Behavioural and Neural Correlates of 'Attentional Blink'

A thesis submitted towards partial fulfilment of

BS MS Dual Degree programme

By

Aswathi K T

(Roll No. 20141016)

Indian Institute of Science Education and Research, Pune

Advisor: **Dr. Sridharan Devarajan**
Assistant Professor, Centre for neuroscience

Indian Institute of Science, Bangalore

Certificate

This is to certify that this dissertation entitled **'Behavioural and Neural Correlates of 'Attentional Blink'**, towards the partial fulfilment of the BS-MS dual degree programme at the Indian Institute of Science Education and Research, Pune represents study/work carried out by **Aswathi K T** at Indian Institute of Science, under the supervision of **Dr. Sridharan Devarajan**, Assistant professor, Centre for Neuroscience during the academic year 2018-2019.

Signature of the student

Aswathi K T

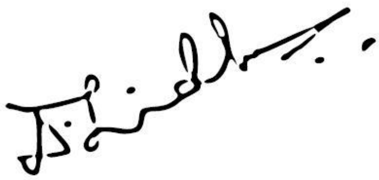
(Roll No. 20141016)

Date –

Place –

Signature of supervisor

Dr. Sridharan Devarajan



<u>Declaration</u>

I hereby declare that the matter embodied in the report entitled '**Behavioural and Neural Correlates of 'Attentional Blink'**, are the results of the work carried out by me at the Department of Neuroscience, Indian Institute of Science, under the supervision of Dr. Sridharan Devarajan and the same has not been submitted elsewhere for any other degree.

Date: 26/03/2017

Place: Bangalore

Aswathi K T

Roll No.: 20141016

Contents

I. Abstract

‘Attentional blink’ which is the inability of processing and reporting the second of the two consecutive targets which appear temporally closer, is a well-studied phenomenon in the consciousness literature for its potential for relieving the temporal dynamics of perceiving and reporting consciously. The phenomenon is thought to involve working memory and attention deficit, both. The present study throws light on the behavioural and neural aspects of the phenomenon. By fitting the results with the multidimensional detection model (m-ADC), it has been found that it is the component of attention called ‘sensitivity’ which gets affected more as opposed to ‘bias’ during the ‘blink period’. The study aims to find out the signatures in the brain for the sensitivity decline in the trials with shorter inter-target interval. The event related potentials (ERPs) of the electrodes from the occipital, parietal and frontal electrodes are found to have decreased amplitude in the ‘blink’ period, suggesting lesser activity in the brain for processing the second of the two targets. Thus, the neural cause of the deficit in the ability correctly report during the ‘blink’ period can be studied by correlating it with the ERP amplitudes.

II. List of Figures

III. Table of Figures

IV. Acknowledgments

I would like to express my sincere gratitude towards Dr. Sridharan Devarajan for his guidance and help as my supervisor during my entire project. I would also like to thank Dr. Collins Assisi for his support as my TAC member.

I am thankful to all the members of the cognition lab at IISc for their constant support and help throughout the project.

I would like to express my gratitude towards the Centre for Neuroscience Department, IISc, for providing me with facilities for carrying out my final year project.

I am also thankful to my parents, friends and seniors for their help and encouragement.

Chapter 1

Introduction

Understanding the neural basis of conscious access has been a fundamental problem in the study of conscious perception in human beings. There has been a plethora of studies conducted and theories proposed regarding consciously perceiving a stimulus and it being available for explicit report.

'Attentional blink' is one of the most studied phenomena in the 'consciousness literature'. The 'attentional blink' is the deficit in consciously perceiving the second target of two targets in the case when the latter stimulus follows the former one within 100–500 ms in a rapid stream of distractors. It is one of the most widespread demonstrations of information processing limitations in the human brain. Although transitory, it is a severe shortcoming, which cannot be wiped out even with extensive training, in which the high-level central resources are being unable to be applied to perceiving the second target. (Sander Martensa and Brad Wyble, 2009)

There have been studies suggesting that the phenomenon is due to impairment of consolidating the second target into working memory representation so as to report it. (Sander Martensa and Brad Wyble, 2009). It has also been suggested that failing to report the second target implicates a loss of information from the visual working memory once the stimulus gets perceived (Shapiro et. al., 1996). Nonetheless, it is ambiguous if the phenomenon is due to a limitation in perception, memory or response (Shapiro et. al., 1997)

A deficit of 'attention' is thought to play central role in the inability of reporting the second target which appears closer to the first one in the time domain since the human brain is known for its shortfall in consciously processing concurrent information. Attention is a cognitive process of filtering out the irrelevant information and selecting the relevant information so as to enable us to effectively interact with our surroundings with our limited cognitive resources. (Sander Martensa and Brad Wyble, 2009).

It is hypothesised that it is the processing of the first target and the inhibition caused due to the distractors which appear in the standard 'attentional blink' task which impairs the re-allocation of the high-level central attentional resources to subsequent targets transiently. There exist various models to explain the phenomena. The distractor-based models propose that the distractors presented shortly after first target causes the attentional blink whereas the capacity-based models put forward that, it is modulated with the difficulty of the first target. (Di Lollo V et. al., 2011)

Visuo-spatial attention is modulated by mechanisms to control for 'perceptual sensitivity' or 'choice bias' which are the two components of attention (Hermann J. Müller and John M. Findlay, 1987). Perceptual sensitivity control is a method for perceiving the target stimuli more clearly as opposed to the noise or non-target stimuli. It is achieved by enhancing the perceptual processing of the task relevant stimuli or the attended target at the expense of the task irrelevant stimuli or the unattended distractors and thus increasing the discriminability. Thus, it can be looked at as a measure of the ability of one to distinguish between signal and noise. Whereas, the choice bias control involves giving differential weightage to one stimulus (the target stimulus) as opposed to the non-target stimuli. Thus, it is a measure of the extent to which one response is more likely than another. Thus, as a result of deploying attention, information from the distractors are eliminated. (Sridharan and Steinmetz, 2014). One could have an innate preference and thus, choice bias (Gold et al., 2008), or biases could be induced in a perceptual task by cueing the spatial location of the forthcoming stimulus. (Mulder et al., 2012)

In an experiment, after collecting the data of the subjects' performance, the sensitivities and biases can be quantified using the theoretical frameworks. Signal detection theory (SDT) is one such tool which helps us to extract those parameters and quantify the behaviour. d', a measure of sensitivity at the attended stimuli and criterion, denoted as c, a measure of bias are the two metrics which SDT provides. When a stimulus is being attended, it is anticipated that, either the sensitivity for stimulus increases or the criterion at the attended stimulus decreases thus increasing the bias (CC) towards the attended stimulus or both happen simultaneously. (Carrasco, Met al., 2004).

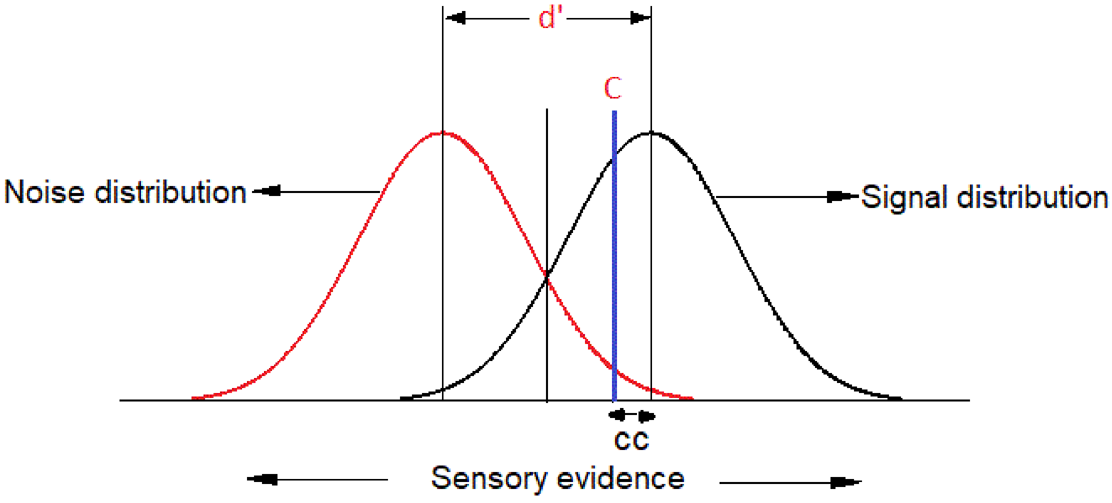


Figure 1: Signal detection model for a detection task.

In Figure 1, Red Gaussian is the decision variable when no stimulus was presented. Black Gaussian is when the stimulus was presented. d' is the sensitivity, cc is the choice criterion and C is the bias.

A detection (Yes/No) task with binary choice of signal. The two distributions are decision variable distributions when stimulus is presented and not presented respectively, which are Gaussian. d' is the perceptual sensitivity for detection, C is the choice criterion for Yes response and CC is the measure of bias.

The contingency table with all possible responses looks like:

Table 1: Contingency table for a detection task.

		Response	
Stimulus		Present	Absent
	Present	HIT	MISS
	Absent	FALSE ALARM	CORRECT REJECTION

Where, Hit is when the subject correctly responds to the presence of the stimulus, miss is when he fails to detect to stimulus present and responds as if the stimulus was absent, false alarm is when the subject incorrectly responds as if the stimulus is present in a no stimulus case and correct rejection is when he correctly denies the presence of the stimulus.

Multi-alternative change detection (m-ADC) model is a signal detection model that helps in dissociating and quantifying perceptual sensitivity and choice bias of behavioural choices in a multi-alternative change detection tasks. In a two-dimensional signal-detection model with 2 alternatives of changes, decision variable components are Gaussian distributions represented along two orthogonal axes. (Sridharan, D. and Steinmetz, N. 2014).

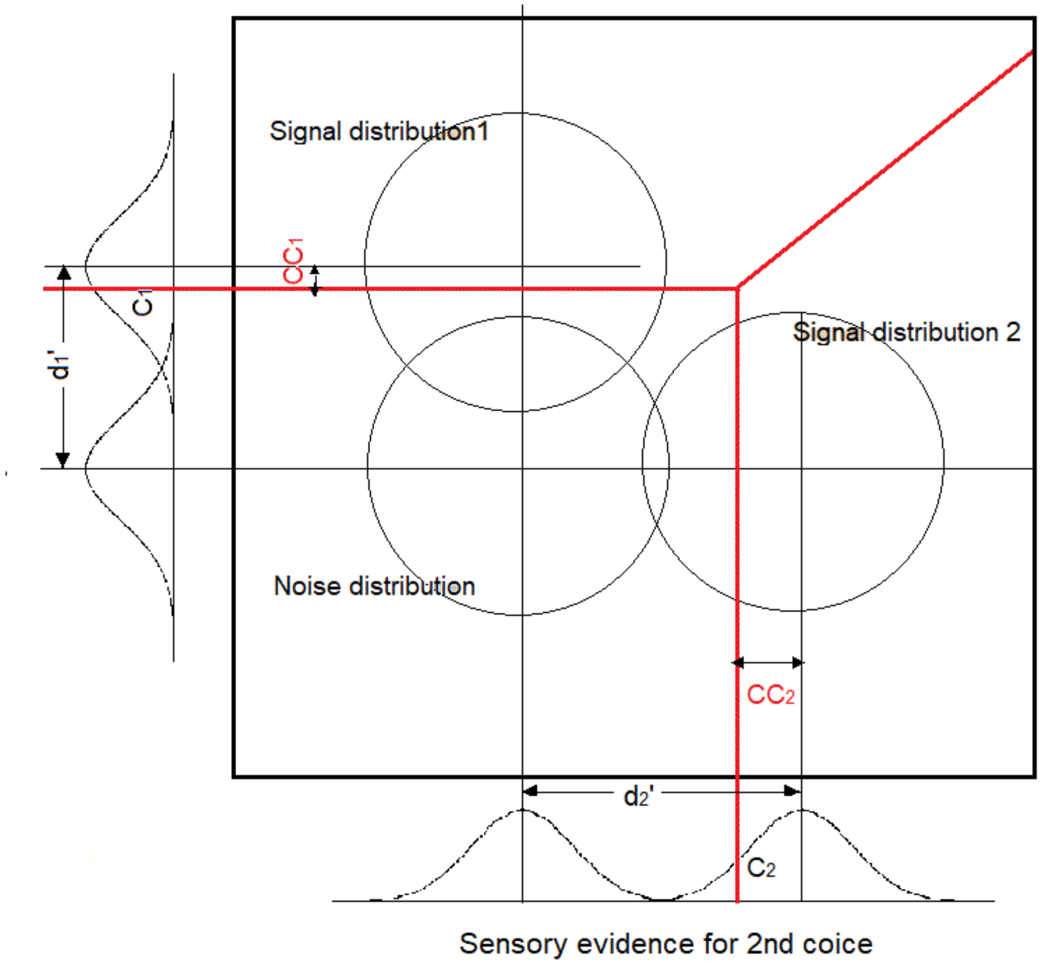


Figure 2: Two-dimensional signal detection model for a 'two alternative choice' task. (Sridharan, D. and Steinmetz, N. 2014).

