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Data Article

Psychophysical data to study the brain network mechanisms involved in reorienting attention to salient events during goal-directed visual discrimination and search tasks

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ABSTRACT

This article presents behavior and EEG dataset collected from 19 healthy human volunteers (10 females) in the age group of 21–29 (mean = 26.9, SD = ±2.15) years at National Brain Research Centre, India during a psychophysical paradigm customized to characterize the brain network interactions during saliency processing. We provide all the raw stimulus files used in developing the experimental paradigm of the linked research article "Organization of directed functional connectivity among nodes of ventral attention network reveals the common network mechanisms underlying saliency processing across distinct spatial and spatio-temporal scales" [1] for replication and use by researchers across various cohorts of the population. Pre-processed EEG time-series segmented into epochs corresponding to three experimental trial conditions, across two visual attention tasks testing the effect of salient distractors on goal-driven tasks are provided. The dataset also includes reaction times corresponding to individual trials. Additionally, structural MRI files corresponding to each individual and 3D EEG sensor locations of all

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volunteers are provided to assist in accurate source localization. Therefore, the presented dataset will not only facilitate the conventional time resolved EEG analysis like evoked activity and time-frequency analysis at the sensor level but will also facilitate the investigation of source level analysis like global coherence or phase-amplitude coupling within selected regions of the brain.

Specifications Table

Subject	Cognitive neuroscience
Specific subject area	Attention, sensory systems
Type of data	Stimulus files, Electroencephalography data, Analysis scripts (Matlab codes)
How data were acquired	EEG Neuroscan, 64 channel EasyCap with SynAmps2 amplifier Neurobehavioral Systems (NBS) Presentation
Data format	Pre-processed EEG time-series data and corresponding RTs (.mat file) Structural MRI (.nii files) EEG sensor locations (.DAT files)
Parameters for data collection	Data was collected from young healthy adults. All participants had University degrees or higher; were right-handed; reported normal or corrected-to-normal vision; and declared no history of neurological or psychiatric disorders. The participants were requested to avoid the intake of any stimulant or medication before reporting for the experiment.
Description of data collection	Behavioral and EEG data were acquired in the EEG recording room where ambient noise, lights and other interferences were strictly controlled during the experiment to the same levels for all recording sessions. Participants viewed the stimuli on a 21″ LED screen (1280 × 1024 pixels) with a 60 Hz refresh rate placed on a 74-cm-high desktop. The center of the screen was placed within 10–20° of the participant's line of sight, at a 60–70 cm distance. The stimuli were presented on a black background over which the static stimulus covered an area of 20 × 20 cm on the screen whereas the diameter of the aperture in the dynamic stimulus was 20 cm.
Data source location	Institute: National Brain Research center, Manesar City/Town/Region: Gurugram, Haryana-122052 Country: India
Data accessibility	Data is hosted on a public repository. Repository name: Mendeley Data Data identification number: doi:10.17632/jfnjhb33yy.1 Direct URL to data: http://dx.doi.org/10.17632/jfnjhb33yy.1
Related research article	Ghosh, P., Roy, D., Banerjee, A., 2021. Organization of directed functional connectivity among nodes of ventral attention network reveals the common network mechanisms underlying saliency processing across distinct spatial and spatio-temporal scales. Neuroimage 117,869. https://doi.org/10.1016/j.neuroimage.2021.117869

Value of the Data

- The stimulus dataset presented here would be of immense interest to researchers who want to understand how salient distractors affect goal-directed attention in real life situations. Other attentional stimuli are severely limited by their design where the salient distractors are either part of the visual display right from the onset of the trial along with the target or there are separate trials (involving valid/invalid cues) for endogenous and exogenous attention that are evaluated independently of each other. Our stimuli, on the other hand,

introduces salient distractors while participants are already involved in a goal-driven task which we believe is a better approach to study the process of reorientation due to saliency.
- Our dataset provides the normative patterns of attentional reorientation from young (21–29 years) healthy individuals which can be used as a standard against attention reorientation patterns in other age groups for studies of plasticity: ageing and maturation.
- The data can also be contrasted against pathological scenarios of neurodevelopmental disorders in individuals who show differential/delayed behavioural patterns of reorientation to salient stimuli to plan interventions.

