Shared connectome and organization in the human cortex irrespective of sensory experience

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Abstract:

To what extent is sensory experience a prerequisite for the development of the functional architecture of the high-level human visual cortex? In this study, congenitally blind and deaf participants were presented with audio-only and video-only versions of the live-action movie *101 Dalmatians*. Three control groups of participants either watched and/or listened to the audiovisual, the audio-only, and the video-only versions of the movie. Using fMRI data from an independent group of participants, individualized category-selective topographies were successfully predicted in both congenitally blind and deaf participants. Category-selective topographies in the ventral visual pathway in congenitally blind participants were highly comparable to those in sighted participants. Functional connectomes were notably similar across the entire cortex, regardless of the modality of sensory input or the content of the stimuli. This study demonstrates that under real-world conditions, the connectome has a similar organization across varying sensory modalities and content, and shows that development of the functional organization of the human high-level cortex can occur independently of prior sensory experience.

Keywords: Naturalistic movie, Hyperalignment, Development, Sensory deprivation

Backgrounds

The human high-level visual cortex responds selectively to different visual categories (e.g., faces, places), and category-selective topographies exist in the lateral occipital cortex, the ventral visual cortex, superior temporal sulcus, and extend to frontal regions. The general layout of these topographies is similar across individuals, but idiosyncrasies exist in their precise conformation and location. Category-specific activations in response to tactile and auditory stimuli in both typically developed, and sensory-deprived individuals (Fairhall et al., 2017; Mattioni et al., 2020; Pietrini et al., 2004) suggest a supramodal functional organization in these ventral-temporal and occipital areas. In addition, classic functional localizers are vision-based (Fox et al., 2009; Pitcher et al., 2011), and it has not been possible to map individual-specific visual category-selective topographies in congenitally blind participants. It is still unclear whether the functional category-selective topography requires early sensory experience to emerge and develop.

In this study, congenitally blind (BD) and deaf participants (DF) were presented with audio-only and video-only versions of the live-action movie *101 Dalmatians* (Dalmatians, Setti et al., 2023), respectively. Three control groups of participants either watched and/or listened to the audiovisual (AV), the audio-only (AD), and the video-only (VD) versions of the movie. It has been established that individualized category-selective topographies can be estimated with high fidelity across movies using connectivity hyperalignment (CHA) (Jiahui et al., 2023). Another fMRI dataset (Visconti di Oleggio Castello et al., 2020) from an independent group of participants who watched the feature movie, *The Grand Budapest Hotel*, and performed a visual category functional localizer task (Budapest), was included to predict the individualized topographies. The predictions were validated with another independent dataset, in which participants watched the movie *Monkey Kingdom* (Monkey Kingdom) and completed a similar functional localizer task.

Results

Similar predicted organizations across groups

We hyperaligned participants across the Budapest and Dalmatians datasets using CHA and derived transformation matrices using the movie data. The individual transformation matrices projected the localizer data from the Budapest dataset into each individual in the Dalmatians dataset. Category-selective topographies were successfully estimated in both congenitally blind and deaf participants for all four categories (faces, bodies, scenes, objects). Notably, the predicted organizations were highly similar in the congenitally sensory-deprived groups and the typical control participants, regardless of the modality of the sensory input (Figure 1). Moreover, the category-selective functional topographies showed normal variability across individuals in all groups (BD, DF, AV, AD, & VD).

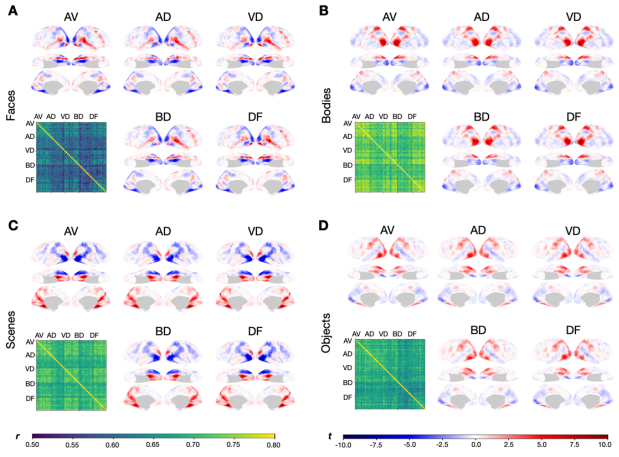

Figure 1: Similar Predicted Organizations across Groups. A. Predicted face-selective topographies

(faces-vs-all) in control groups (AV, AD, VD) and patient BD and DF. The similarity matrix at the lower left corner shows the Pearson correlation coefficients (*r*) between predicted topographies of each pair of individuals across the five groups. **B, C, & D.** Predicted and similarity matrices of body- (bodies-vs-all), scene- (scenes-vs-all), and object-selective (objects-vs-all) topographies accordingly.