In Figure 2, The two circles represent a two-dimensional decision variable for the two circles, represented along two perpendicular axes and the noise distribution is a decision variable for the noise. d_1' and d_2' are the two sensitivities, CC_1 and CC_2 and the two criteria and c_1 and c_2 are the two biases corresponding to the two distributions.

The contingency table in that case with all the responses looks like:

Table 2: Contingency table for a 2 alternative change detection task.

Stimulus \ Response	Choice 1	Choice 2	Absent
Choice 1	HIT 1	MISS IDENTIFICATION 2	MISS 1
Choice 2	MISS IDENTIFICATION 1	HIT 2	MISS 2
Absent	FALSE ALARM 1	FALSE ALARM 2	CORRECT REJECTION

The parameters are the same as in the one- dimensional case but the indices 1 and 2 indicates the two choices. An extra response called mis-identification also arises in this case. Mis-identification 1 indicates incorrectly identifying choice 1 as choice 2 and vice-versa.

Spatial orientation is a primitive feature of visual stimuli whose partial processing is thought to happen in the early visual cortex. The presence of a series of array which are tuned to

The study investigates the modulation of attention by examining its components, by varying the inter-target interval (ITI) in an attentional blink paradigm. It aims at studying the behavioural and neural correlates of the deficit correctly reporting the orientation of the second of the two targets which appear closer in temporal domain, if any. i.e., when the ITI is 100 to 600ms.

Chapter 2

Materials and methods

In the experiments conducted, students of the Cognition lab at IISc, all with normal or corrected-to-normal vision participated. In the EEG cohort, healthy volunteers who are students of IISc were participated. Upon completion of the experiment, the participants of the EEG cohort are provided with financial compensation for their time and a written consent was taken from them.

The experiments are carried out in the Cognition lab at Indian Institute of Science, in accordance with the protocols approved by the Institute Human Ethics Committee of IISc. The subjects are seated approximately 60 cm in front of computer monitor in a dark room, the viewing point being the centre of the screen. A chin-rest is used to stabilize the head. A rapid serial visual processing paradigm (RSVP) is used in which visual items are continuously presented on the screen to the participant, to study the 'attentional blink' phenomenon. The task in which the RSVP method is employed was developed at cognition lab (original task designed by Vishnu Chandrashekhar and Swagata Haldar), Indian Institute of Science, and presented using Psychtoolbox, a MATLAB (R2017a) based psychophysics Utility. The subjects are asked to fixate their eyes at the centre of the screen where a fixation point appears, throughout the experiment. To ensure fixation and that the subjects are not blinking during the trials, eye movements are tracked and recorded using 'EyeLink 1000' eye tracker which has a 1000 Hz resolution. At the end of each trial, subjects responded by button press on the response box provided (Cedrus – RB-540) and the responses are all saved in a MATLAB readable format.

In order to acquire the electrophysiological activity while performing the task, the EEG data are collected using anEGI 128-channel Geodesic Sensor Net which is saline based, continuously at 1000 Hz (sampling rate) from the EEG cohort. EEG cap with128 channels appropriate for the subject's head size is put on with Cz channel being at the intersection of the plain containing nasion and inion, and the two tragus of the ears, on the head. The Geodesic Sensor Net is connected to the 'Net Amps' amplifier which provides amplifies and provides signal at high SNR (signal to noise ratio) required for acquiring high-quality EEG data.Net Station software which is a mac-based data-acquisition software saves the data and is then later converted into MATLAB readable format.

The aspects of the variations of the attentional blink task and the analytic procedure are described separately here.

Task design:

The task structure is as follows: A trial starts with the presentation of a fixation point where the subjects are asked to fixate during the entire trial which is directly in front of the subject and at the centre of the screen. Followed by that, a series of distractors appear in which two targets (T1 and T2) are embedded with a grey background on the screen. The stimuli presented are of diameters 3 DVA (degrees per visual angle) and is at the centre of the screen. T1 is a low special frequency (0.03 cycles per degree) sine-gabor oriented clockwise or anti-clockwise at an angle staircased for each participant for an accuracy of 90%. Thus, there are two possible responses for T1 (Clockwise orientation or anti-clockwise orientation). The method of staircasing is explained below. T2 is a high special frequency (0.06 cycles per degree) sine-gabor oriented clockwise or anti-clockwise at 45 degrees. T2 is absent in some of the trials which are called ‘catch trials’. This is done in order to make sure that the subject is not randomly pressing the buttons without paying attention. A trial end is marked by the beginning of response window when the two targets oriented vertically would appear sequentially in order to indicate the time when the subject is supposed to respond with a button press on the cedrus. The ITI consists of 0ms or 100ms to 1000ms with an increment of 100ms. Refresh rate of the screen is 100Hz. In each 100ms, new stimulus appears on the screen with 70ms stimulus appearing on the screen and 30ms blank.

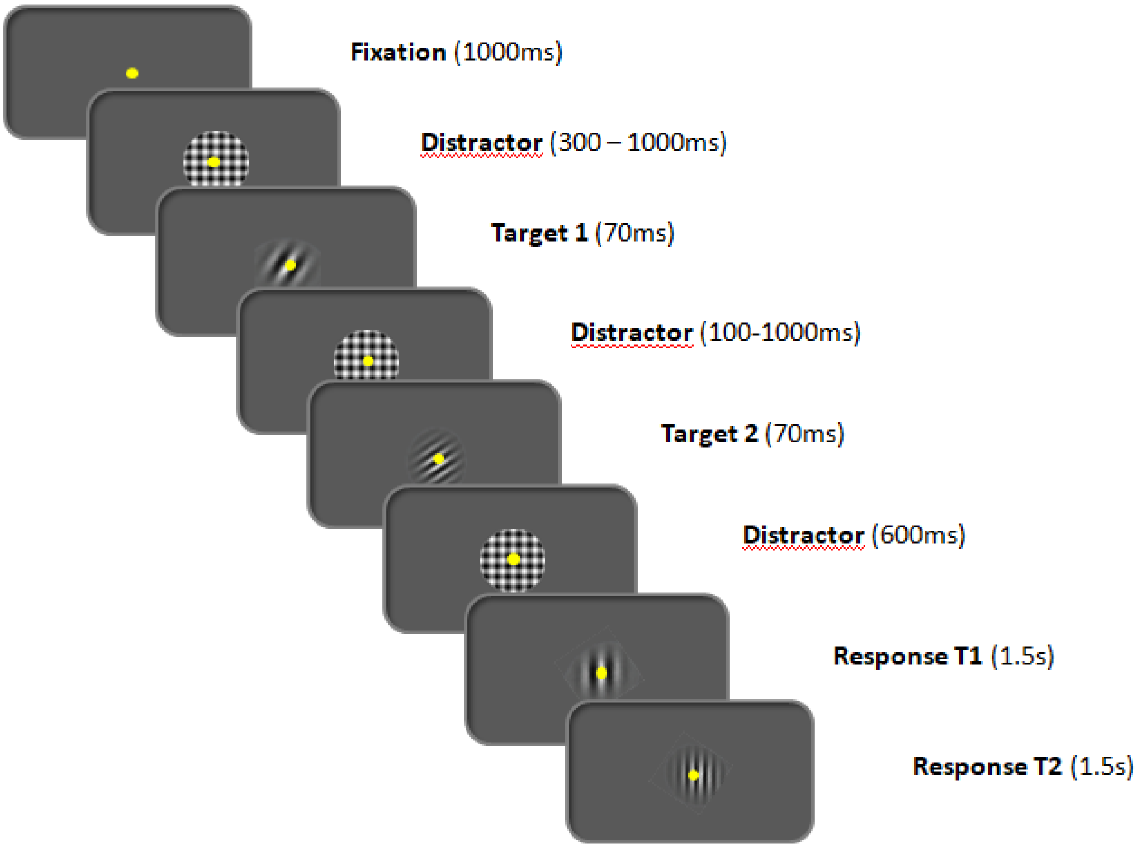
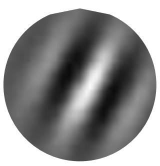
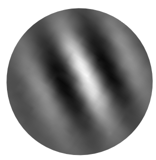


Figure 3: Trial structure.

<u>Target 1 choices:</u>

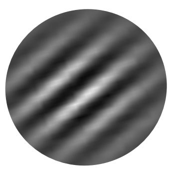
(a) 

Clockwise- tilted

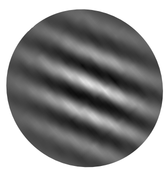
(b) 

Anticlockwise-tilted

<u>Target 2 choices:</u>

(a) 

Clockwise- tilted

(b) 

Anticlockwise-tilted

(c)

Target 2 Absent

The basic task structure (i.e., the presentation of different stimuli) remains the same through-out, with different combinations of the stimuli (Target 1, distractor and Target 2) being tested in different cohorts.

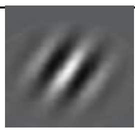
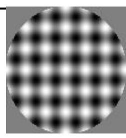
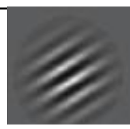
Prior to the main block, subjects are given a training block after giving instructions about the task. Feedbacks for both the stimuli are presented showing if the response was correct or incorrect. This is done in order to get the subjects accustomed with the task and to see if he is doing the task properly which can be assessed by looking at the psychophysical curve that's plotted online.

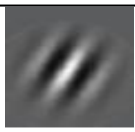
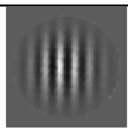
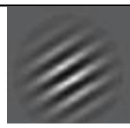
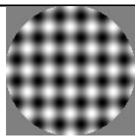
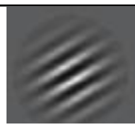
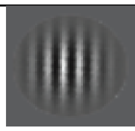
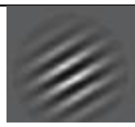
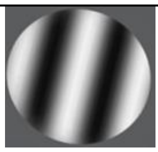
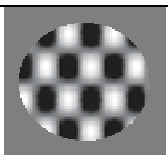
The angle with respect to the vertical is staircased for each subject. This is done once the subject gets accustomed to the task after training. By this, an angle suitable for each subject is obtained, in which he gives an accuracy of 90%. In order to staircase, 20 blocks containing 6 trials each is presented. To start out, gabors oriented at an angle of 3 degrees with respect to vertical is presented in the first block. Depending upon the performance accuracy, it gets automatically adapted to higher or lesser angle if the accuracy was lesser or greater than 90% respectively. That angle is chosen nearby which the accuracy oscillates around 90% performance accuracy, for the main task.

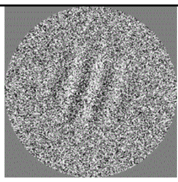
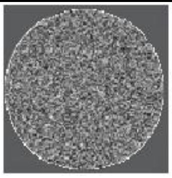
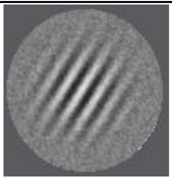
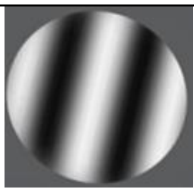
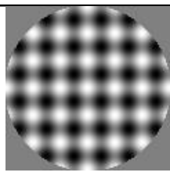
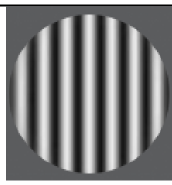
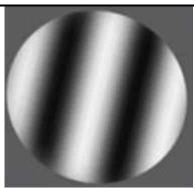
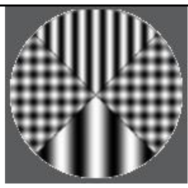
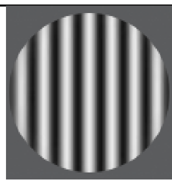
In the main task, the trials are all chosen pseudo-randomly. A block consists of 126 trials and 4 such blocks are presented to the subjects. Subjects started each block at will with a button press.

Task variations – 8 variations of the task all having the same structure, were tried out in order to obtain an attentional blink in detecting and discriminating orientations.