1. Data Description

The data contained in *'timeser&rt.mat'* in the linked repository [2] are from total 19 participants, where the first 35 trials (of all the workspace variables) are from Subject 1, next 35 from Subject 2 and so on, adding up to a total of 665 trials (19 × 35). This time-series data is a 3D matrix of form 'time-points × channels × trials'. We used a Polhemus Fastrak system to record the 3D location of electrodes (provided with the dataset with folder name *'3D_loc'*) of each participant using a set of fiducial points (Cz, nasion, inion, left and right pre-auricular points) while the EEG cap was placed on the participant's head. We also provide the MRI files of all the 19 participants in the folder named *'MRI'*. Latest version of SPM software package [3] can be used to read the MRI files for implementing further source localization methods to the dataset. The *'stimuli'* folder in the repository [2] contains all the stimulus files that were used in the creation of the experimental paradigm as explained in the 'Experimental Design' section. Use the README.txt files provided in the folders for a step-by-step guide to generating the static and dynamic stimuli tasks. All the responses to stimuli were made on a computer keyboard using left/right/up/down arrow keys and were recorded by receiving triggers at keyboard presses. Triggers were also set with the onset of each trial and the onset of the inter-stimulus interval screen (which overlapped with the offset of the previous trial). Using this trigger information from the EEG data, epochs of 1150 ms were extracted which included first 150 ms of pre-saliency period followed by 1000 ms of post-saliency period, matched equally across WT, ST and NT categories. This pre-processed data has been provided in the Mendeley dataset [2] with filename *'timeser&rt.mat'*. The variable names containing these time-series in the .mat file are described below:

'wt_static'-preprocessed EEG time series of trials without saliency of static task
'st_static'-preprocessed EEG time series of trials with saliency of static task
'nt_static'-preprocessed EEG time series of neutral trials of static task
'wt_dynamic'-preprocessed EEG time series of trials without saliency of dynamic task
'st_dynamic'-preprocessed EEG time series of trials with saliency of dynamic task
'nt_dynamic'-preprocessed EEG time series of neutral trials of dynamic task

The corresponding reaction time data were also recorded which was the duration from the onset of the salient distractor (time-stamps matched equally for WT and NT) till the participant hit the response button. In the .mat file *'timeser&rt.mat'*, variables 'rt_wt_static', 'rt_st_static' and 'rt_nt_static' contain the static task reaction times of WT, ST and NT, respectively whereas variables 'rt_wt_dynamic', 'rt_st_dynamic' and 'rt_nt_dynamic' contain the dynamic task reaction times of WT, ST and NT, respectively. Fig. 2 shows the mean with the standard error of the mean of reaction times of all trials (35 trials each from 19 participants) for each of the three categories of trials (WT, ST and NT) across both static and dynamic tasks. Subsequently, the power spectral density for each trial was computed on the pre-processed time-series data using a multi-taper spectral analysis method provided by the Chronux toolbox [6]. Using the toolbox script mtspectrumc.m, discrete Fourier transform was computed for each epoch time series with 5 Slepian tapers, time-bandwidth product equal to 3 and a sampling frequency of 1000 Hz. Fig. 3 shows the global power spectral densities (1/f noise removed) of all trial categories (WT, ST and NT) across static and dynamic stimuli.

Table 1
Trial distribution across tasks.

Trial information	Dynamic stimulus	Static stimulus
Total no. of blocks	8	8
No. of trials per block	70	30
Neutral trials (NT)	20	10
Without saliency trials (WT)	20	10
Saliency trials (ST)	30*	10

* To reduce the drop in the pop-out effect of salient distractors due to habituation after multiple trial presentations, 3 kinds of salient distractors were used, varying in either color or size or both from the other moving dots. 10 trials each of an equisized red, a larger red and a larger white dot were presented in a block as a salient distractor along with the rest of the moving dots in ST.

