**Title**
Consistency and variability in functional localisers



**Authors**
Ong, Rachel
Samano-Lerma, Tanya
Empranthiri, Divya

**Publication Date**
2020-05-01

# "Consistency and variability in functional localisers"

By Rachel Ong, Tanya Samano-Lerma

Cognitive Science and Psychology Undergraduate Laboratory @ Berkeley

Undergraduate Student Mentor: Divya Empranthiri

Graduate Student Mentor: Zuzanna Balewski

University of California, Berkeley

**Acknowledgements**:

We would like to thank our graduate student mentor, Ms. Zuzanna Balewski, for her constant encouragement, guidance, and patience throughout the process of our project.

We would like to thank Professor Mark D'Esposito for his support in working on this project.

We would like to thank the executive board of Undergraduate Lab @ Berkeley, Psychology and Cognitive Science Division, for their assistance and opportunity to work on this project.

**Abstract**

Much of research surrounding reading difficulties is based solely on behavioral analyses. A child's early and correct diagnosis is imperative to insure that they receive adequate resources and support which can severely affect equal opportunities for success in the future. After studying different methods of diagnosis for reading difficulties, we saw most of these tests could not assert significant differences between children with and without reading difficulties. This contributes to diagnoses being heavily reliant on behavioral observations. Since statistically significant distinction can't be made with behavioral tests, researchers are pushed to explore different approaches.

In order to explore more concrete approaches to diagnoses, we then looked at fMRI data to determine if we could accurately attribute functional localizations in the brain to responses to words and pictures. Through this, researchers aimed to use specific neuroanatomical images to determine how the brain activity of a person without reading difficulties corresponds to word- and image-processing. We compared data between two runs of the same subject as well as between subjects in order to determine consistency of the study. Although we could not find consistency between subject, we were able to explore possible ways to optimize fMRI studies for future diagnoses. We hope to one day optimize the data collection system in order to use the localization of brain activity to diagnose children with reading difficulties in an unbiased, systematic way.

## Introduction

In our study, we aimed to use fMRI analysis to determine the consistency and variability of functional activations in the brain. No two brain anatomies are the same, and this natural variation is an obstacle comparing subject data. To overcome this, a standard model of the brain is used as a template and mapped onto a three-dimensional grid space referred to as voxels. By fitting the subject data into this standard model, we can determine brain activity via the general number of voxels being activated in a certain area.

Another difficulty faced in fMRI analysis is the inability to directly measure brain activity. To overcome this, we measure the amount of oxygen present in specific parts of the brain instead, which we call the BOLD signal. Increased levels of oxygen concentration lead to a decrease in deoxyhemoglobin concentration, and the latter's paramagnetic properties cause an increase in fMRI intensity. The highlighted portions in the brain maps are areas which displayed a statistically significant increase in BOLD signal, which can be interpreted as significant brain activity.

As technology expands to find new diagnostic solutions, functional neuroimaging studies are increasingly utilized to determine responses to various stimuli with regards to diagnostic and functional uses. This works by collecting additional scans of participants performing different tasks – in the process, the functionally defined region-of-interests (fROI) are identified before evaluating their response profile. This design operates under the underlying assumption that the functional localizations are consistent – however, is this really the case? In "Consistency and variability in functional localisers," Drs. Duncan, Pattamadilok, Knierim, and Devlin challenged this assumption by measuring the consistency of activation for faces, scenes and body parts;

while the study confirmed that the activation strength of peak voxels sere consistent, it failed to account for the frequency of activation itself. Thus, this paper aims to evaluate the consistency and variability of activation within the brain, specifically in functionally localizing reading and objective sensitive area of the left occipoto-temporal cortex.

**Methods**

In "Consistency and Variability in Functional Localisers," , researchers collected data from a group of 45 participants, 23 males and 22 females, who only speak English. The group had an age range of 19 to 39 with a mean of 25. All of the participants were right handed with normal or corrected vision. The subjects did not have any history of neurological disease and each of them gave consent to the procedure (Duncan, Pattamadilok, Knierim, & Devlin, 2009).

For our project, our group needed to used the program FSL (FMRIB Software Library) to analyze the fMRI BOLD images and develop an analysis of this data. This program has multiple features to it, but for our purposes, we only used the BET brain extraction and FEAT FMRI analysis in order to extract brain images and run tests.

First, we extracted the brain from the original image of the fMRI scan by using the BET brain extraction. Once we had the scan of the brain without the skull in sight, we continued with the analysis with the FEAT FMRI analysis. Once it was launched, we selected the 4D data which would be the bold image of the subject. This will be done for each run. The first two volumes were deleted. Then, we continued to the Pre-stats tab and increased the Spatial smoothing to 6mm. Next is the Registration and on this tab, we uploaded the extracted brain image the main structural image and the standard space. Finally, on the Stats tab, our group kept the options of FILM prewhitening and Standard Motion Parameters as conditions to smooth out our data.

We had four main interests in this analysis. The main interests were words, scrambled words, objects, and scrambled objects. To set up the regression, we had to create text files for each interest. These text files had 3 columns. Column 1 was the onset of block, column 2 was the duration of the blick and column 3 was the magnitude which was 1 for all blocks. The four interests were put into 4 EVs. In each of them, we filled in the name, changed the basic shape to the custom 3 columns, uploaded the corresponding text file, changed the convolution to Double-Gamma HRF, and removed the option to add temporal derivative. EV1 is for words. EV2 is scrambled words, EV3 are objects and EV4 are scrambled objects. After the EVs were set up, we continued to the Contrast and F-test tab. Here we increased the contrast to 2 and titled the categories, "word_loc" and "object_loc". In the first contrast, we assigned a value of 1 to EV1 which is words. In "object_loc", we assigned 1 to objects and -1 to scrambled objects. Once we finished filling it out, we clicked "done" in order to get a visual model of the task and clicked on "Go" to get the analysis.

**Results**

**Subject 1**

The mean displacement was 0.23mm (absolute) and 0.03mm (relative).