Table 3: Different combinations of targets and stimuli tested (Angles mentioned are all with respect to vertical)

Combinations	Target 1	Distractor	Target 2	No. of Subjects
	 (Tilted at staircased	 (Plaid – a	 (45/-45-degree	

1	angle)	superimposition of 0 and 90-degree gabors)	tilted gabor)	3
2	 (Tilted at staircased angle)	 (gabors with 22.5 and -22.5 angle alternating in each frame)	 (45/-45-degree tilted gabor)	3
3	 (Landolt C With the slit being on the left side or right side from trial to trial)	 (Plaid – a superimposition of 0 and 90-degree gabors)	 (45/-45-degree tilted gabor)	3
4	 (Landolt C With the slit being on the left side or right side from trial to trial)	 (gabors with 22.5 and -22.5 angle alternating in each frame)	 (45/-45-degree tilted gabor)	3
5	 (Tilted at staircased angle)	 (Plaid – a superimposition of 45 and -45-degree gabors with staircased	 (10/-10-degree tilted gabor with the contrast staircased for each subject for having a 75%	4

		contrast)	accuracy in the longer time-lag case)	
6	 (Gabor embedded in noise mask)	 (Noise mask)	 (gabor embedded in noise mask)	6
7	 (Tilted at staircased angle)	 (Plaid – a superimposition of 0 and 90-degree gabors with phase shift of 180 degrees from frame to frame)	 (10/-10-degree tilted gabor)	6
9	 (Tilted at staircased angle)	 Distractor with features of T1, T2 and plaid which is a super imposition of 0 and 90 degrees	 (45/-45-degree tilted gabor)	10 in the behavioural cohort and 10 in the EEG cohort.

Behavioural data analysis and model fit:

In order to study the attentional deficit, if any, happening during the attentional blink duration, i.e., the dearth in the attentional components in the trials with short ITI as compared to longer ones, sensitivity and criterion values for the target 2 are computed and psychophysical functions are plotted by fitting the 2 dimensional m-ADC model to the experimentally obtained behaviour data. The two signal distributions for target 2 correspond to clockwise and anti-clockwise orientations of the gabor and noise corresponds to the no target 2 case (Figure 2)

Psychometric parameters such as sensitivity (d') and bias (cc) are estimated using the formulae provided by SDT, Viz.,

$$d' = \varphi^{-1}(HR) - \varphi^{-1}(FA) \quad \text{and} \quad cc = c - d'/2 \quad \text{where } c = -\varphi^{-1}(FA)$$

(where φ^{-1} represents the probit function, the inverse cumulative distribution function associated with the standard normal distribution, HR is the hit rate and FA is the false alarm rate which are obtained by calculating the accuracy of subjects' performance in the behavioural task).

Sensitivity and bias for both detection and discrimination at all time-lags are calculated for the configuration in which blink happens, in order to find out the component of attention getting impaired.

Only the trials in which subject made a correct response to T1 are taken into consideration for the calculation of the percentage accuracies of the other responses and to plot psychophysical and psychometric data.

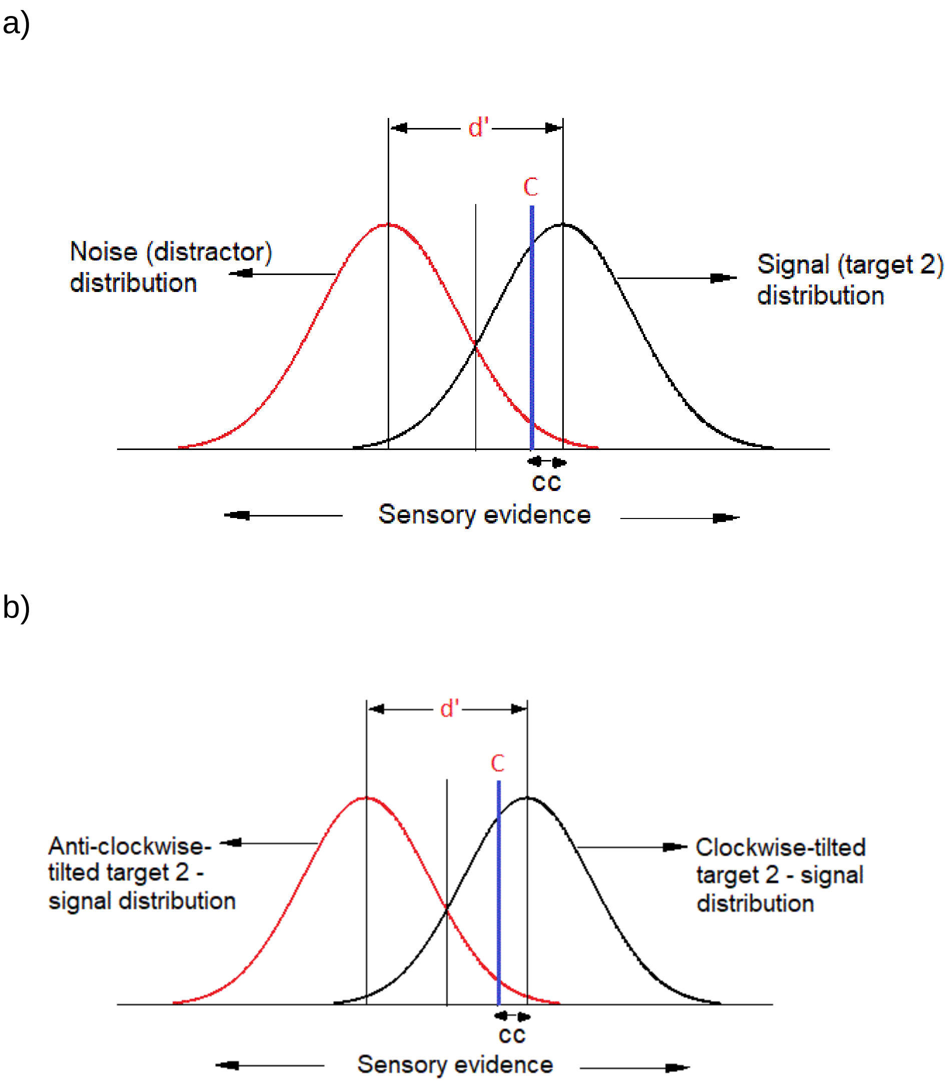


Figure 4: illustration of SDT model in the context of the experiment showing a) sensitivity and bias for detection of target 2 b) sensitivity and bias for detection of target 2. sensitivity and bias for the discrimination of target 2.

Electrophysiological data analysis:

In order to study the neural correlates of attentional deficit, if any, happening in the attentional blink duration, the EEG data acquired from the EEG cohort is analysed once the experiment is done. The data is first undergone through pre-processing the primary step of which is to filter the data. This is done using a filter MATLAB filter function 'bandpassfir' with the cut-off frequencies F_l= 1 and F_h = 45. Thus, all the frequencies which don't come in the range are filtered out. Followed by that the time windows containing the relevant information are extracted out from the continuous signal. This process is called as 'EEG Epoching'. Epoching is done in a manner that it contains 300ms before the target onset, 100ms when the target is present and 600ms after the target offset. And it is done separately for T1 and T2. **Figure 5** shows the time-windows that are epoched out.

Demeaning, which is a process of removing the mean activity of each channel and average re-referencing which is, removing the average across all the electrodes, in order to extract the activity relevant to the task are done separately for each epoch after concatenating all of them. De-trending is done followed by that in order to remove the linear trend observed. The pipeline is illustrated in the Figure **6** .Steps ‘a’ to ‘e’ are included in the pre-processing pipeline.

The EEG activity for trials are sorted based on the responses given by the subjects. i.e., hit, miss, mis-identification, false alarm and correct rejection. And later done the other analysis with the data thus obtained.

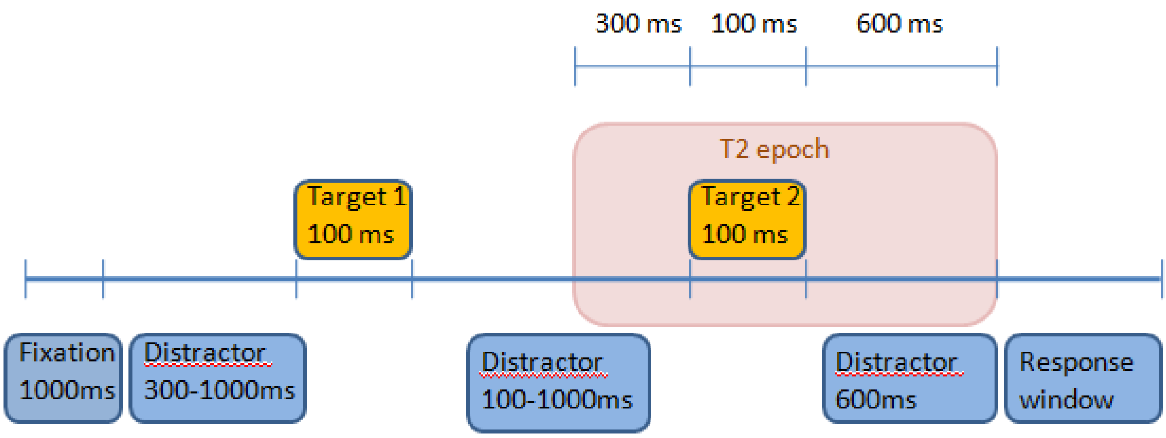


Figure 5: Task structure indicating the epoch. The T2 epoch starts from 300ms before T2 onset till 600ms after T2 offset

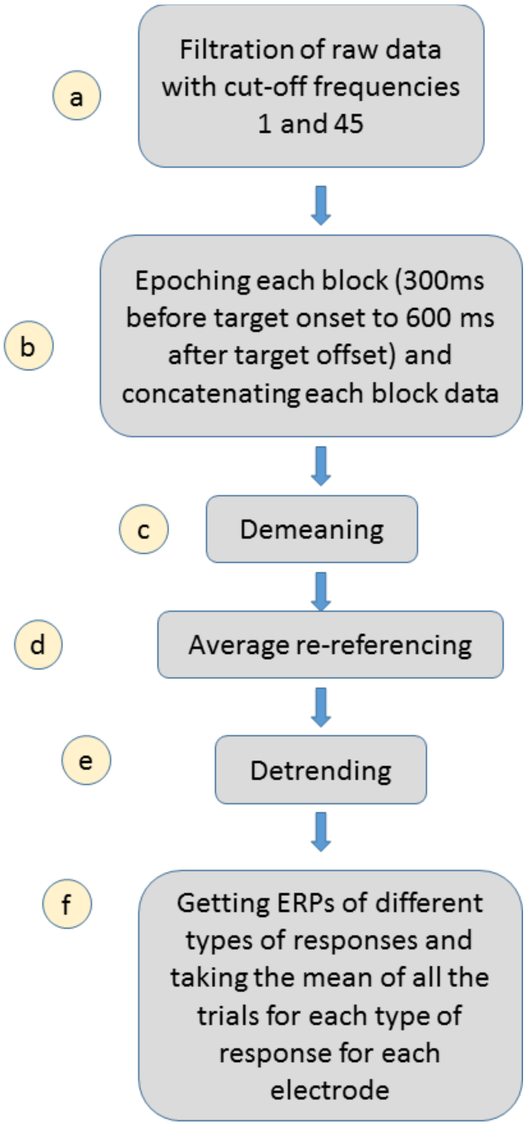


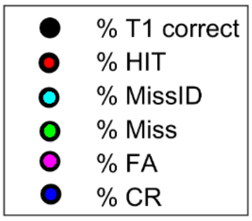
Figure 6 : Illustration of the pipeline of the pre-processing of the raw EEG data

Chapter 3

Results and discussion

3.1 Preliminary runs for obtaining the behavioural correlates of ‘attentional blink’

The task structure is as given in the Figure 3 . Different combinations of target 1, 2 and distracters are as given in the Table 3: Different combinations of targets and stimuli tested (Angles mentioned are all with respect to vertical). The legend for all of the psychometric figures Figure 7 to Figure 16 is given below:



‘% T1 correct’ at each time-lag is the percentage of correct responses made for target 1.

‘%Hit’ is the percentage of hit responses made at each time-lag. i.e., Number of hit responses divided by the sum of number of hits, mis-identification, miss responses.

‘%missID’ is percentage of mis-identification responses at each time-lag. i.e., Number of miss-identification divided by the sum of number of hits, mis-identification, miss responses.

‘%miss’ is the percentage of miss responses at each time-lag. i.e., Number of miss responses divided by the sum of number of hits, mis-identification, miss responses.

‘%FA’ is the percentage of false alarm responses at each time-lag. i.e., Number of false alarm responses divided by the sum of number of false alarm and correct rejection responses.

‘%CR’ is the percentage of false alarm responses at each time-lag. i.e., Number of correct rejection responses divided by the sum of number of false alarm and correct rejection responses.

