# Reliable Individual Differences in Brain Responses during Naturalistic Movie Viewing

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## Abstract:

**How brain functional architecture differs across people is a key question in neuroscience. Naturalistic stimuli are instrumental in studying these differences by affording rich experiences during brain imaging. Brain responses to the stimulus can be considered as the sum of responses shared by the group, specific to the individual, and noise. Therefore, when people's brain responses differ, it is difficult to know whether it's caused by individuating responses or noise. In this study, we used an fMRI dataset where 100 participants watched the same movie twice, and the repetition enabled separating individual differences from noise. For each cortical vertex, we partitioned the variance of its response time series into three components: shared, idiosyncratic, and noise. The amount of idiosyncratic variance was more prominent than shared variance for much of the cortex, especially lateral and medial prefrontal regions. The only exception was visual and auditory cortices, where shared variance was predominant. Together, these results demonstrate the substantial amount of idiosyncratic brain responses to naturalistic stimuli and the great potential to use these responses to study individual differences in cortical functional architecture.**

**Keywords: naturalistic imaging; individual differences; precision neuroscience; brain functional organization.**

## Introduction

A key topic in neuroscience is to understand how brain functional architecture differs across individuals, how these differences develop, and how they lead to individual differences in behavior (Bijsterbosch et al., 2020; Dubois & Adolphs, 2016; Gabrieli et al., 2015; Gratton et al., 2020). Naturalistic stimuli afford rich sensory, cognitive, affective, and social experiences, allowing sampling a wide range of neural responses with limited scan time (Finn et al., 2022; Haxby, Gobbini, et al., 2020; Leopold & Park, 2020; Nastase et al., 2020; Sonkusare et al., 2019). In this work, we examine how neural responses differ across individuals during naturalistic movie viewing.

## Intra- and inter-subject correlation

We used fMRI data from 100 participants that were collected while they watched a portion of the movie *Whiplash* in the scanner. The movie stimulus was 30 minutes long. Each participant watched the movie twice, approximately one year apart. The analysis was based on 90 participants with superior data quality.

Data were aligned based on cortical surface anatomy (Fischl et al., 1999). For each cortical vertex, we computed the intra- and inter-subject correlation of the response time series to the movie. We computed the intra-subject correlation as the correlation between the time series of the two sessions of the same participant, and the inter-subject correlation as the correlation between two sessions of different participants (Hasson et al., 2004; Nastase et al., 2019). We averaged the intra-subject correlation across all participants, and the inter-subject correlation across all pairs of participants. Throughout the cortex, intra-subject correlation was higher than inter-subject correlation, suggesting individuals differ in brain responses (Figure 1).

## Reliable response across repetitions

Based on the two repetitions of each participant, we separated the responses reliable across repetitions and the residual responses. The ratio between the amount

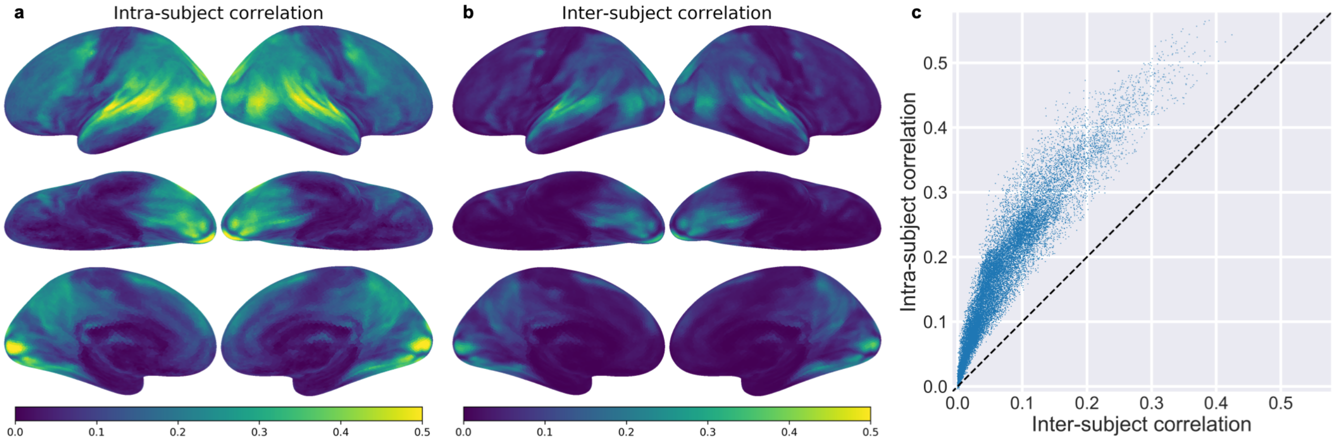

**Figure 1. Intra- and inter-subject correlation of brain responses to the movie.** (a and b) For each cortical vertex, we computed the intra-subject correlation (a) and inter-subject correlation (b) of brain responses to the movie. (c) Intra-subject correlation was higher than inter-subject correlation throughout the cortex. This suggests that much information in neural responses is specific to the individual rather than shared by the group.