**Run 1**

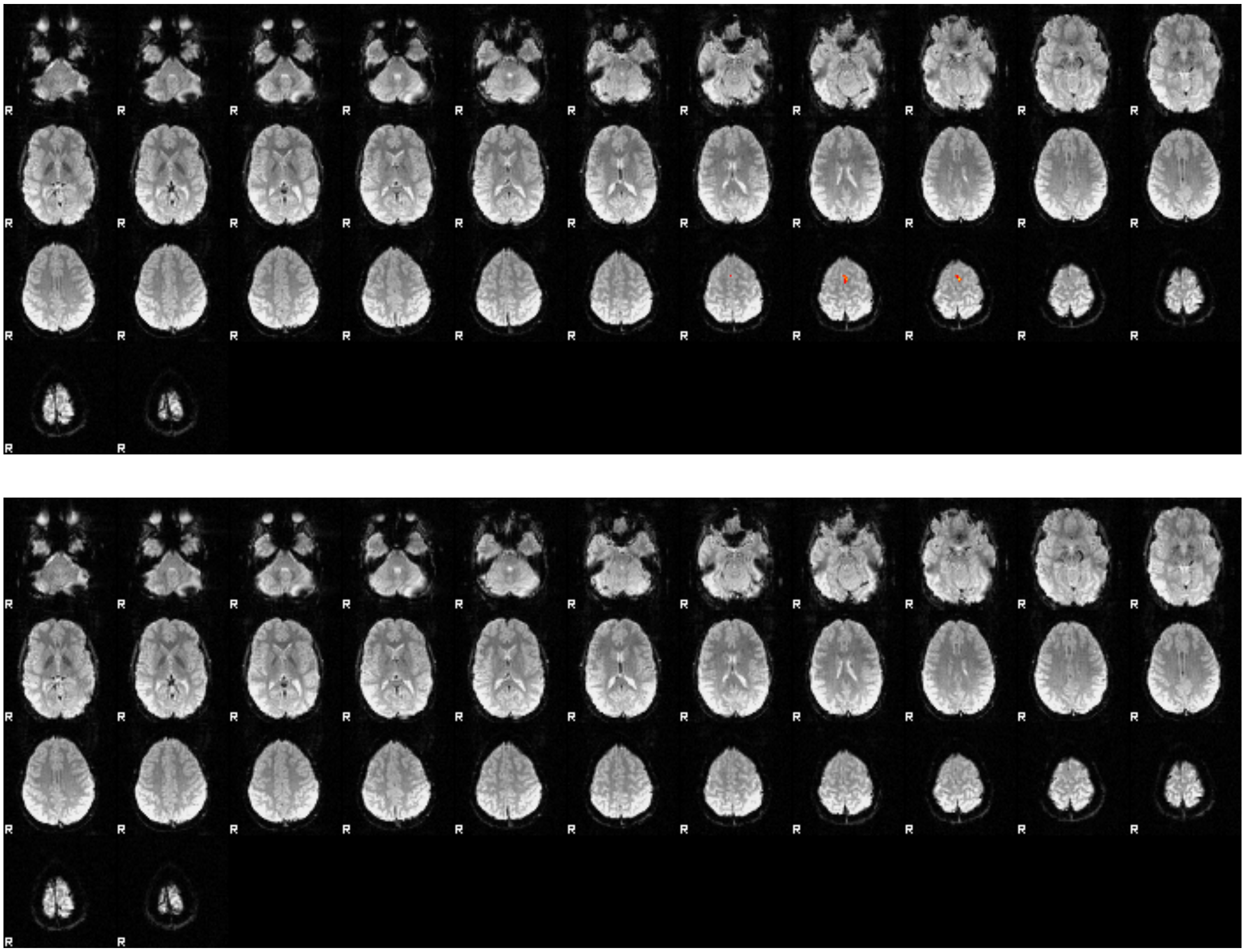
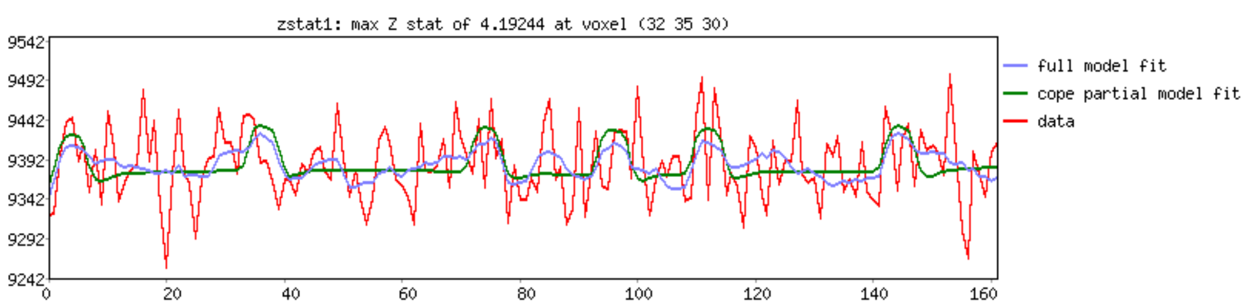


Fig.1 brain map of subject 1 in run 1



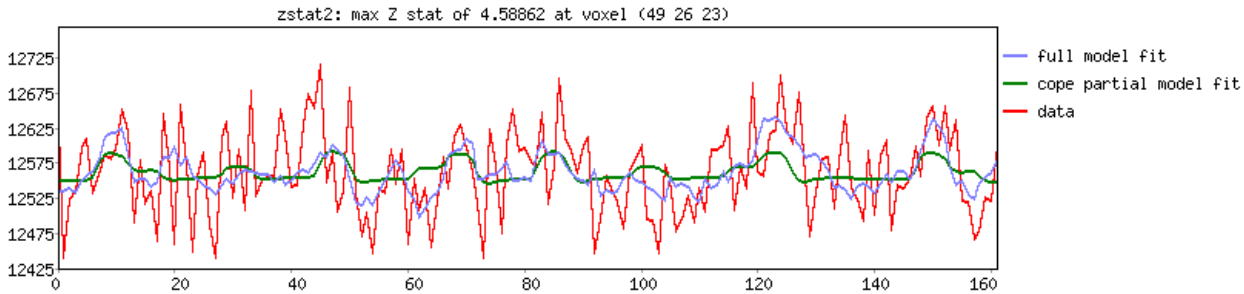



Fig. 2 Data - mean displacement=(abs=0.23mm, rel=0.03), effect required= (c1=1.833, c2=1.622), threshold activation images= (3.1-4.1) more image on c1

**Run 2**

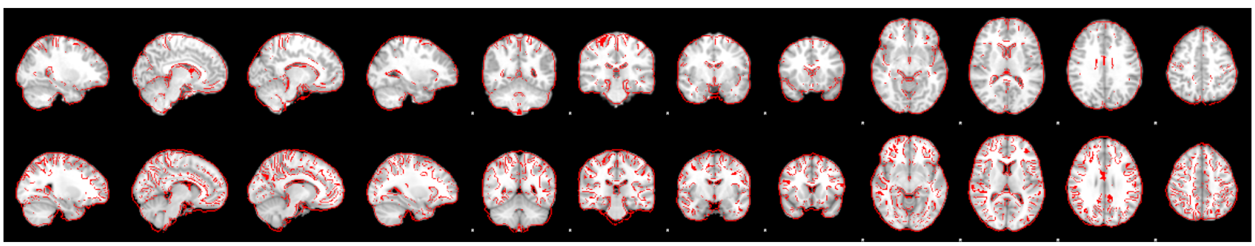


Fig. 3 Brain map for Subject 1, run 2

**Subject 2**

The mean displacement in run 1 was 0.04mm (relative) in comparison to 0.03mm (relative) in run 2.