Only the trials in which subject made a correct response to T1 is taken into consideration for the calculation of the percentage accuracies of the other responses

Combination 1:

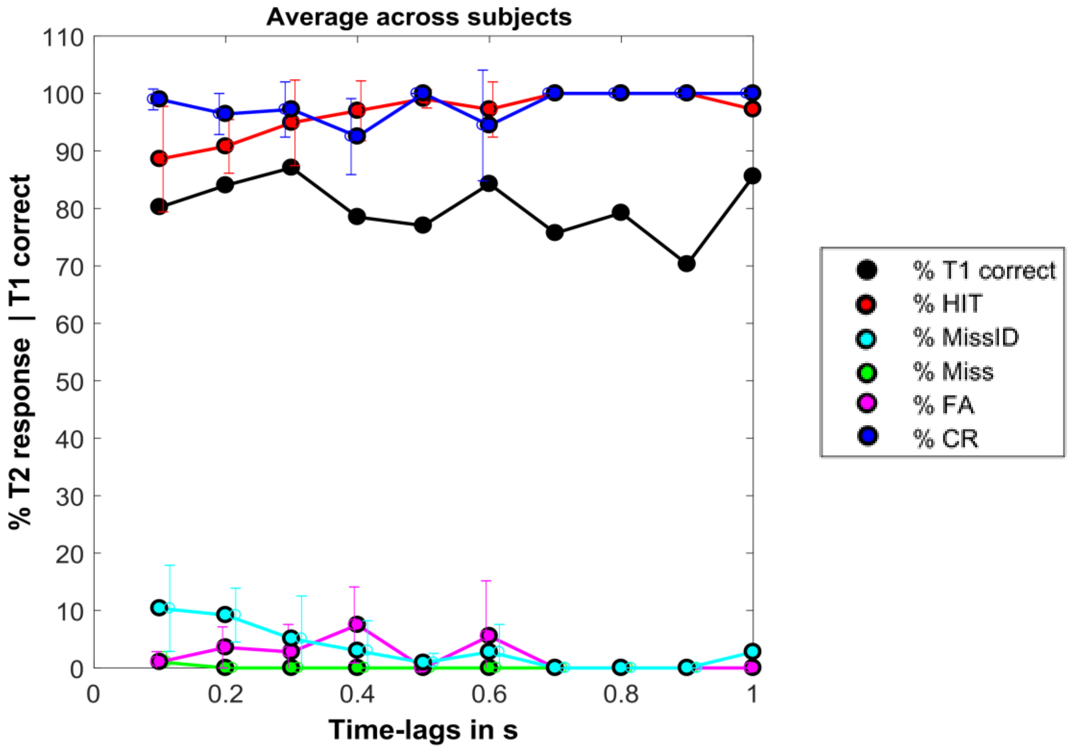


Figure 7: Psychophysical plot for combination 1

There is a little impairment in the percentage of correct responses in the cases when the time-lag is shorter as compared to when it is longer. The inter-subject variability of having an attentional blink is higher as the error bars for hits and mis-identification (missID) is greater in the shorter time-lag case. The task seems to be simple as the plaid distractor, which is a superimposition of 0 and 90 degrees gives a reference for judging if the orientation of targets is clockwise or anticlockwise with respect to the vertical (Figure 7).

Combination 2:

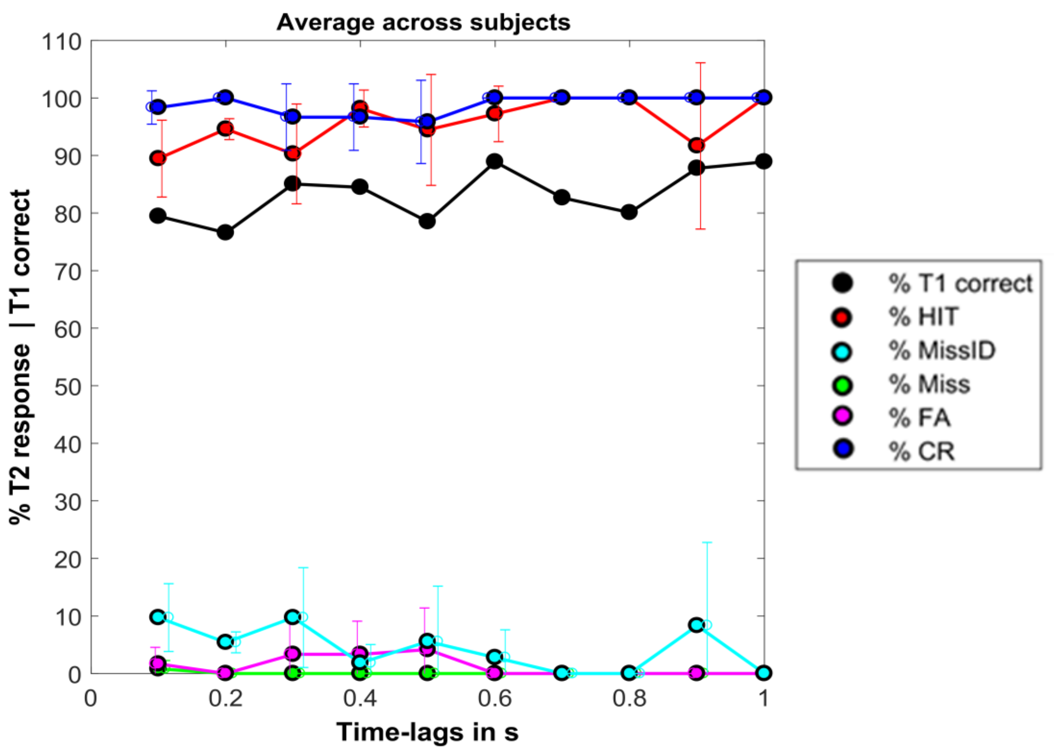


Figure 8: Psychophysical plot for combination 2

In order to make the task more difficult, the distractor is changed from plaid to gabor with the same spatial frequency as T2, changing the orientations from 22.5 to -22.5 degrees from frame to frame (Figure 8). But it is observed there is not much of an improvement in the 'blink'. Even though the reference which the previous distractor thought to be provided, is removed, the task still remains simple.

Combination 3:

There is an impairment of discrimination ability which is a little better than previous two cases. The Landolt C as target 1 seems to have greater cognitive load and in this combination the plaid seems to be distracting better. But the drop in the ability is not as much as desired (Figure 9).

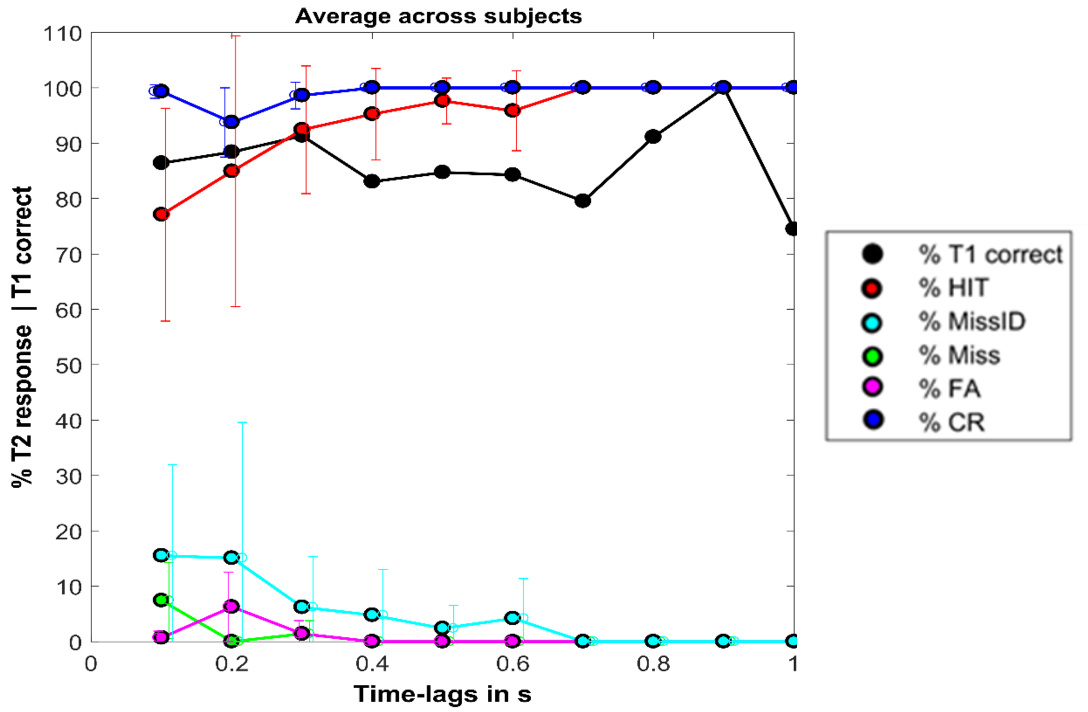


Figure 9: Psychophysical plot for combination 3

<u>Combination 4:</u>

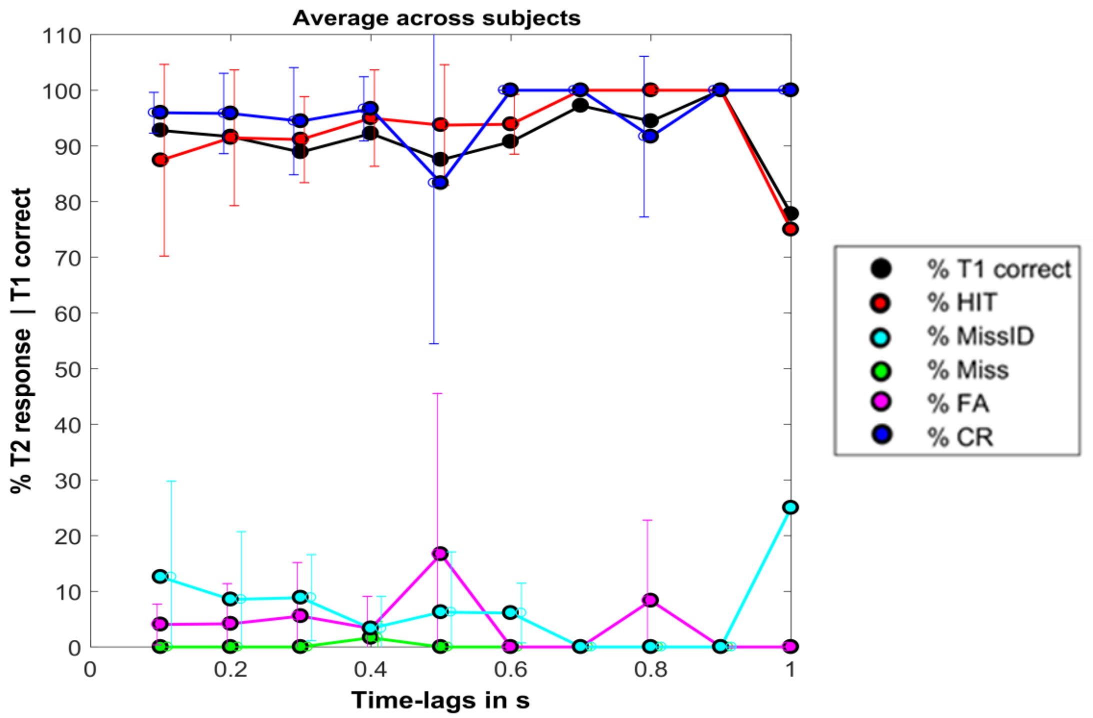


Figure 10: Psychophysical plot for combination 4

Although the impairment in the discrimination is present in the shorter time-lag case in this combination, the drop seems to be lesser as compared to that in the combination 3.

It is also interesting to note that although the subject recovers from 'blink' at 700ms time-gap to give a 100 percent accuracy in the discrimination ability, at 1000 ms, the ability drops again (Figure 10). This can be due to the lesser number of trials in the longer time-lag cases because of the exponential distribution of the trial numbers.