Any requests for additional data as long as it does not violate the ethical guidelines can be made to Senior author (arpan@nbrc.ac.in).

2. Experimental Design, Materials and Methods

All the participants performed goal-directed visual discrimination and search tasks which incorporated two stimulus conditions where in one, the stimulus evolved rapidly through time (dynamic) and in the other (static), it did not. Both the tasks had three categories of trials: 'Without Saliency Trials' **(WT)**, 'Saliency Trials' (**ST**) and 'Neutral Trials' (**NT**) (Please refer to Table 1 for distribution of trials across blocks). The participants were not aware of the categorization in trials. They were briefed only with the static and dynamic tasks' respective goals at the beginning of the experiment and were instructed to be as quick and accurate as possible in making responses. Stimulus presentation and behavioral response collection were done using Neurobehavioral Systems (NBS) Presentation software.

Dynamic task: The dynamic stimuli viewing consisted of a direction-discrimination task in a four-alternative forced-choice (4-AFC) set-up. The stimuli consisted of videos (provided in the dataset) where the participants were presented with white-colored equal-sized randomly moving dots where a proportion of dots moved in a particular direction according to a certain coherence assigned to them. The coherence of the dots was kept at 0.6 for all the trials, which means that out of 100 dots, 60 dots moved in one specific direction and the other 40 moved in random directions, uniformly distributed over all angles between 0–360°. The speed of motion of all the dots were kept constant across all trials. The participants were instructed to identify the net direction of the moving dots which could either be left/ right/ up/ down and respond using the respective arrow keys on the keyboard. The duration of each video was 2000 ms. The goal for the participant was the same for WT, NT and ST, with the only difference in ST being the emergence of a salient dot appearing at a latency of 150 ms from the onset of the trial, moving randomly within the same aperture as the other dots. This was introduced with the purpose of causing distraction from the goal-directedness in the task. In the case of NT, the dots moved with zero coherence, i.e., all the dots (white-colored equal-sized) moved in random directions. Since, there was no net direction, NT was the most difficult task. The experimental schematic is illustrated in Fig. 1a.

Static task: The static stimuli set-up consisted of a two-alternative forced-choice (2-AFC) paradigm. The participants were presented with two similar pictures on the screen, successively. Each picture pair made up one trial and was randomly selected from a pool of twenty such picture pairs (provided in the dataset). The pictures were naturalistic images (from both indoor and outdoor settings; no faces included), of sort that one would encounter in real life on a daily basis. A white-colored '+' shape was added to all the images at random positions. Multiple copies of a single image with a '+' shape at different positions were created such that there was no image and '+' position memory association. Each picture was presented for 2000 ms such that each trial (consisting of pictures 1 and 2) lasted for 4000 ms. This was a visual search task where the