**Run 1**

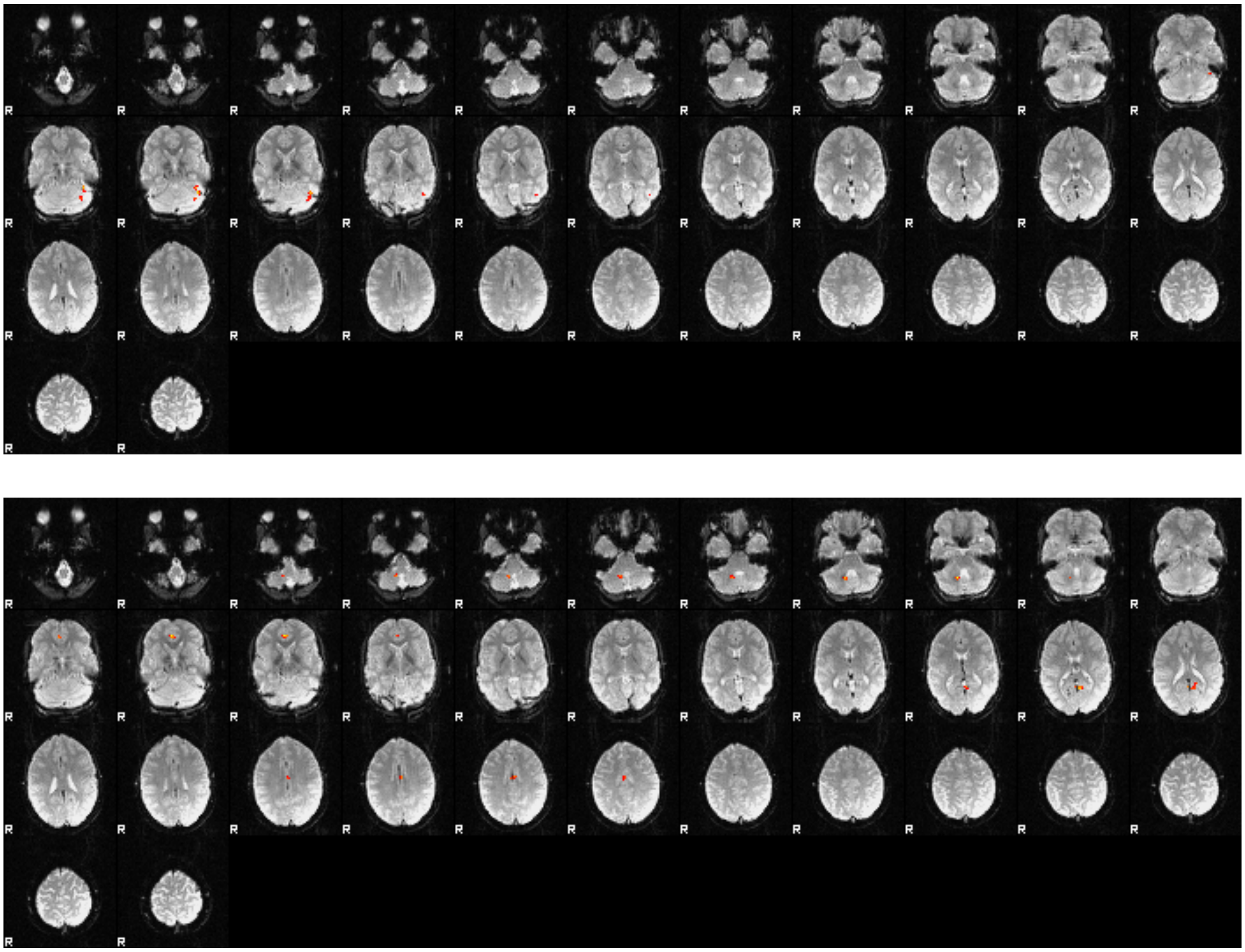
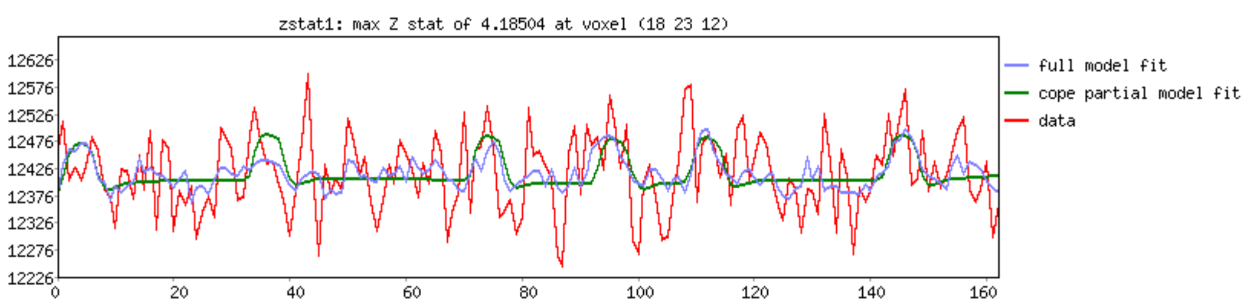


Fig. 4 - Brain map for Subject 2, run 2



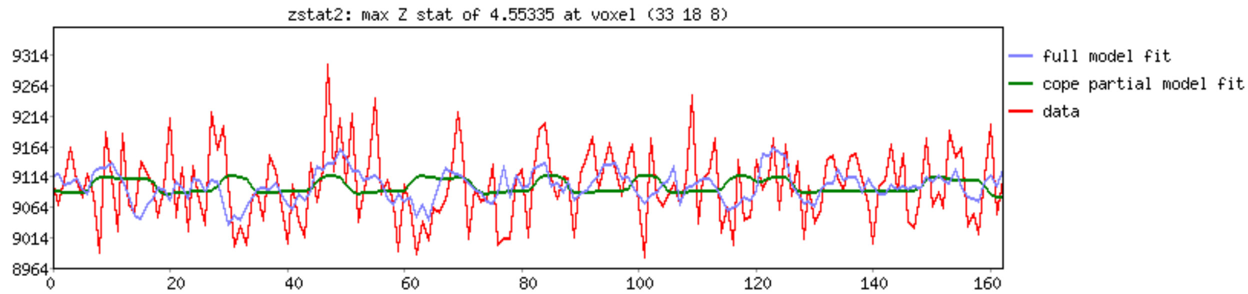



Fig. 5 Data - threshold activation images= 3.1-4.5, effect required= (c1=1.592, c2=1.758), mean displacements= (abs=0.14mm, rel=0.04mm)/ more overlap through 50-90