Combination 5:

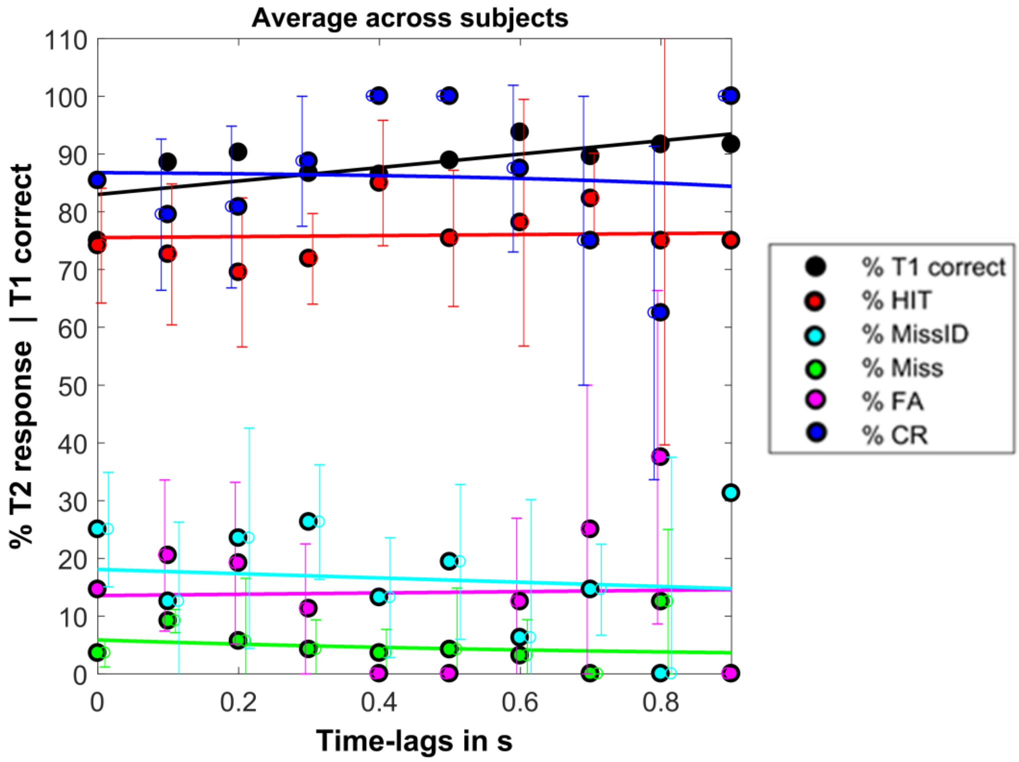


Figure 11: Psychophysical plot for combination 5

In order to get a prominent drop in the discrimination ability, we tried to make the task difficult. A variation of task 1 is tried with the distractor as a plaid which is a superimposition of 45 and -45 degrees oriented gabors. Target 2 angle is also reduced from 45 degrees to 10 degrees so that subjects need to pay more attention in order to identify the orientation. The contrast of Target 2 and the distracters are set as that obtained from staircasing for a 75% correct Target 2.

The psychophysical graph is plotted and fitted with exponential function. (Figure **11**)

It is observed that the subjects are not having difficulty in correctly responding to T2 even in the short ITI. This could be because when the distractor contrast is reduced, it is not able to distract as much as when it is in full contrast.

Combination 6:

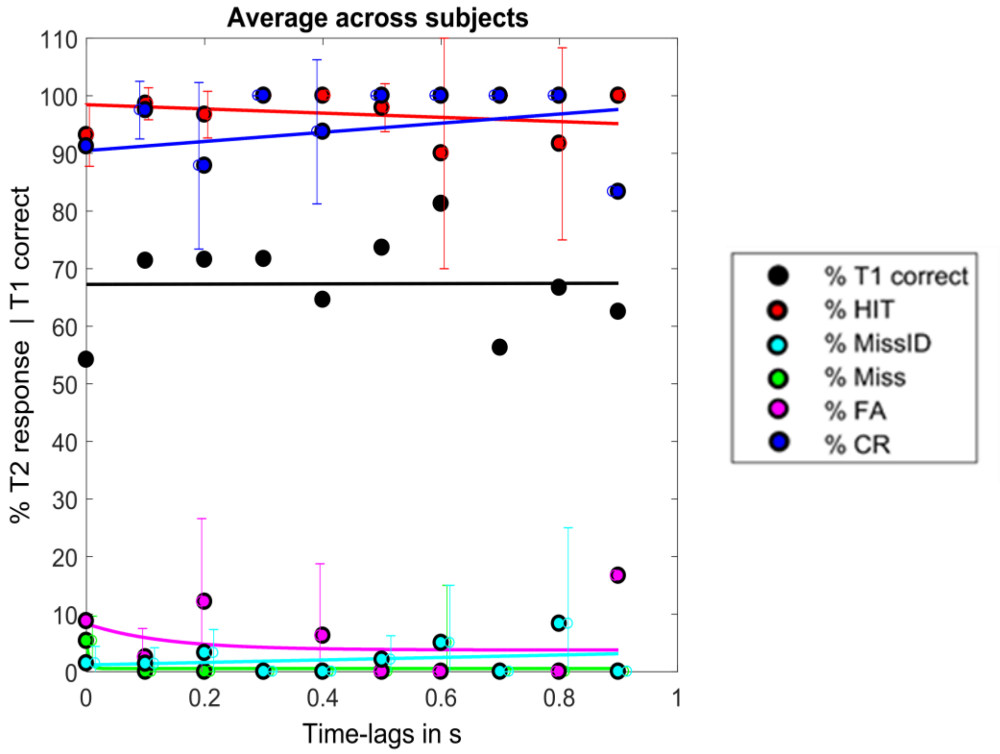


Figure 12: Psychophysical plot for combination 6.

The T2 detection and discrimination task seems to be very easy since the targets which are gratings embedded in noise mask sticks out from the noise mask distractor and becomes easy to detect. Thus, there doesn't seem to have any difficulty in detecting and discriminating even in the shorter time-lag cases. None of the responses are getting impaired as the time-lag decreases

The psychophysical graph is plotted and fitted with exponential function. (Figure 12).

Combination 7:

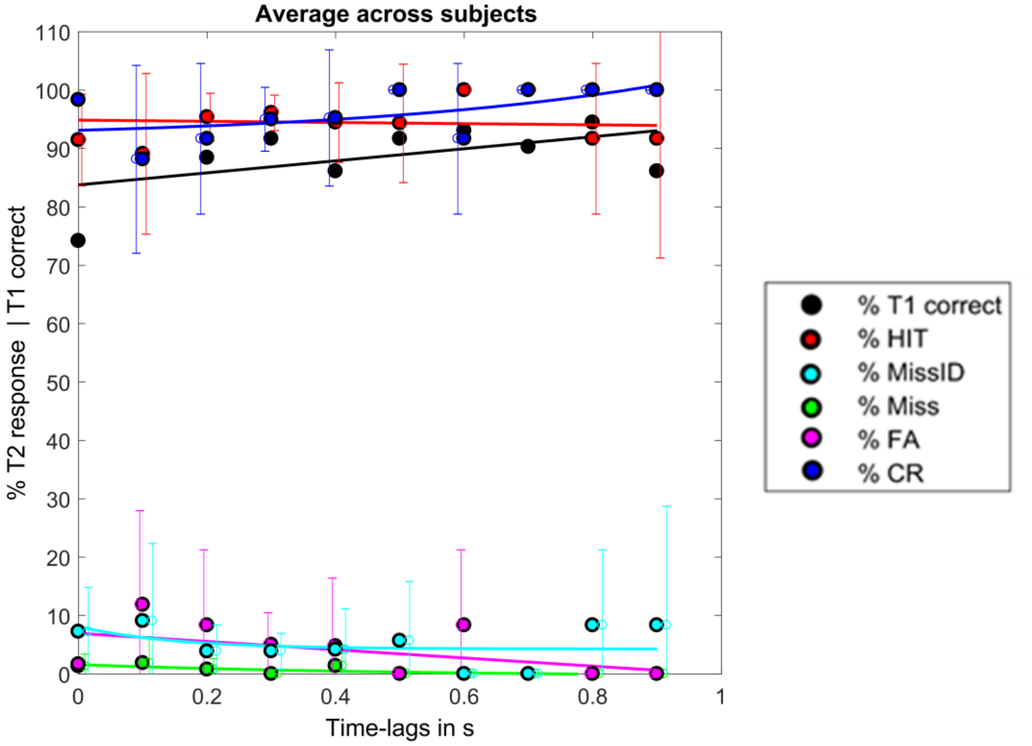


Figure 13 Psychophysical plot for combination 7

A combination which is similar to the combination 1 but more difficult, is tried out. The target 2, unlike 45 degree tilted in the case of combination 1, is 10 degree titled from the vertical. The distractor, unlike the same being flashed in each frame, now changes the phase in each frame so as to not give reference to the vertical. But this seems to be even less difficult than the task with combination 1 which is not expected.

The psychophysical graph is plotted and fitted with exponential function. (Figure 13).

Combination 8

Since the plaid distractor seems to not distract much distractors which are pure combinations of the two targets were tested but that were all distracting the subjects in such a level that they were not able to detect the two targets in any of the trials. Thus, we decided to use a distractor which is made of plaid and having the features of both the targets. Figure 14

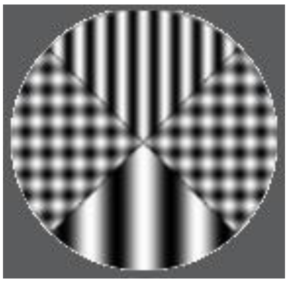


Figure 14: Distractor for combination 8

The angle with respect to vertical of the two lines which are the boundaries of the plaid with the targets, is increased or decreased from subject to subject in order to make the task more difficult or easier respectively, depending on the performance of the subject in the training block.

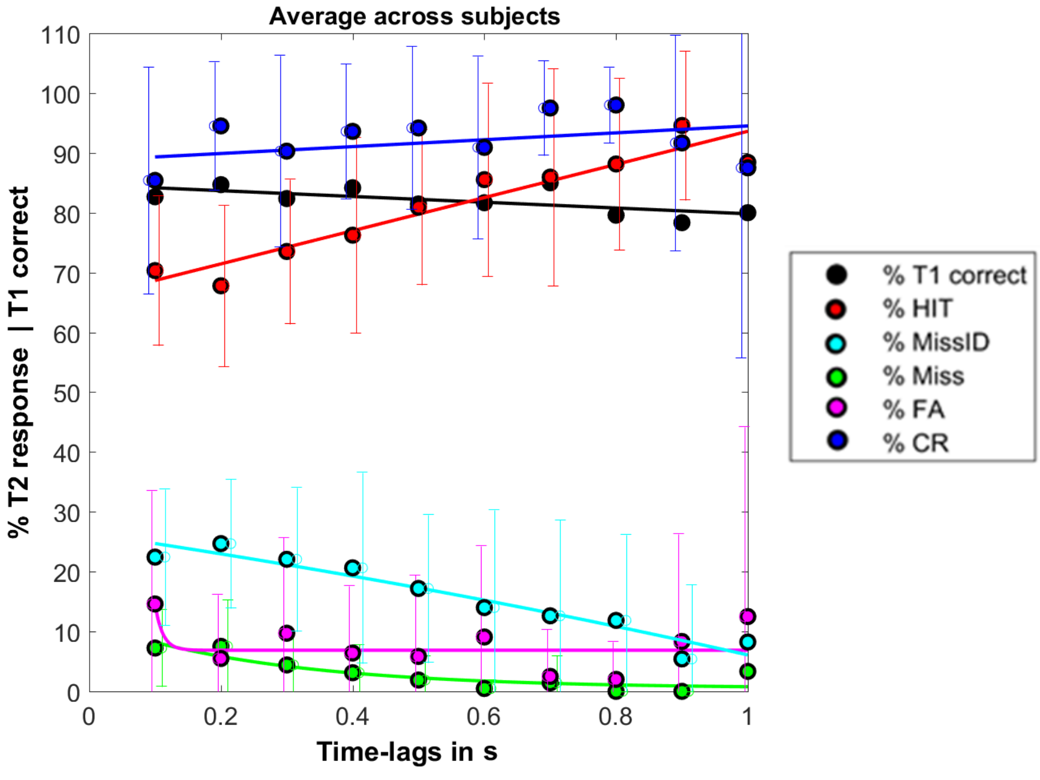


Figure 15: Psychophysical plot for combination 8

This combination that gives a noticeable attentional blink in the discrimination ability since both hit and miss identification are getting impaired as the time-lag gets shorter. This combination could be a potential one for studying the neural correlates of attentional blink in discrimination ability. It can be noticed that it is not only those two responses but also all the responses are having decreased percentage accuracies in the shorter time-lag case.