Shared connectome across groups and contents

To better understand the functions underlying the similar topographies predicted using CHA, we compared the functional connectome between Budapest and all groups in the Dalmatians dataset when participants watched movies. We found that functional connectomes were highly similar across the entire cortex, regardless of the modality of sensory input. Using searchlight analysis, we demonstrated that functional connectivity was largely shared regardless of the movie content. When visual or auditory information was shared between groups, participants' connectomes showed higher similarity in the corresponding early visual and temporal auditory cortices. Connectomes in the bilateral superior temporal cortices, which are involved in multisensory information processing, were analogous across all participant groups (Figure 2).

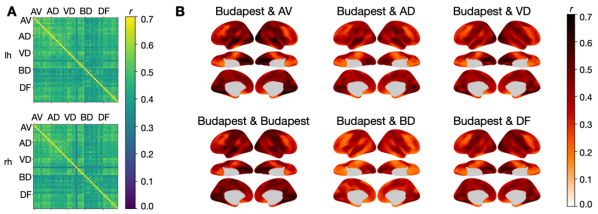

Figure 2: Shared functional connectome in the whole brain and searchlights across groups and contents. A. Correlation matrices of whole-brain connectome across groups in each hemisphere. **B.** Correlations of functional connectome searchlight-by-searchlight across movie contents and groups.

Predictions are specific

To validate whether the predicted topographies were specific to each individual, we included another independent group of participants who watched a different movie (Monkey Kingdom) and had category-selectivity functional localizer scans. Similar to the previous prediction steps across datasets, we derived transformation matrices across the *101 Dalmatians* and *Monkey Kingdom* movies using CHA, and applied the transformations to the predicted topography for each individual in the Dalmatians dataset. By doing this, individualized category-selective topography was estimated in the Monkey Kingdom dataset. Then, we compared the predicted and own topography estimated based on the functional localizer scans.

We discovered that the predicted topography based on the Dalmatians dataset was highly similar to the topography estimated from their own functional localizer, and the correlation was close to and, in some cases, surpassed the noise ceiling of the functional localizer scans. To examine the specificity of the prediction in the Dalmatians dataset for each individual, we shuffled the correspondence of the participants and their predicted topographies before repeating the prediction steps for the Monkey Kingdom dataset. Interestingly, shuffling the correspondence in any of the groups in the Dalmatians dataset significantly lowered the prediction ($p < 0.001$ for all groups and categories), suggesting participant-specific predictions in the Dalmatians dataset based on the Budapest dataset (Figure 3).

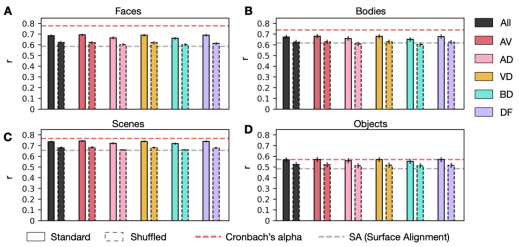

Figure 3: Validation of Participant-Specific Predictions. A. Correlations between predicted topography (face-vs-all) based on the Dalmatians dataset and own topography estimated from the functional localizer for all groups in both standard and shuffled conditions. **B. C. & D.**, Correlations for body- (bodies-vs-all), scene- (scenes-vs-all), and object-selective (objects-vs-all) topographies.

Summary

With real-world, naturalistic stimuli, this study demonstrates that the functional connectome maintains a similar organization across input from different sensory modalities and with different histories of congenital sensory deprivation. The structure of the part of the connectome that is associated with visual category-selective topographies is conserved even in adults with no history of visual experience. These results show that development of the functional organization of the human high-level visual cortex can occur independently of visual experience and introduce a method for identifying category-selective areas in adults who have never seen those categories.

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