**Run 2**

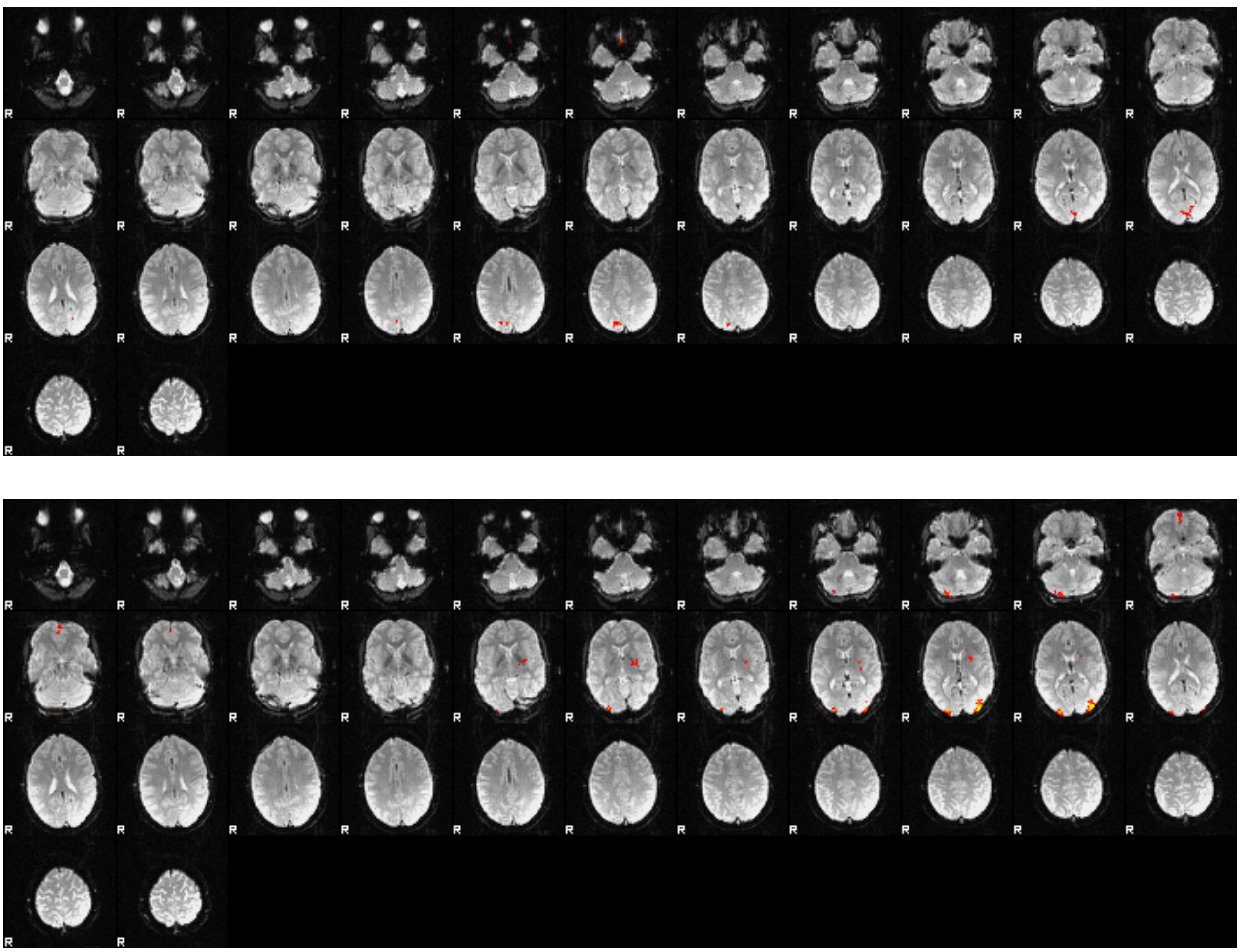
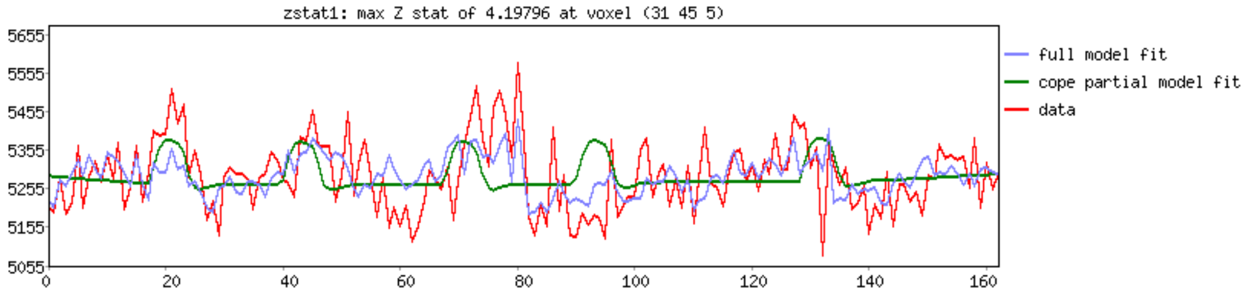


Fig. 6 Brain map of subject 2, run 2



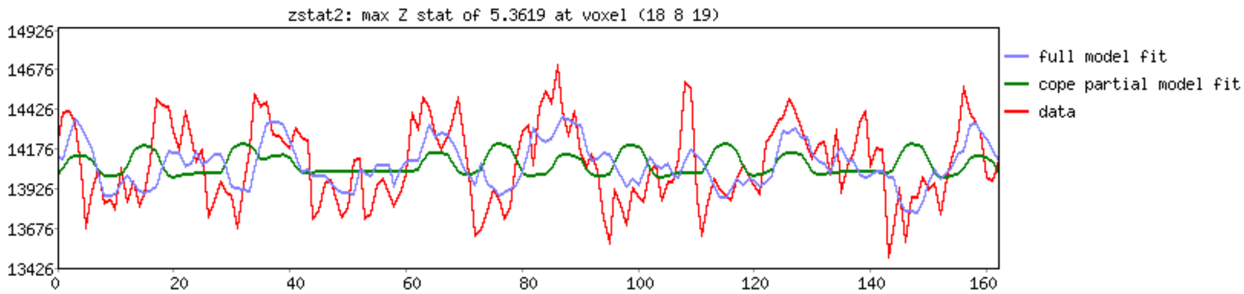
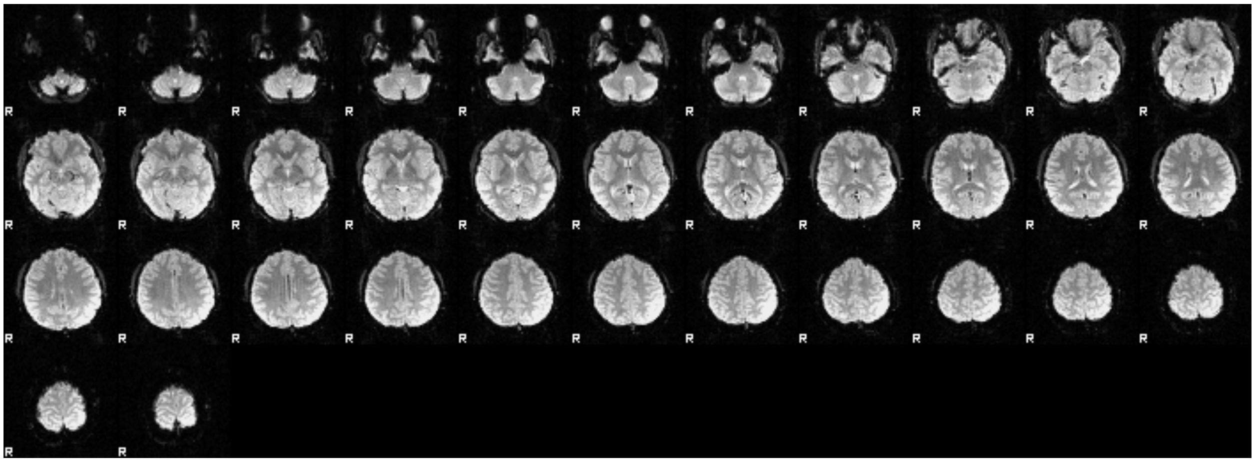




