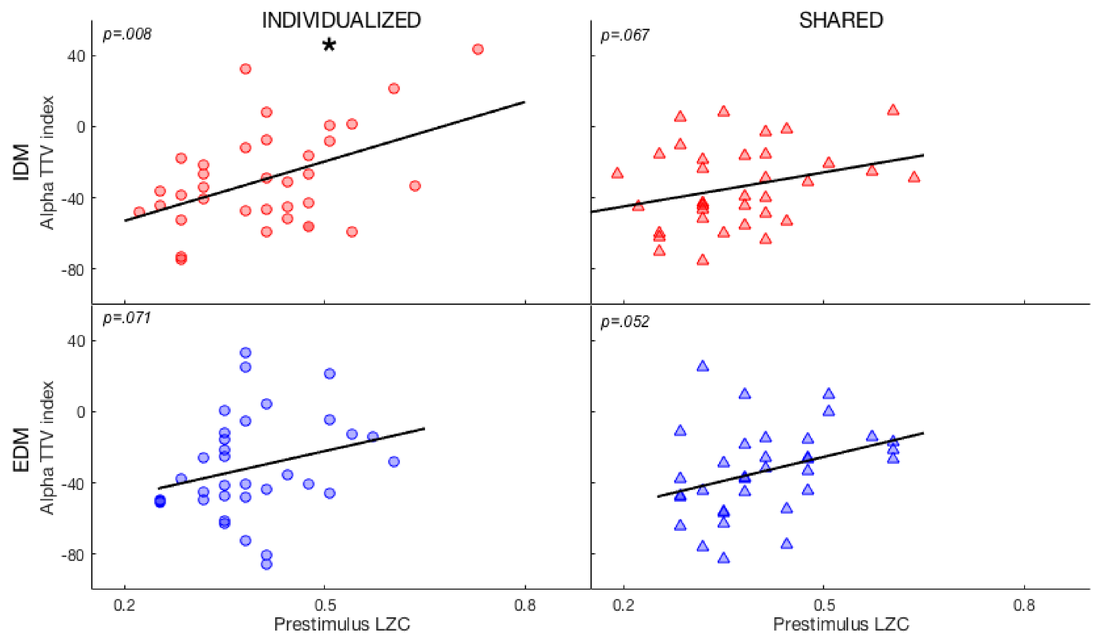


**Fig 5**: Prestimulus Lempel-Ziv complexity (LZC) correlates with alpha TTV index. Significant correlations were found in the individualized stimuli in the IDM condition, not the shared. Neither the individualized nor the shared stimuli had significant correlations in the EDM condition.

## Discussion and Conclusion

Given that in the poststimulus period both TTV and complexity were quenched, we suggest that a reduction in information complexity and variability during the poststimulus period are central to mediating the individual's neural response to stimuli. Our data indicate that spontaneous prestimulus activity and stimulus-induced activity is both nonadditive and individualized. If an interaction were additive, one would observe increases in both TTV and complexity; following the law of variance, the contributions of both spontaneous activity and stimulus are added during stimulus-induced activity.

Furthermore, the mechanism of TTV reduction has previously been related to the disambiguation of stimuli which allows for better information processing in the cortex [3]. Modeling studies have shown that variability reduction can occur from recurrent network processing; in a multi-attractor system, the stimulus presentation can stabilize one attractor thereby suppressing the transition to other attractors. This stabilization of one attractor reduces net neural variability by increasing the neural orderliness. This increased uniformity then leads to a decrease in the transfer of information - according to Shannon information theory – as reduced variability is associated with more structure, and hence with increased predictability in data. This decreasing transfer of information and clarification of stimuli may be evident in the reduced complexity after stimulus onset shown here.

*References:*
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