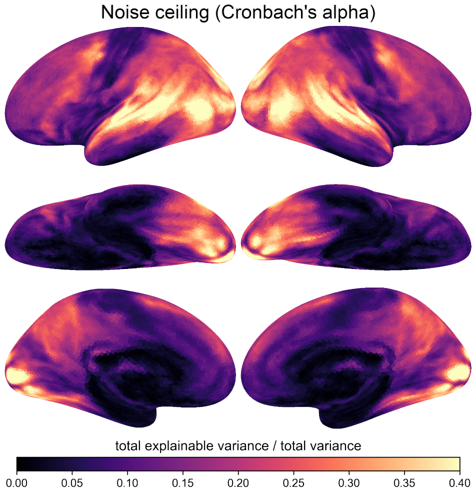

**Figure 3. Proportion of reliable variance across repetitions.** Cronbach's alpha coefficient measures the ratio between explainable variance (i.e., reliable variance across repetitions) and total variance. Higher alpha means that brain response time series of the vertex are more reliable across repetitions.

of reliable variance and total variance is the Cronbach's alpha coefficient, which is often referred to as the noise ceiling. Note that the residuals are not necessarily all noise, and they can contain meaningful information, such as how the movie experience changes when watching it a second time (Lee et al., 2021). Cronbach's alpha was high for almost the entire cortex (Figure 2).

## Separating shared and idiosyncratic responses to the movie

Based on the group-average responses, we further separated the reliable variance into two parts: those can be accounted for by the average responses (shared by the group), and residuals around the group mean (specific to the individual). In other words, we partitioned the variance of each cortical vertex into three parts in total: shared variance, idiosyncratic variance, and noise. Idiosyncratic variance was larger than shared variance for much of the cortex (Figure 3), indicating that brain responses to naturalistic stimuli can be a powerful tool to study individual differences in brain functional organization. Idiosyncratic variance was larger than shared variance in higher order cortices, suggesting that after early sensory processing, information in naturalistic stimuli is processed more idiosyncratically.

Idiosyncrasies may be in the information that is represented (e.g. interpretation of plot and characters, recognition of background music) or in how representation is distributed differently across vertices in fine-grained topographic patterns. Both sources of individual variation may be meaningful. Studies that use anatomical alignment do not distinguish these two types of individual variation in functional cortical anatomy, limiting interpretability. They can be distinguished by resolving topographic differences with hyperalignment and related methods (Feilong et al., 2018, 2021, 2023; Haxby, Guntupalli, et al., 2020).

## Conclusions

Brain responses to naturalistic stimuli encode a substantial amount of meaningful information. These responses are mostly shared across individuals in visual and auditory cortices, and highly idiosyncratic throughout the cortex, especially in prefrontal cortices.

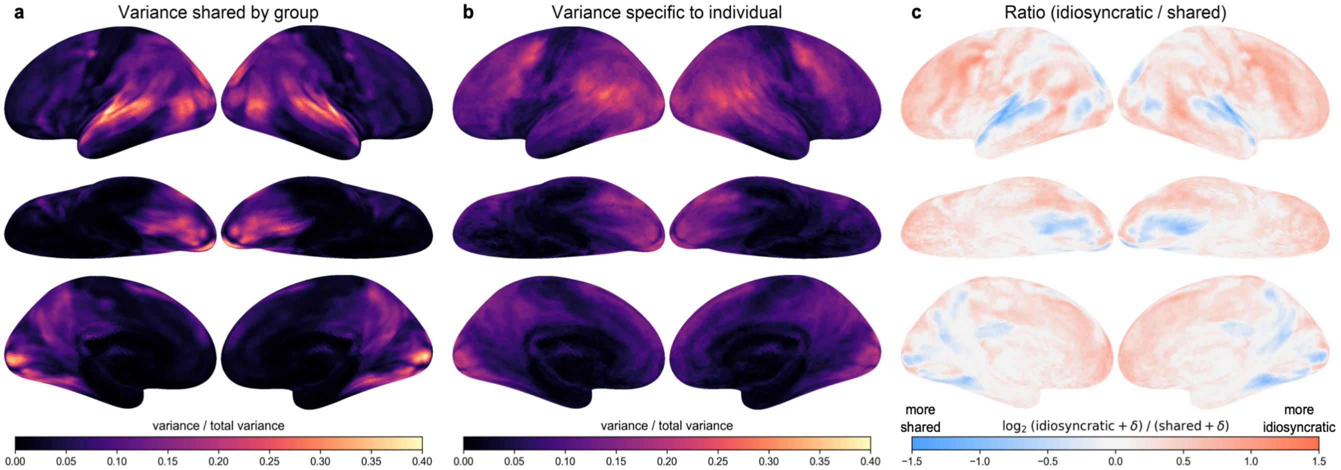

**Figure 2. Separating shared and idiosyncratic neural responses to the movie.** (a and b) The reliable variance can be separated into variance shared by the group (a) and variance specific to the individual (b). (c) For much of the cortex, idiosyncratic variance in neural responses is larger than shared variance.

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