Fig. 7 Data - threshold activation images= 3.1-5.3, effect required= (c1=1.805, c2=1.668), mean displacements= (abs=0.11, rel=0.03mm)/ more overlap at 80

**Subject 3**

The mean displacement in run 1 was 0.05mm (relative) as well as 0.05mm (relative) in run 2.

**Run 1**



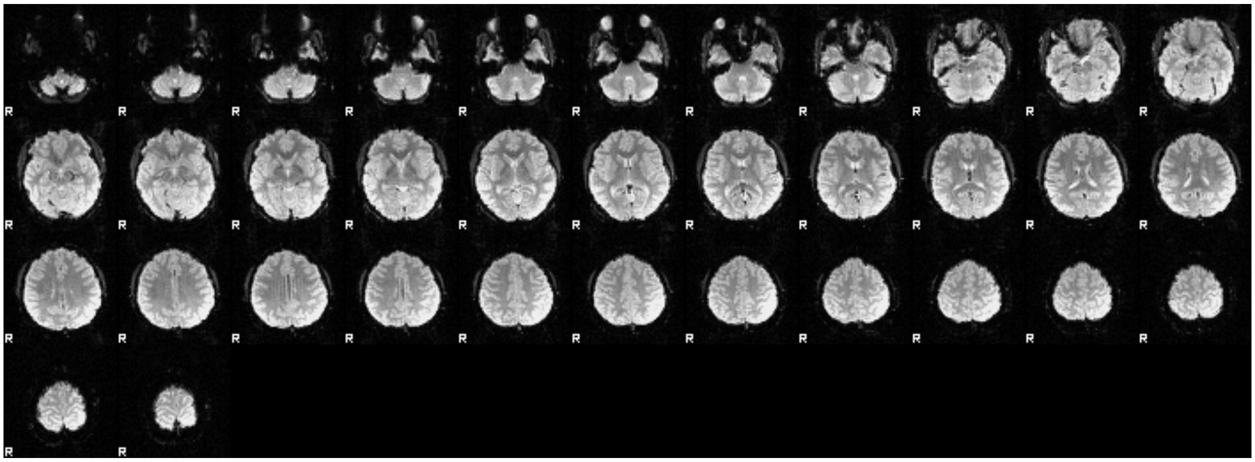



Fig. 8 Brain map for Subject 3, run 1

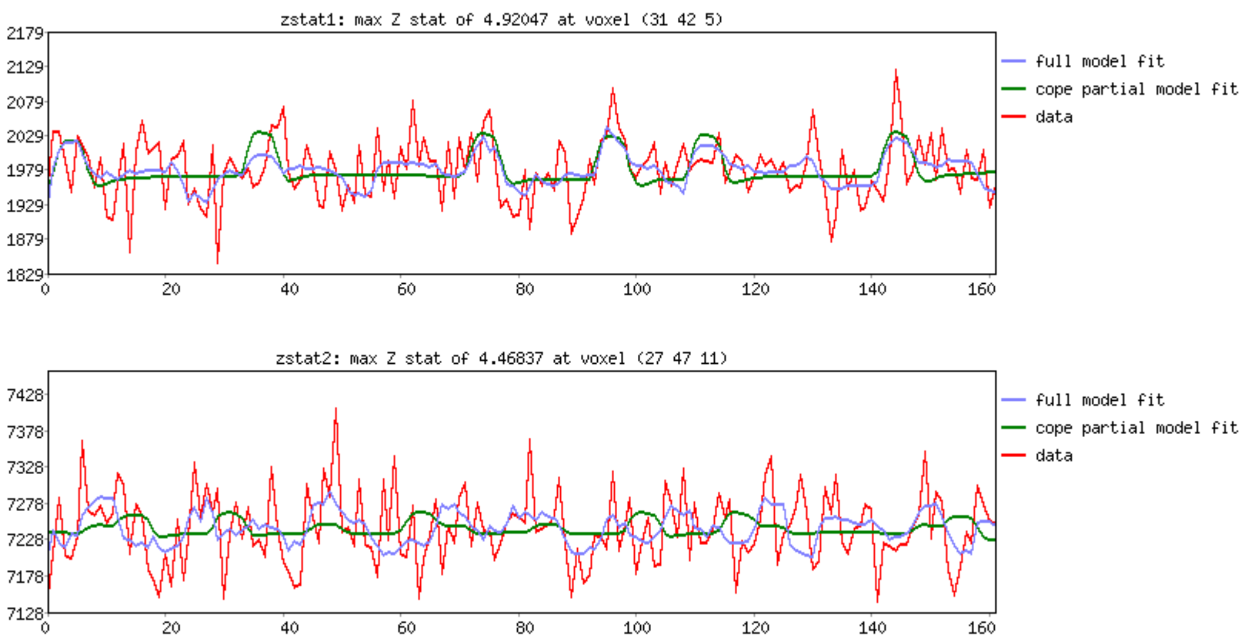



Fig. 9 Data - mean displacements= (abs=.2mm, rel=0.05mm), effect required= (c1=2.119, c2=1.583), activation images=2.3-8.0