3.2 Deficit in the attentional components during attentional blink

Behavioural data of EEG cohort:

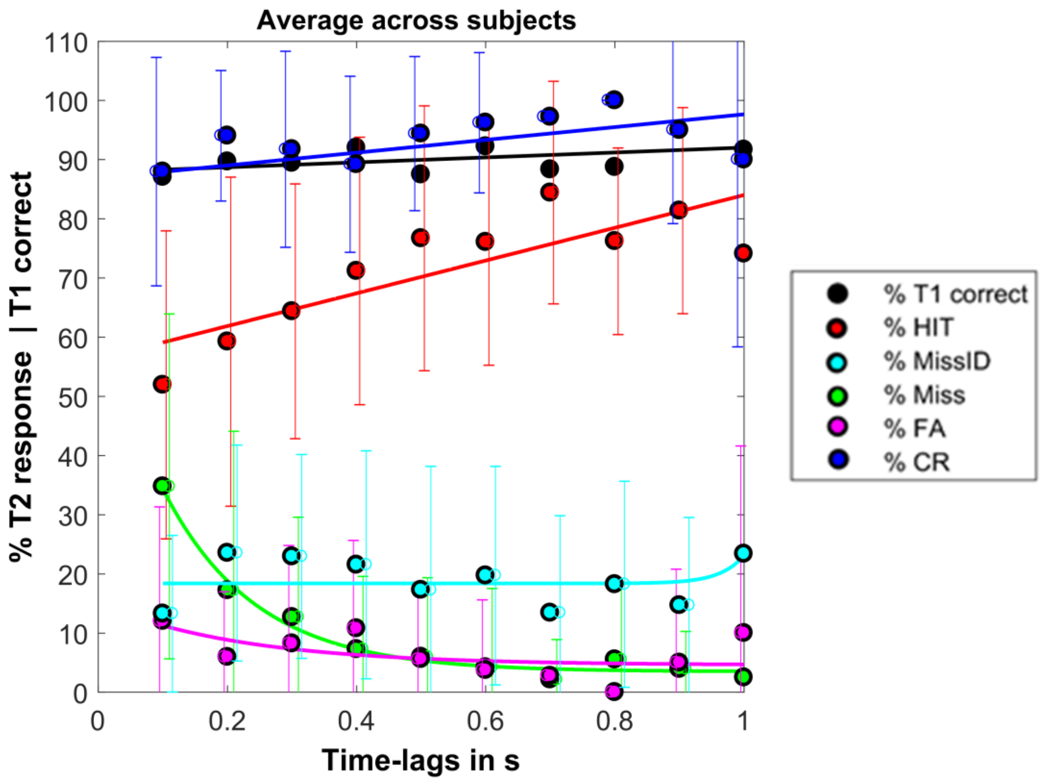


Figure 16: Psychophysical plot for combination 8 in EEG cohort

The psychophysical graph is plotted and fitted with exponential function (Figure **16**).

On considering the psychophysical plots of each individual, the inference made is that the time for recovering from attentional blink is subjective and varies from 200 to 600ms. The subjects have decreased accuracies in the responses during the 'blink' time and it gets to a level which no more changes as you increase the time-lag. It can also be comprehended from the figures Figure 7 to Figure 16 that the time for recovering also depends on the task configurations.

Psychometric data analysis (Sensitivity and bias analysis):

In order to confirm that the decreased accuracies in the correct responses is due to deficit in attention, the components of attention at all the time-lags is looked at.

Sensitivity and bias for both detection and discrimination (Figure 4 a and b) at shorter time-lags are both compared to those at longer time-lags. Figure 17 and Figure 18

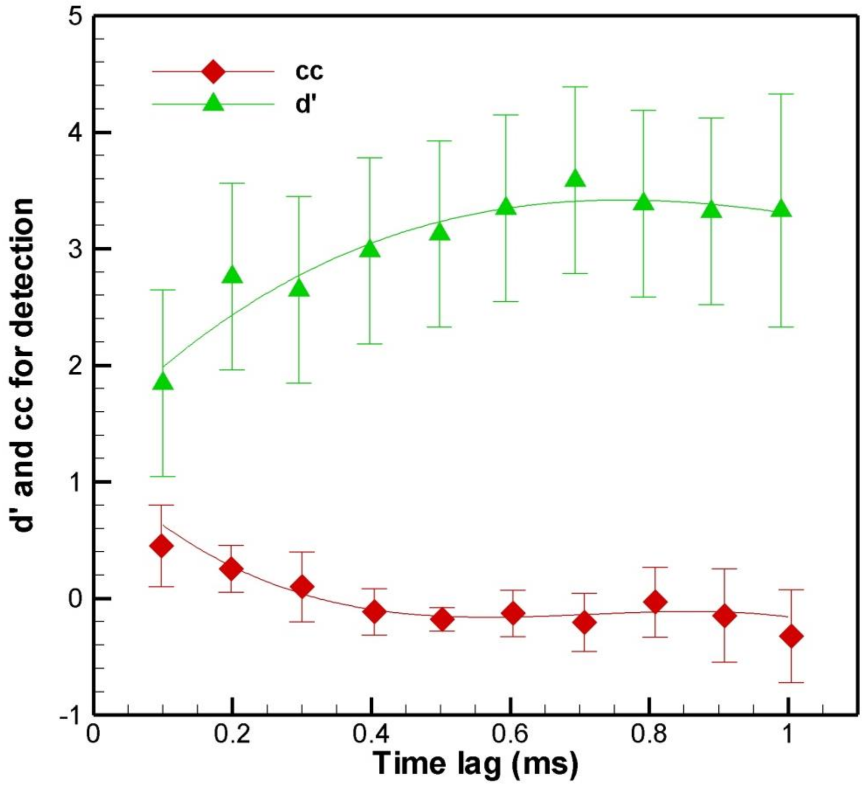


Figure 17: sensitivity(d') and bias(cc) for detection of T2

The sensitivity and bias analysis clearly show a dip in the sensitivity in the short time-lags (Figure 18). Bias remains the same through-out, irrespective of the ITI. Figure – and – illustrate the deficit in the sensitivity in the case of detection and discrimination both. Whereas, bias seem to get not affected even when the ITI is short. It can be comprehended that, the decline in the performance accuracy is associated with a drop in the attention due to the reduction of its sensitivity component.

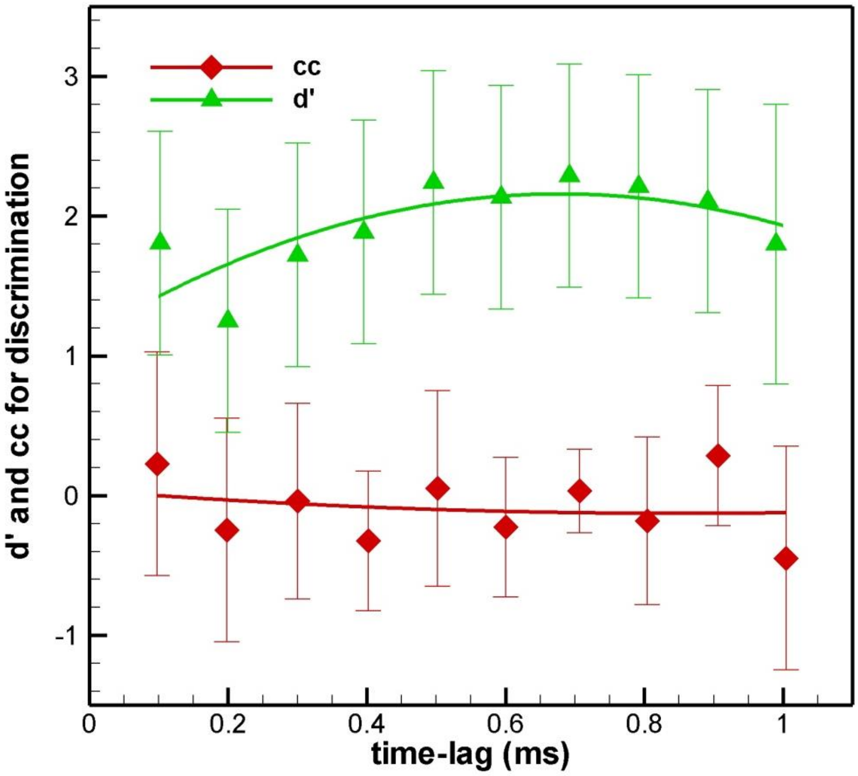


Figure 18: sensitivity(d') and bias(cc) for discrimination of T2 orientation

3.3 Neural correlates of 'attentional blink'

3.3.1 Event related potential (ERP) analysis results:

Electrode activities from the occipital, parietal and frontal regions are assessed separately for three different types of time-lags – short (100ms, 200ms, 300ms), medium (400ms, 500ms, 600ms), long (700ms, 800ms, 900ms, 1000ms). Figure 19 to Figure 30 represent the electrode activities from 300ms before T2 onset to 600ms after T2 offset for four different responses viz., hit (H), correct rejection (CR), miss (M), false alarm (FA) as well as the electrodes chosen to do the analysis. The two vertical red lines indicate the T2 onset and offset respectively. The two vertical red lines indicate the T2 onset and offset respectively. X axis represents the time and Y axis represents the activity in micro-Volts. .

<u>Occipital activity for different time-lags – average across all subjects</u>

Electrodes chosen:

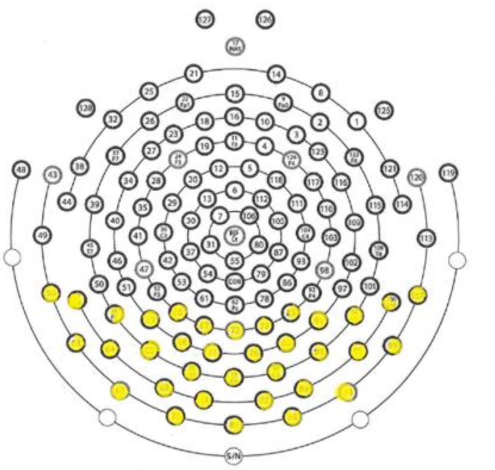


Figure 19: Occipital electrodes chosen for the analysis

ERP for Short, Medium and long time-lags

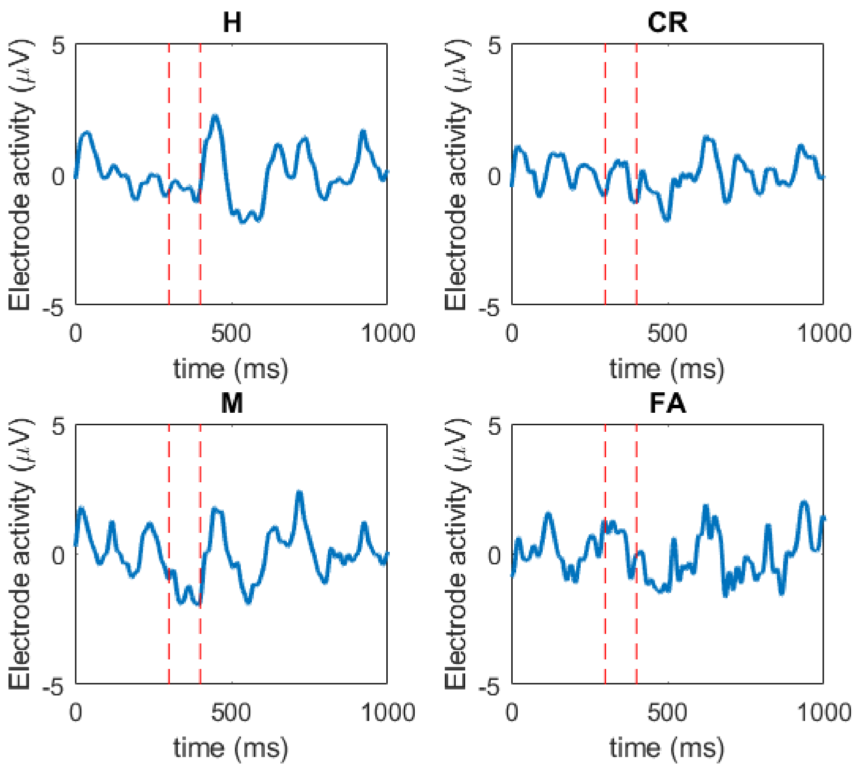


Figure 20: Electrode activities from the occipital region in the case of trials with short time-lags.

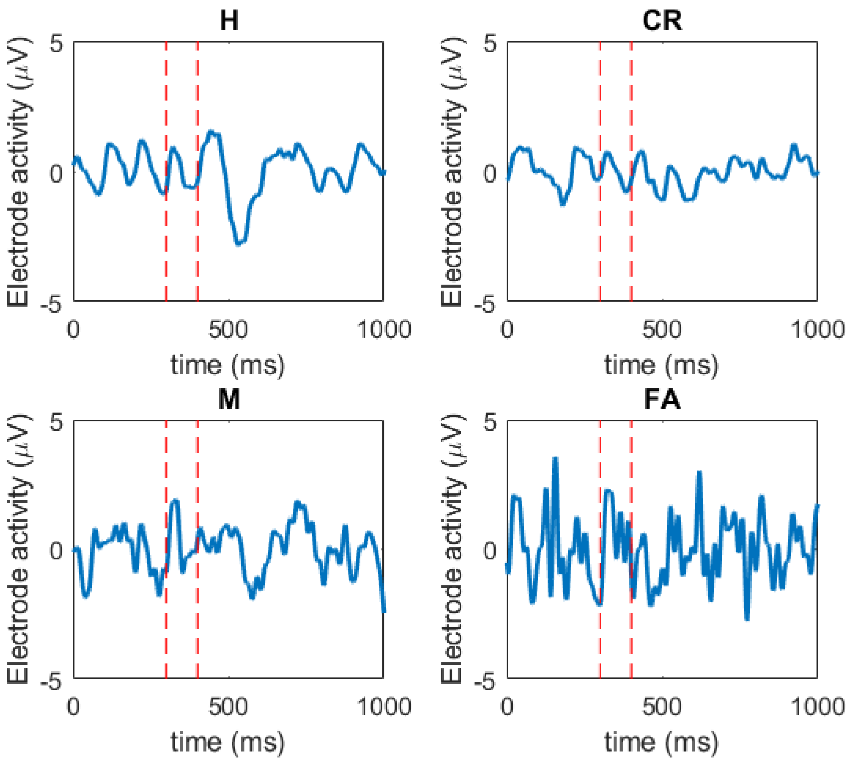


Figure 21: Electrode activities from the occipital region in the case of trials with medium time-lags.