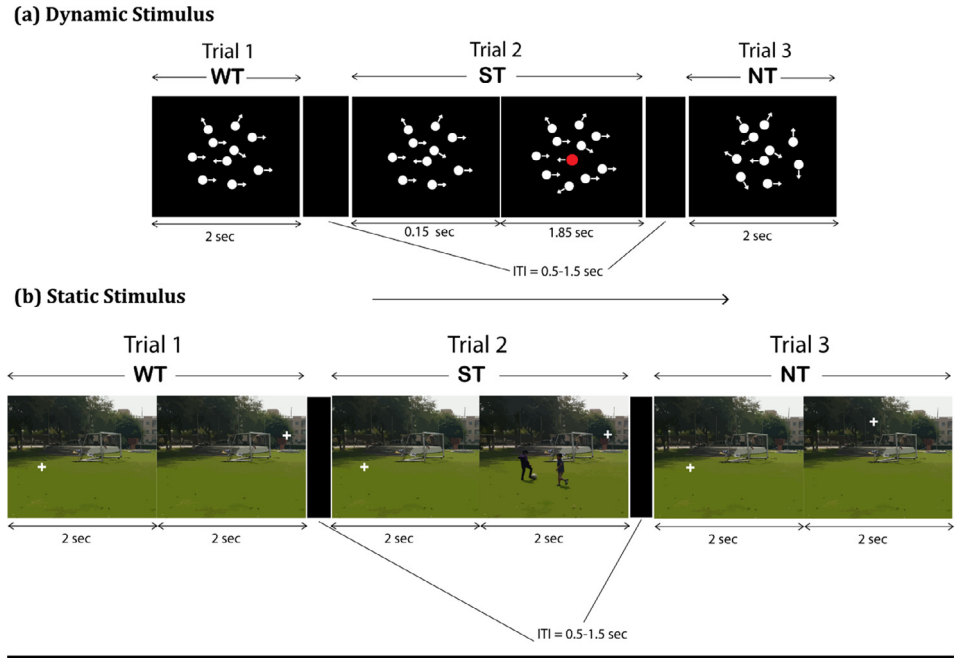

Fig. 1. Experimental paradigm. An example of the visual discrimination and search tasks is shown which is comprised of videos in the (a) Dynamic stimulus condition and static images in the (b) Static stimulus condition. The figures illustrate the three different categories of trials: neutral trials (NT), without saliency trials (WT) and saliency trials (ST) along with their presentation durations within a block. Figure adapted from the related research article [1].

participants had to search for the white-colored '+' shape in both the pictures and report if the '+' changes in position in the second picture with respect to the first picture. For convenience, the participants were advised to imagine a vertical line bisecting the screen into left and right halves. They were instructed to press the upward arrow key if the '+' sign moved to the same half of the screen in the second picture, i.e., the '+' sign did not cross the imaginary line to move to the other half; and to press the downward arrow key if the '+' sign changed its position and moved to the other half of the screen i.e., from the left half to the right half or vice versa. The goal in the task remained the same for WT, NT and ST. However, the only difference in stimulus in the NT was that the '+' sign was presented on the imaginary midline itself (instead of left or right half) in either of the two pictures (picture 1 or 2) whereas in the ST a salient ('pop-out') object was introduced in the second picture at any random position. Examples of each of these categories are presented in Fig. 1b.

The NT were designed to give an impression of the most difficult trials to the participants which, if attended to, were expected to produce the longest reaction times. Technically, these trials did not have any correct response as such but the participants were unaware of it. NT trials serve as a control to identify if the aspect of saliency (ST being different to both WT and NT) or task-difficulty (WT different from NT) are key factors for observed differences between brain response differences respectively.

All the pre-processing steps for static and dynamic tasks' data were done using the EEGLAB toolbox [4] and custom-written scripts in MATLAB [5]. EEG signals were recorded from 64 channels placed according to the International 10–20 system. Raw EEG (.cnt) data files were imported using EEGLAB toolbox. The raw time-series data were first filtered using a band-pass filter of 0.1–80 Hz followed by a notch filter between 45 and 55 Hz to eliminate line noise at 50 Hz. The data was further average re-referenced by computing the average of the signal at all electrodes