**Run 2**

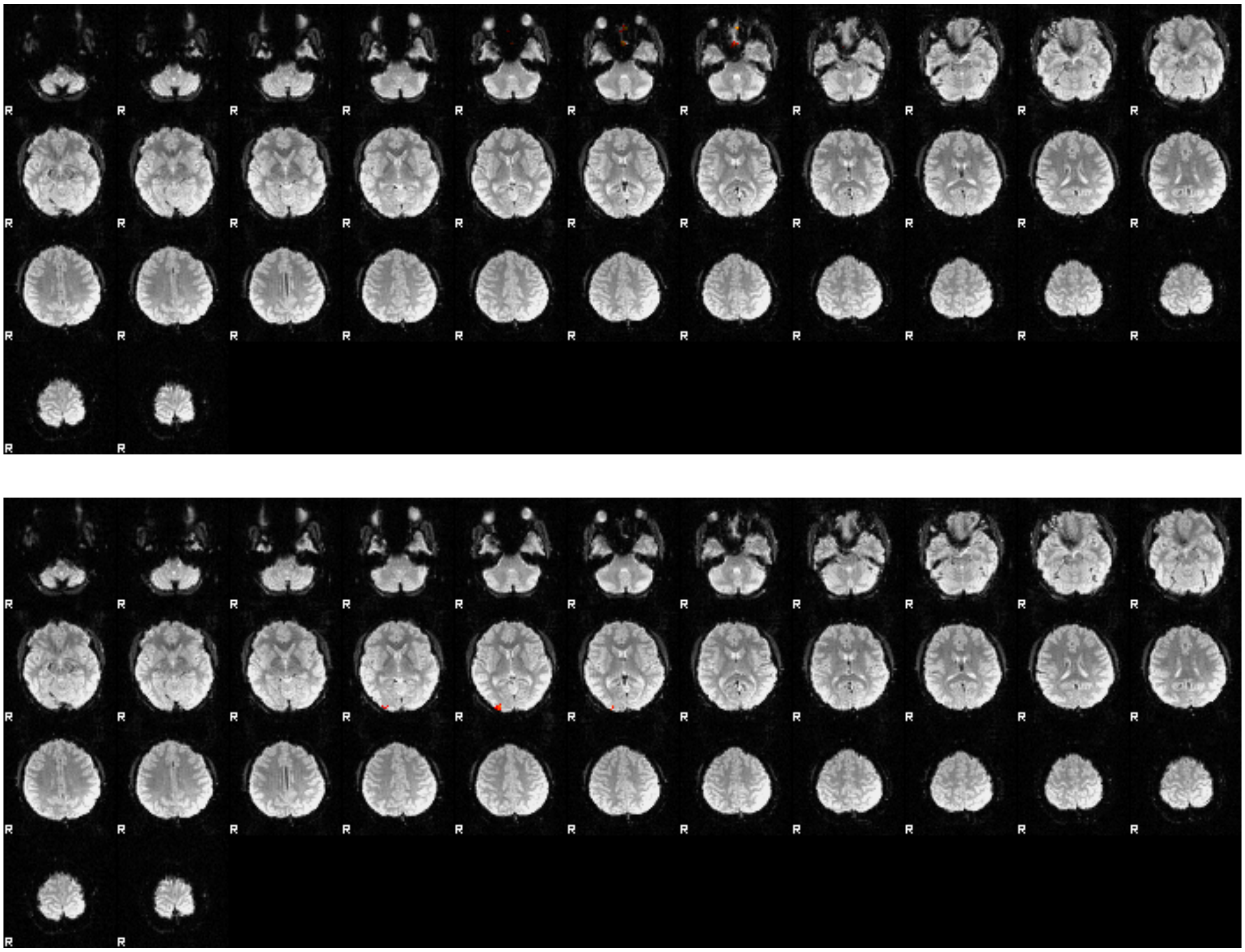
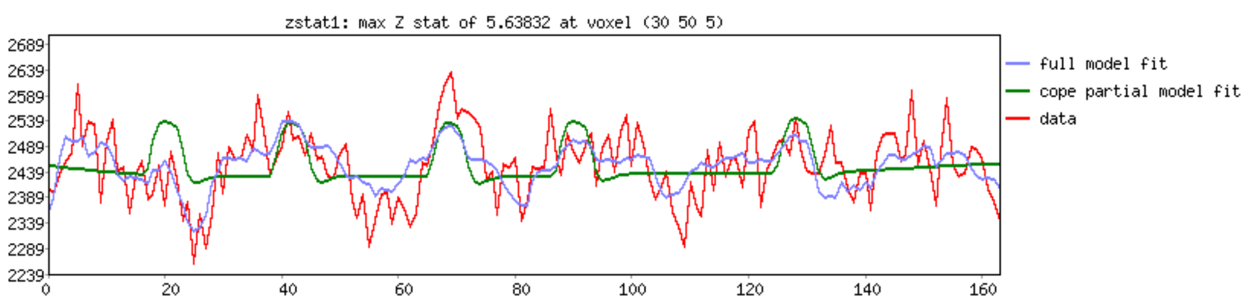


Fig. 10 - Brain map for Subject 3, run 1



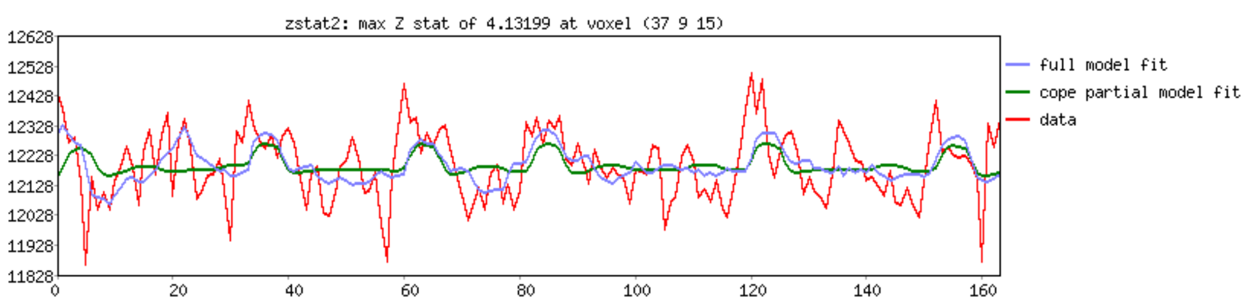
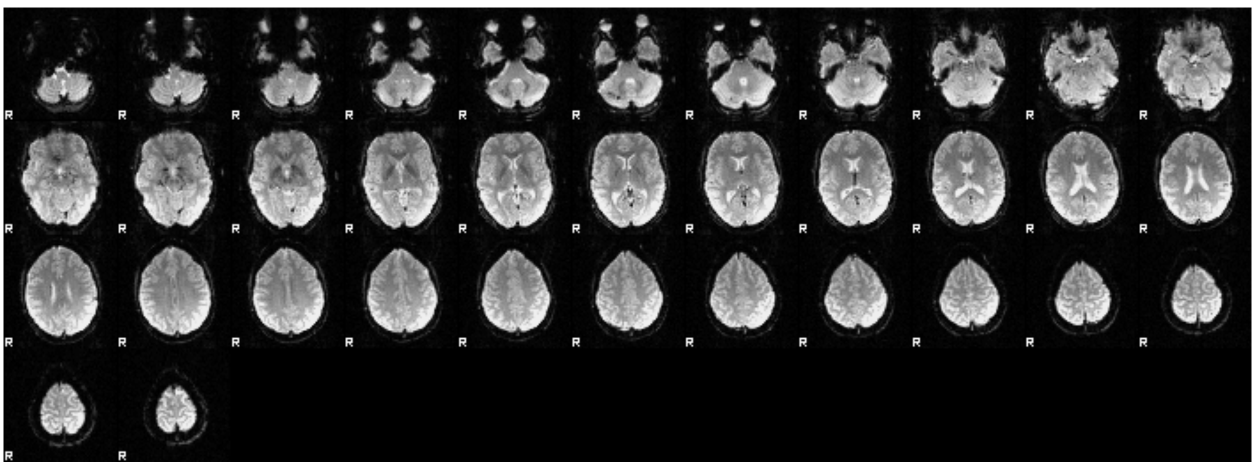