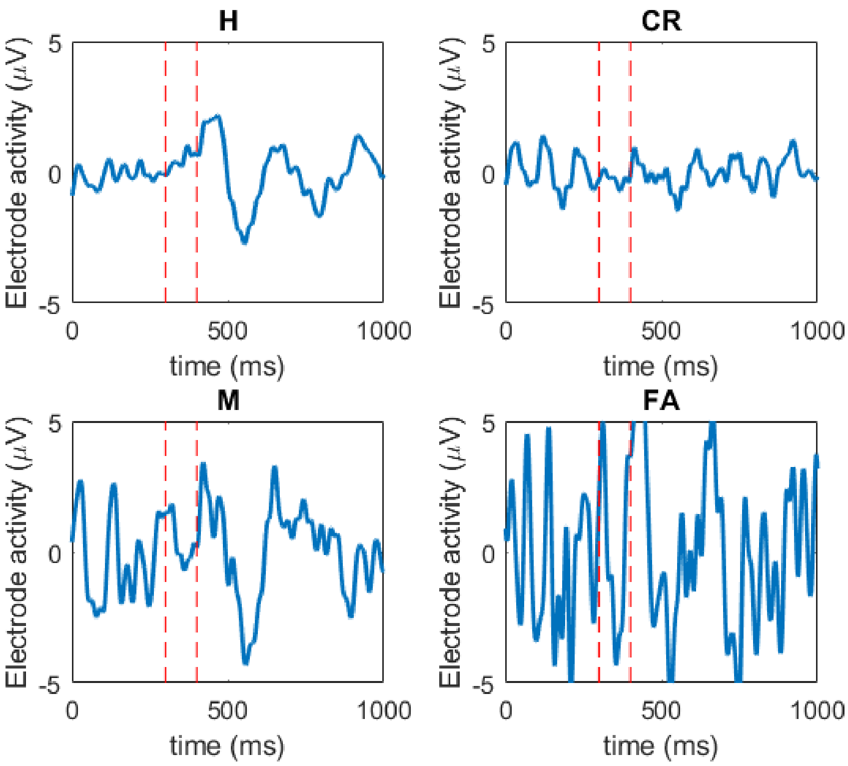


Figure 22: Electrode activities from the occipital region in the case of trials with long time-lags.

Parietal activity for different time-lags – average across subjects

Electrodes chosen:

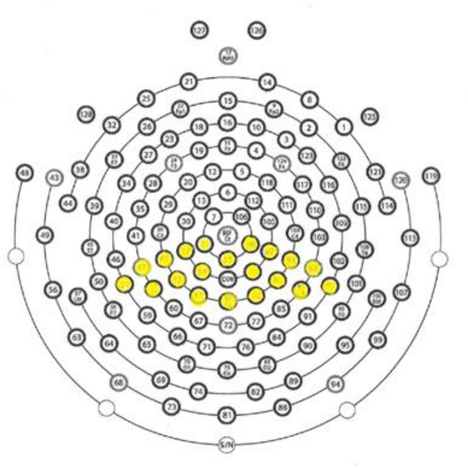


Figure 23: Parietal electrodes chosen for the analysis

ERP for Short, Medium and long time-lags

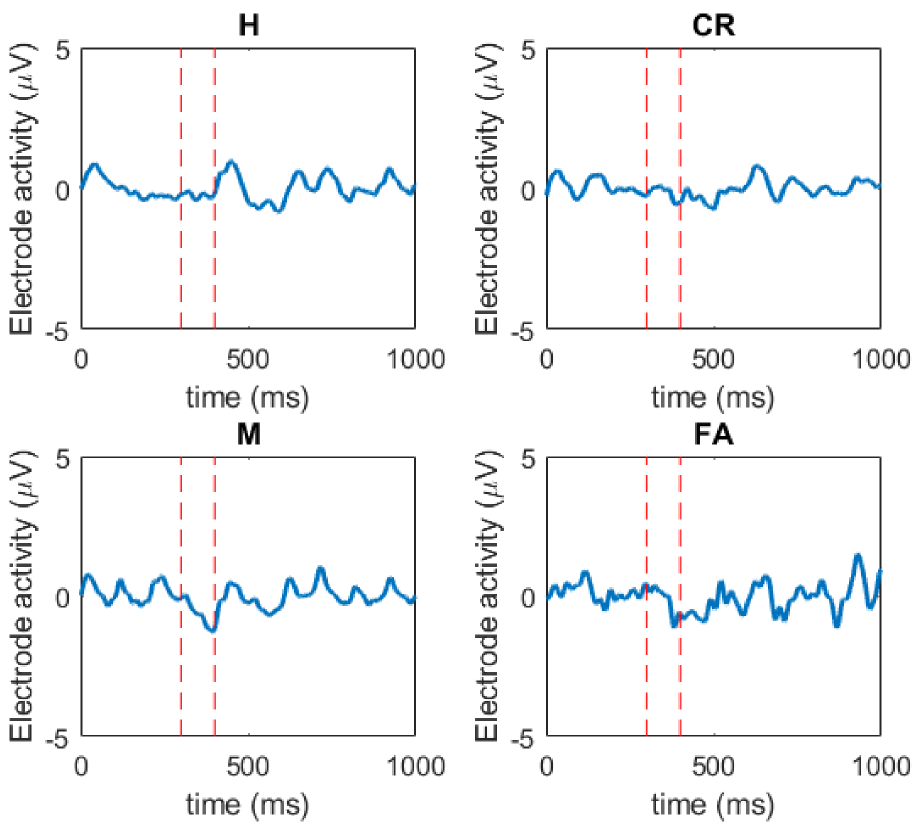


Figure 24: Electrode activities from the parietal region in the case of trials with short time-lags.

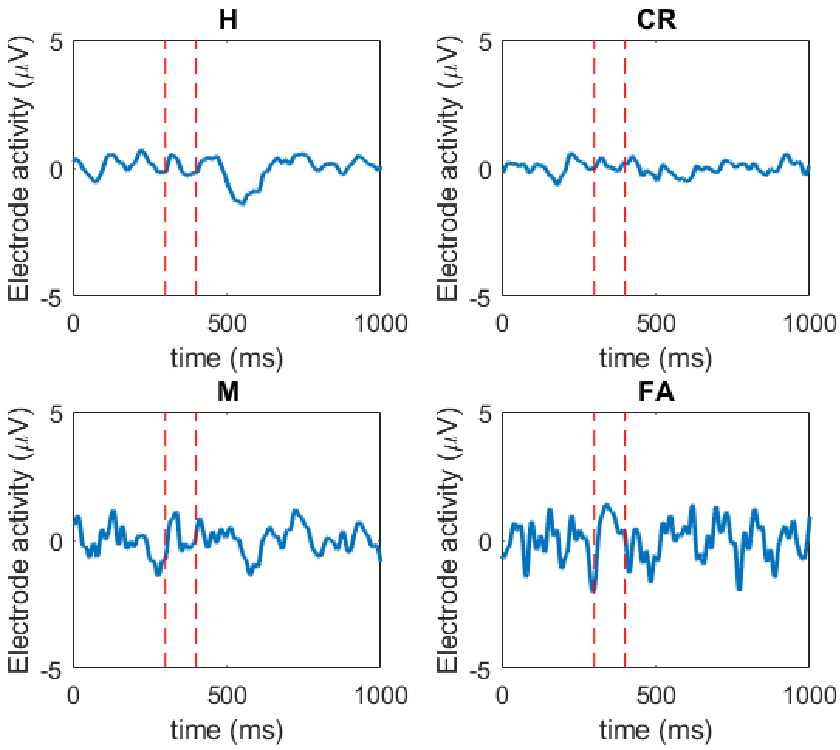


Figure 25: Electrode activities from the parietal region in the case of trials with medium time-lags.

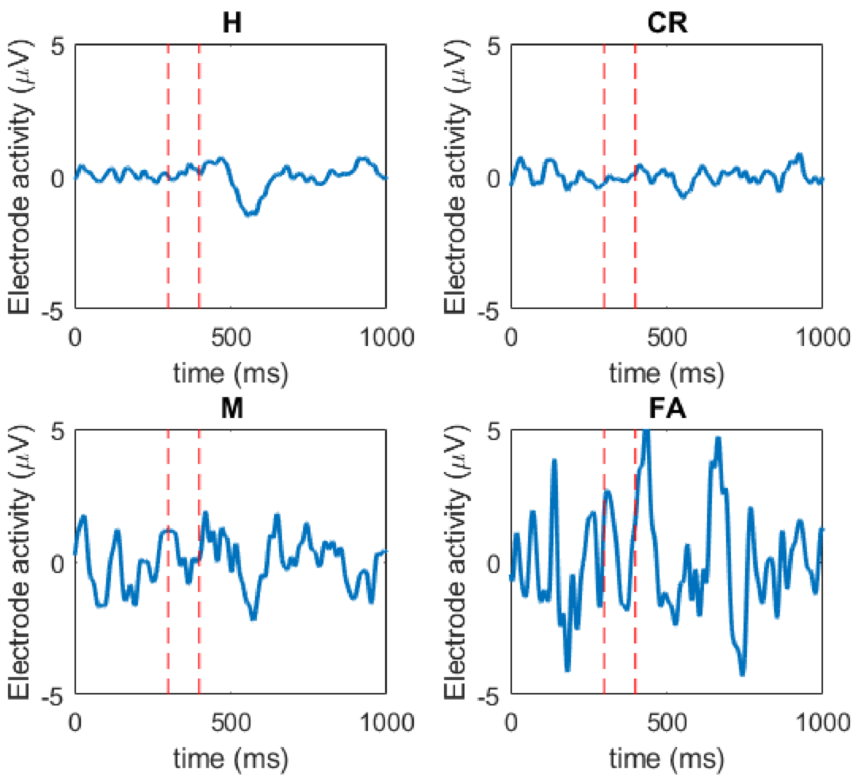


Figure 26: Electrode activities from the parietal region in the case of trials with long time-lags.