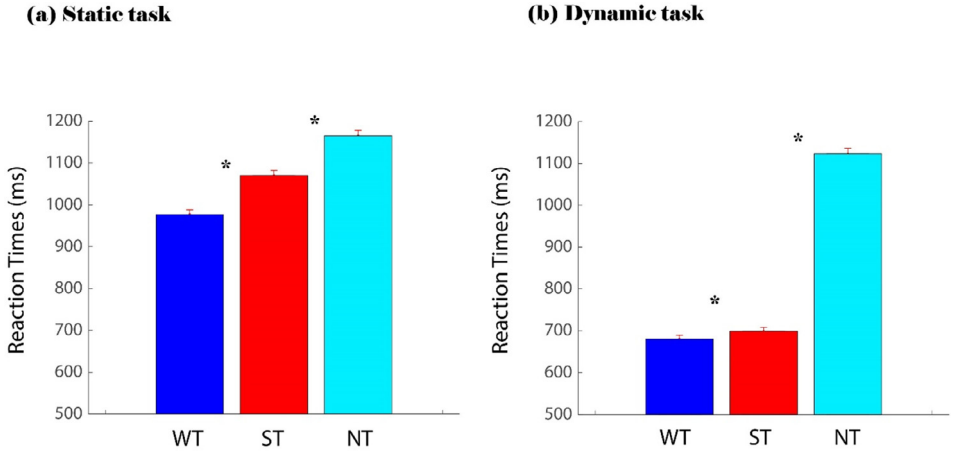

Fig. 2. Reaction-time plots. The mean and standard error of the mean of neutral trials (NT), without saliency trials (WT) and with saliency trials (ST) for all the 665 trials are shown for the static and dynamic task conditions. The significant differences ($p < 0.05$) between any two categories of trials (indicated by *) within a task condition was tested at 95% confidence interval using Wilcoxon ranksum test.

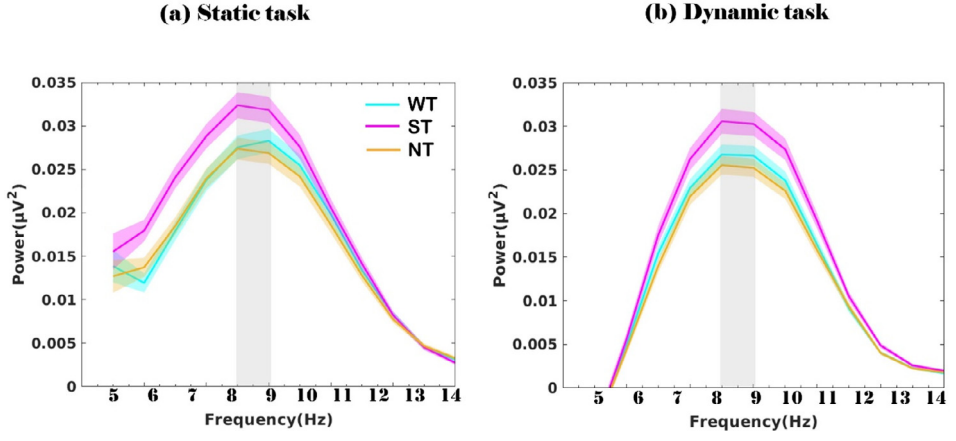

Fig. 3. Power spectral density(PSD) plots. The mean global power spectra plots for the (a) Static task condition and the (b) Dynamic task condition are shown, representing the normalized power spectra of neutral trials (NT), without saliency trials (WT) and saliency trials (ST) with the standard error of mean (SEM) as shaded region. On comparison using a Wilcoxon's rank-sum test, we found that the powers of ST > WT and ST > NT between 8 and 9 Hz (gray shaded region, $p < 0.05$) in both the tasks as tested at 5% significance level. No significant differences were seen in the powers of WT and NT in both tasks. Figure adapted from the related research article [1].

and subtracting it from the EEG signal of each electrode. The sampling rate of data acquisition was 1000 Hz. The default reference was close to Cz, grounded to AFz and channel impedances were monitored to be below 10 kΩ. The data were visually inspected and the trials with any abnormal or noisy segments (jitters with very large amplitudes) were removed. All linear trends were removed from the data on a trial-by-trial basis and the eye-blink, ocular, muscular and electrocardiograph artifacts were removed by rejecting trials crossing a threshold of ±75 μV.

Ethics Statement

The study was carried out following the ethical guidelines and prior approval of the Institutional Human Ethics Committee (IHEC) of the National Brain Research center, India (Ethics approval number: IRB# 00007523(NBRC) to Dr Arpan Banerjee). Written informed consent was obtained from all participants before the experiment.

CRediT Author Statement

Priyanka Ghosh: Conceptualization, Experimental design, Software, Data collection, Formal analysis, Visualization, Writing-Original draft preparation and editing; **Dipanjan Roy:** Visualization, Writing-Reviewing and editing, Supervision, Funding; **Arpan Banerjee:** Conceptualization, Experimental design, Resources, Formal analysis, Visualization, Writing-Reviewing and editing, Supervision, Funding.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

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