Fig. 11 Data - mean displacements= (abs=0.26mm, rel=0.05mm), effect required=(c1=1.700, c2=1.552), activation images=3.1-5.6

**Subject 4**

The mean displacement in run 1 was 0.03mm (relative) in comparison to 0.05mm (relative) in run 2.

**Run 1**



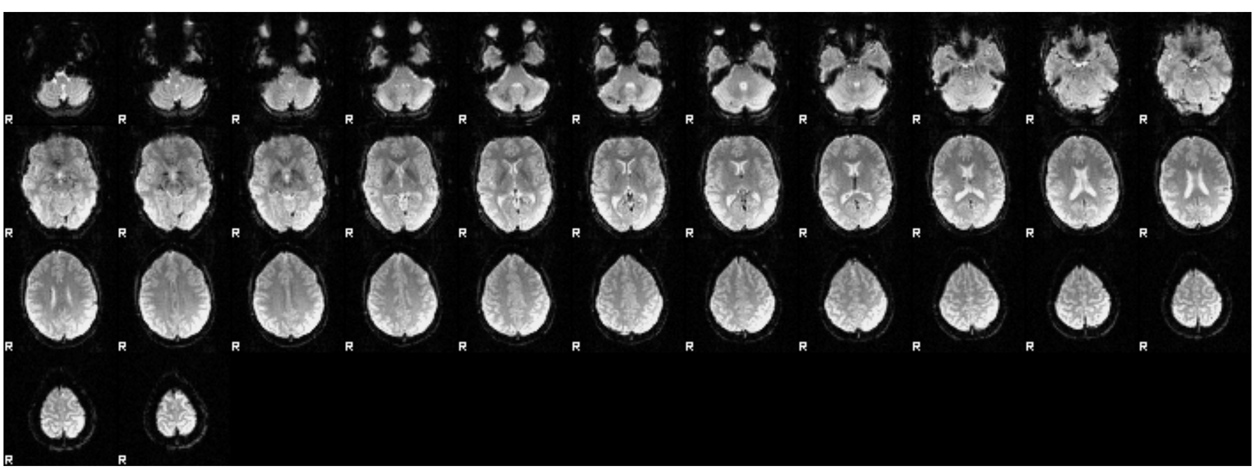


Fig. 12 Brain maps of Subject 4, run 1

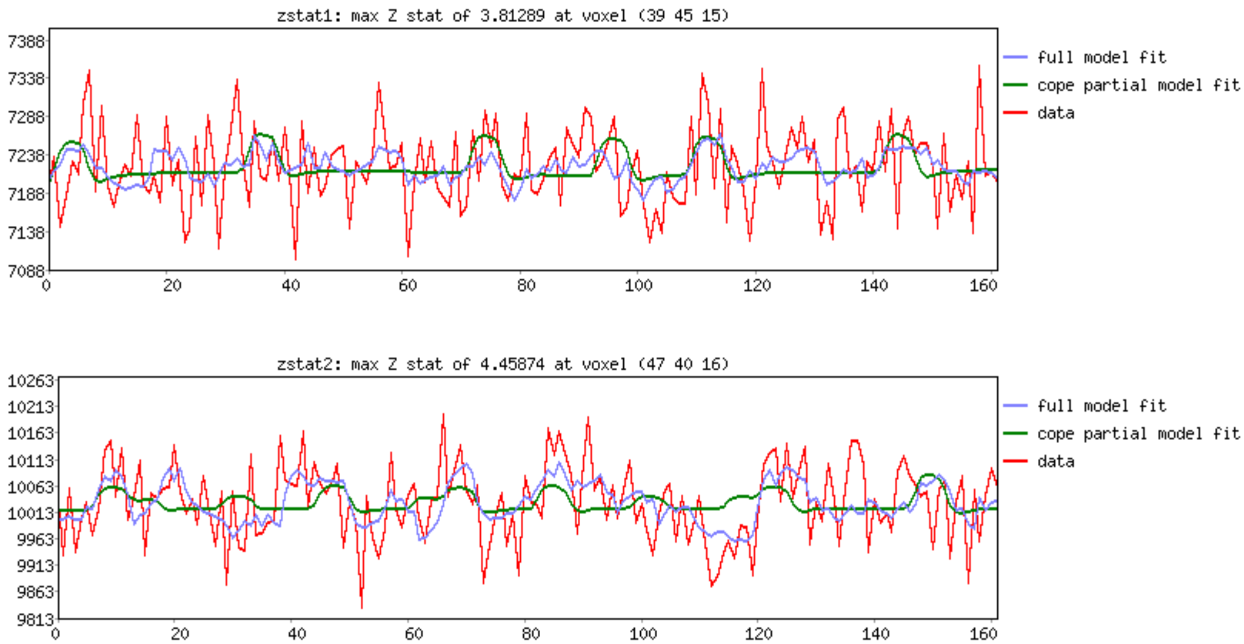



Fig. 13 Data - Mean displacements: absolute=0.11mm, relative=0.03mm; effect required= (c1=1.741, c2=1.618) threshold= (2.3-8.0)

**Discussion**

**Mean displacement**

There are two recorded values for mean displacement, namely absolute and relative displacement. Absolute displacement refers to the overall displacement from the volume mid-scan, while relative displacement measures the average displacement between one volume and the one taken right after it.

The subjects' head movement during data collection causes a misalignment of spatial units from one voxel to the next over time. This reduces the quality of recorded images and affects the accuracy of localizing BOLD signals when morphed onto the standard brain model. While the processed data has been motion-corrected to compensate for head movement, the displacement values are still a crucial factor towards determining the reliability of data.

Overall, there is a much larger variation seen in the absolute displacement values (range: 0.15mm) compared to that of relative displacement values (range: 0.02mm). However, this is to be expected due to relative displacement measuring differences between each volume, which provides a more useful comparison compared to absolute displacement. Subject 2 had the lowest values of relative displacement (0.3mm), while subject 3 had the highest values of relative displacement (0.5mm). While this implies that subject 3's data is less reliable in comparison to other subjects, it is still an acceptable value after taking the voxel size into account.

**Effect required for localizing areas**

The effect required for localizing an area refers to how well we can isolate the sections of the brain which specializes in a particular task (namely, processing words or objects). This allows us to access the reliability of our data as a predictor of brain activity when performing certain tasks.

As previously mentioned, the two areas of left occipito-temporal cortex functionally localized in this study were the reading-sensitive and object-sensitive areas (referred to as c1 and c2 respectively). Overall, there is a larger effect observed in the word-sensitive areas compared to object-sensitive areas, as seen by the average of 1.81 for c1 compared to average of 1.64 for c2. In other words, we identified more areas specializing in reading-based tasks compared to object-sensitive tasks. However, we also observed extremely high levels of variation between c1 runs – the general range for c1 is 0.2-0.4 compared to 0.1-0.3 for c2. The higher variability seen in c1 can be attributed to the abnormally high c1 value of 2.119 recorded for subject 3, run 1 (as compared to the typical range of 1.6-1.8 for all other runs). In conclusion, while the c1 runs identified a large amount of specialized areas, there is little consistency in the identified areas themselves when compared between all subjects. This makes it an unreliable baseline in predicting brain activity.

**Threshold activation image**

As mentioned previously, the highlighted portions in the brain map represent areas with a statistically significant increase of BOLD signals. This allows us to visually compare the locations and activation intensity between subjects. Neither the c1 nor c2 runs yielded any reliable patterns in brain activation when compared among subjects. This further verifies the conclusion drawn when analyzing the effect required, that the low consistency in brain activation among subjects makes it an unreliable predictor of brain activity.

**Conclusion**

This study concluded that functionally localizing word- and object-sensitive region of the occipito-temporal cortex varies within individual subject, thus yielding a surprisingly low intra-subject consistency. Nonetheless, one can draw crucial takeaways in optimizing experimental designs when using functional localizers. Perhaps the most significant consideration would be to optimize the process of data collection; possible suggestions include collecting larger quantities of data, reducing sources of variability as well as optimizing stimuli and tasks. One can also improve consistency via applying a factorial design rather than separate localizer scans, where the data used to define fROI is also used to interrogate the response profile of the region. Moreover, readers can better understand and evaluate the robustness of findings if the methods used to functionally localize regions are clearly reported. We hope that this study can further be used in relation to the behavioral data that is used to characterize many reading difficulties. Being able to distinguish the areas of the brain that relate to many reading difficulties can additionally improve impartial diagnoses and analytical determination of behavioral symptoms. Functional localizers undoubtedly play a vital role in cognitive neuroscience. Thus, being able to maximize sensitivity and avoid sources of bias will improve its future use in diagnostics.

**Paper Source:**

Duncan, K. J., Pattamadilok, C., Knierim, I., & Devlin, J. T. (2009). Consistency and variability in functional localisers. *NeuroImage*, *46*(4), 1018–1026. doi: 10.1016/j.neuroimage.2009.03.014

**Other Sources:**

Cardenas, D. P., Muir, E. R., Huang, S., Boley, A., Lodge, D., & Duong, T. Q. (2015). Functional

MRI during hyperbaric oxygen: Effects of oxygen on neurovascular coupling and BOLD fMRI signals. *NeuroImage*, *119*, 382–389. doi: 10.1016/j.neuroimage.2015.06.082

Gross, W. L., & Binder, J. R. (2014). Alternative thresholding methods for fMRI data optimized for surgical planning. *NeuroImage*, *84*, 554–561. doi: 10.1016/j.neuroimage.2013.08.066

Hillman, E. M. (2014). Coupling Mechanism and Significance of the BOLD Signal: A Status Report. *Annual Review of Neuroscience*, *37*(1), 161–181. doi: 10.1146/annurev-neuro-071013-014111

Horowitz-Kraus, T., Buck, C., & Dorrmann, D. (2016). Altered neural circuits accompany lower performance during narrative comprehension in children with reading difficulties: an fMRI study. *Annals of Dyslexia*, *66*(3), 301–318. doi: 10.1007/s11881-016-0124-4

Hutton, J. S., Phelan, K., Horowitz-Kraus, T., Dudley, J., Altaye, M., DeWitt, T., & Holland, S. K. (2017, May 31). Story time turbocharger? Child engagement during shared reading and cerebellar activation and connectivity in preschool-age children listening to stories. Retrieved from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0177398

Kim, Y.-S. G. (2015, September 3). Direct and mediated effects of language and cognitive skills on comprehension of oral narrative texts (listening comprehension) for children.

Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0022096515001885

Kronbichler M. Hutzler F. Wimmer H. Mair A. Staffen W. Ladurner G. The visual word form area andthe frequency with which words are encountered: evidence from a parametric fMRI study. NeuroImage 2004;21:946–953. [PubMed: 15006661]

Kung C.C. Peissig J.J. Tarr M.J. Is region-of-interest overlap comparison a reliable measure of category specificity? J. Cogn. Neurosci. 2007;19:2019–2034. [PubMed: 17892386]

Larsson J. Heeger D.J. Two retinotopic visual areas in human lateral occipital cortex. J. Neurosci.2006;26:13128–13142. [PubMed: 17182764]

Moore C.J. Price C.J. Three distinct ventral occipitotemporal regions for reading and object naming. NeuroImage 1999;10:181–192. [PubMed: 10417250]

Price C.J. McCrory E. Noppeney U. Mechelli A. Moore C.J. Biggio N. Devlin J.T. How reading differs from object naming at the neuronal level. NeuroImage 2006;29:643–648. [PubMed: 16137894]

Scarpina, F., & Tagini, S. (2017). The Stroop Color and Word Test. *Frontiers in Psychology*, *8*. doi: 10.3389/fpsyg.2017.00557

Voyvodic, J. T., Petrella, J. R., & Friedman, A. H. (2009). fMRI activation mapping as a percentage of local excitation: Consistent presurgical motor maps without threshold adjustment. *Journal of Magnetic Resonance Imaging*, *29*(4), 751–759. doi: 10.1002/jmri.21716

Yuhas. (2012, June 21). What's a Voxel and What Can It Tell Us? A Primer on fMRI. Retrieved from https://blogs.scientificamerican.com/observations/whats-a-voxel-and-what-can-it-tell-us-a-primer-on-fmri/