Frontal activity for different time-lags – average across subjects

Electrodes chosen:

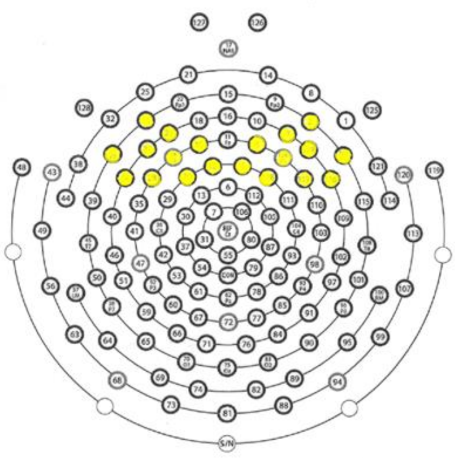


Figure 27: Frontal electrodes chosen for the analysis

ERP for Short, Medium and long time-lags

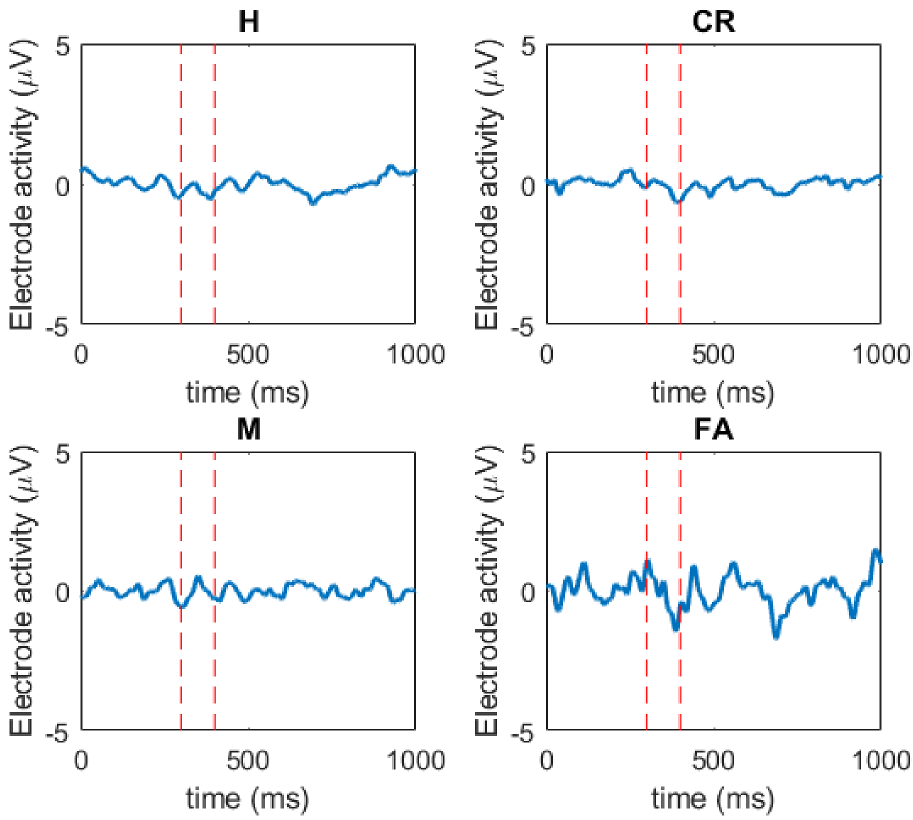


Figure 28: Electrode activities from the frontal region in the case of trials with short time-lags.

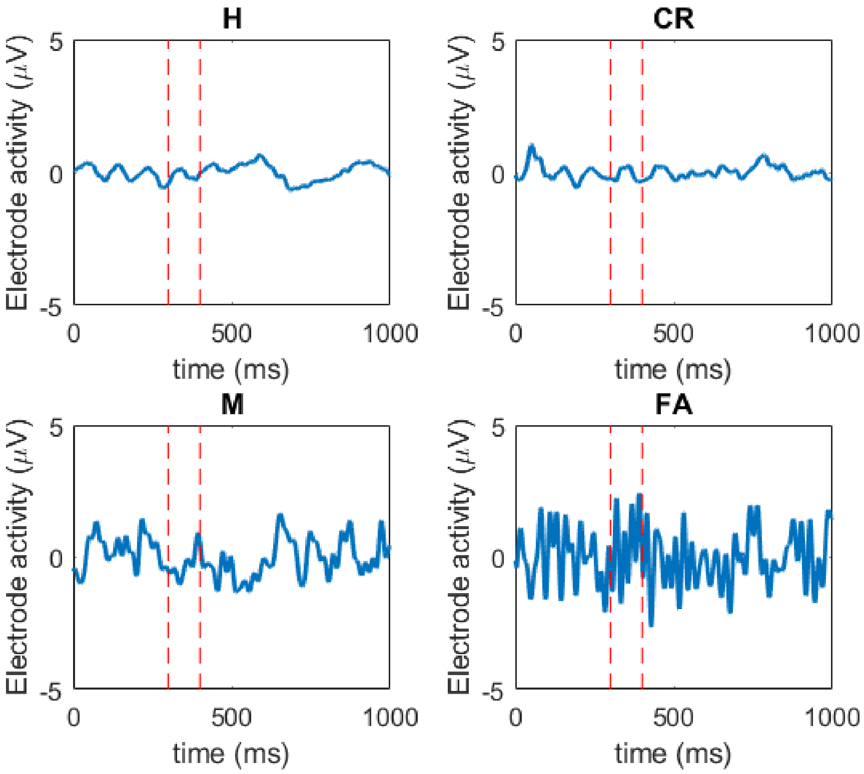


Figure 29: Electrode activities from the frontal region in the case of trials with medium time-lags.

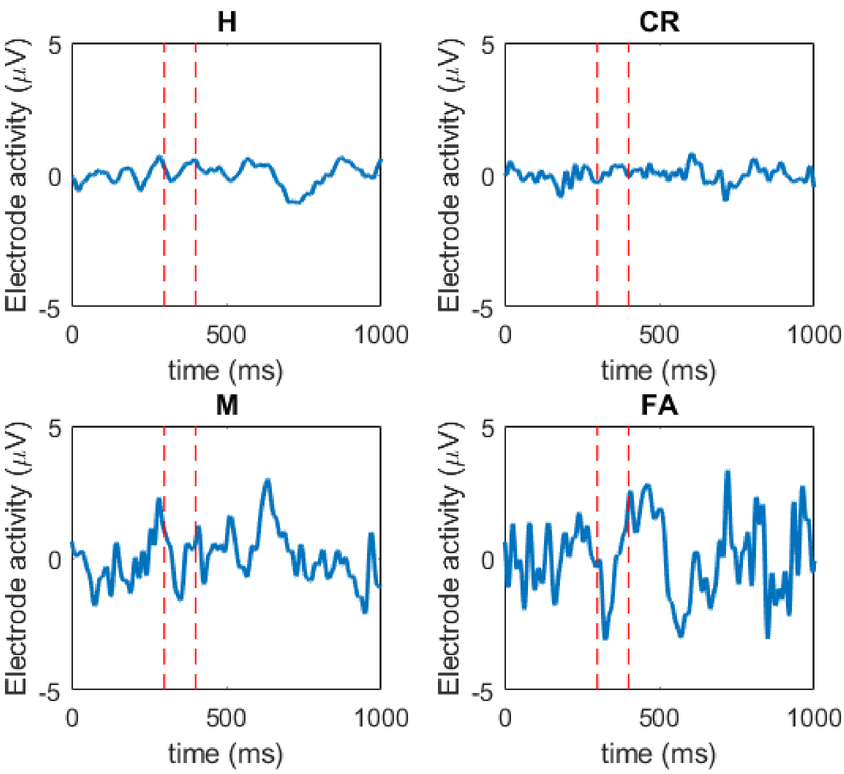


Figure 30: Electrode activities from the frontal region in the case of trials with long time-lags.

Discussion:

Occipital:

Considering the plots for hit trials, Figure 20 to Figure 22 indicate that there is an ERP associated with the target 2, with the positive peak with a latency of 45ms and negative peak at a latency of about 150ms after the target offset. It is an important that, the amplitude decreases as we move from long to short time-lags. This suggests that, when the two targets are far apart, the activity in the occipital region increases.

Such a peak is absent altogether in the case of correct rejection where the target 2 is not presented to the subjects.

In the case of plots for hit and and correct rejection for all time-lags, an oscillation occurring with 10 waves in the 1000 ms duration can be seen which the stimuli is flickering at a frequency of 10Hz.

The miss, mis-identification and false alarm plots are not relevant since those samples do not represent the actual population because of being smaller in number.

Parietal:

Considering the plots for hit trials, Figure 24 to

Figure **26** indicate that there is an ERP from the parietal region associated with the target 2, with the peak at a latency of about 150ms after the target offset. This is similar to what is seen in the case of occipital electrodes but with a lesser amplitude. The amplitude decreases as we move from long to short time-lags, similar to the case of occipital electrodes suggesting that, when the two targets are far apart, the activity in the parietal region increases.

As in the case of occipital electrodes, the peak seen in the hit trials is absent altogether in the correct rejection trails where the target 2 is not presented to the subjects.

Since the miss, mis-identification and false alarm are not of adequate number, those plots are not considered because of the same reason as mentioned before.

Frontal:

Considering the plots for hit trials Figure 28 to Figure 30 indicate that there is an ERP from the frontal region associated with the target 2, with the peak at a latency of about 350ms after the target offset. This amplitude is even lesser than that of the parietal electrodes. The amplitude decreases as we move from long to short time-lags, similar to the case of occipital and parietal electrodes suggesting that, when the two targets are far apart, the activity in the frontal region increases.

Like occipital and parietal electrode activities, in the correct rejection trails where the target 2 is not presented to the subjects, the peak seen in the hit trials is absent. The miss, mis-identification and false alarm are insufficient to make any conclusion because of the inadequate number of trials.

3.3.2 Topoplots

Topoplots showing all the electrode activities are plotted for the entire epoch for all kinds of responses separately, for short medium and long time-lags, using the pre-processed EEG data. The time points of the epoch at which a noticable activity is seen in case of hit trials is plotted below for hit and correct rejection. Because of inadequate number of responses, the plots for the other three responses is not comprehensible.

<u>Hit</u>

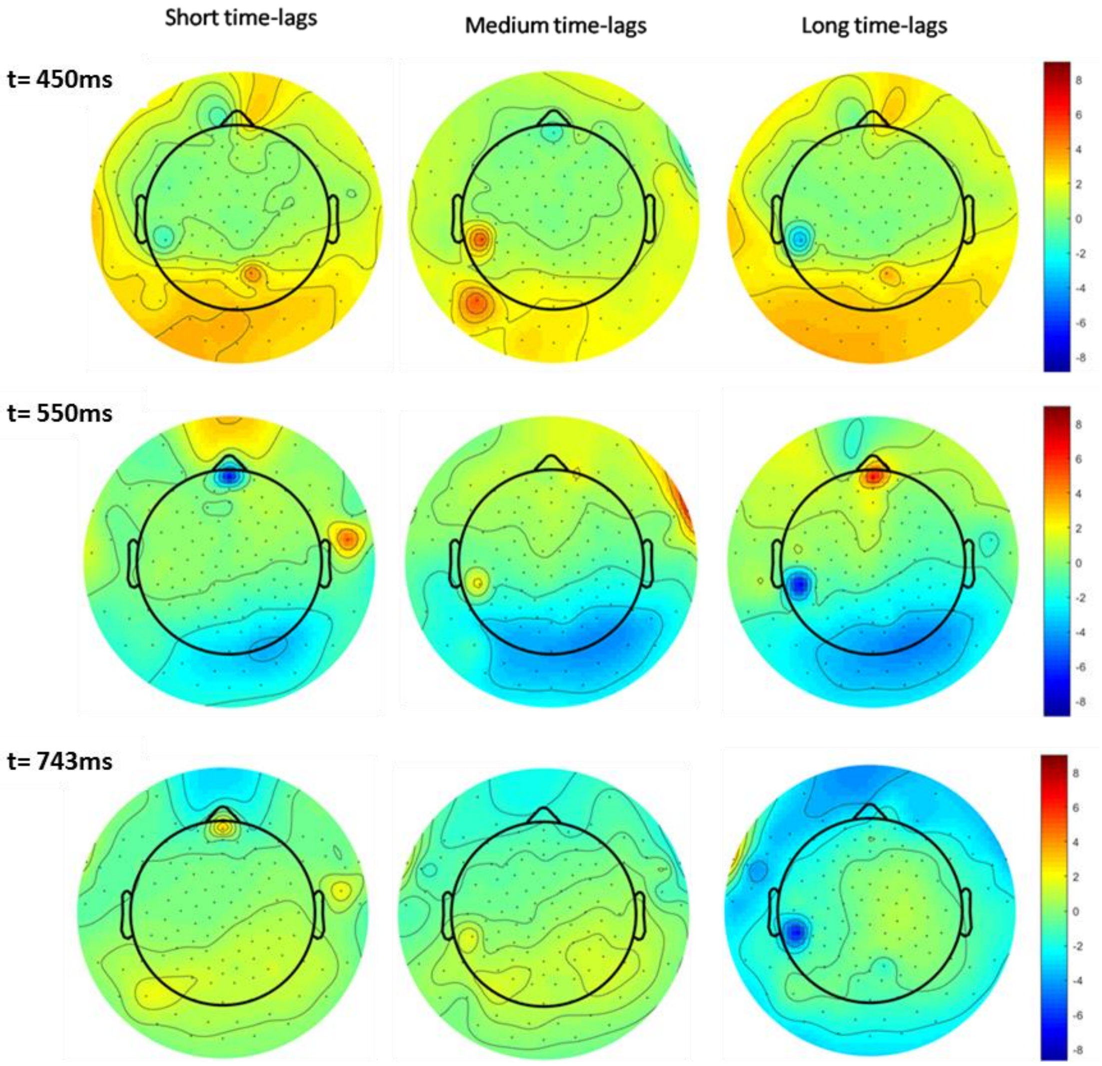


Figure 31: Topoplots for t=450ms (first row), t= 550ms (second row), t= 743ms (last row) where t= 0 is 300ms before the T2 onset for hit trials. First column has the plots for short time-lags, second, the medium time-lags and third, the long-time-lags.

Correct rejection

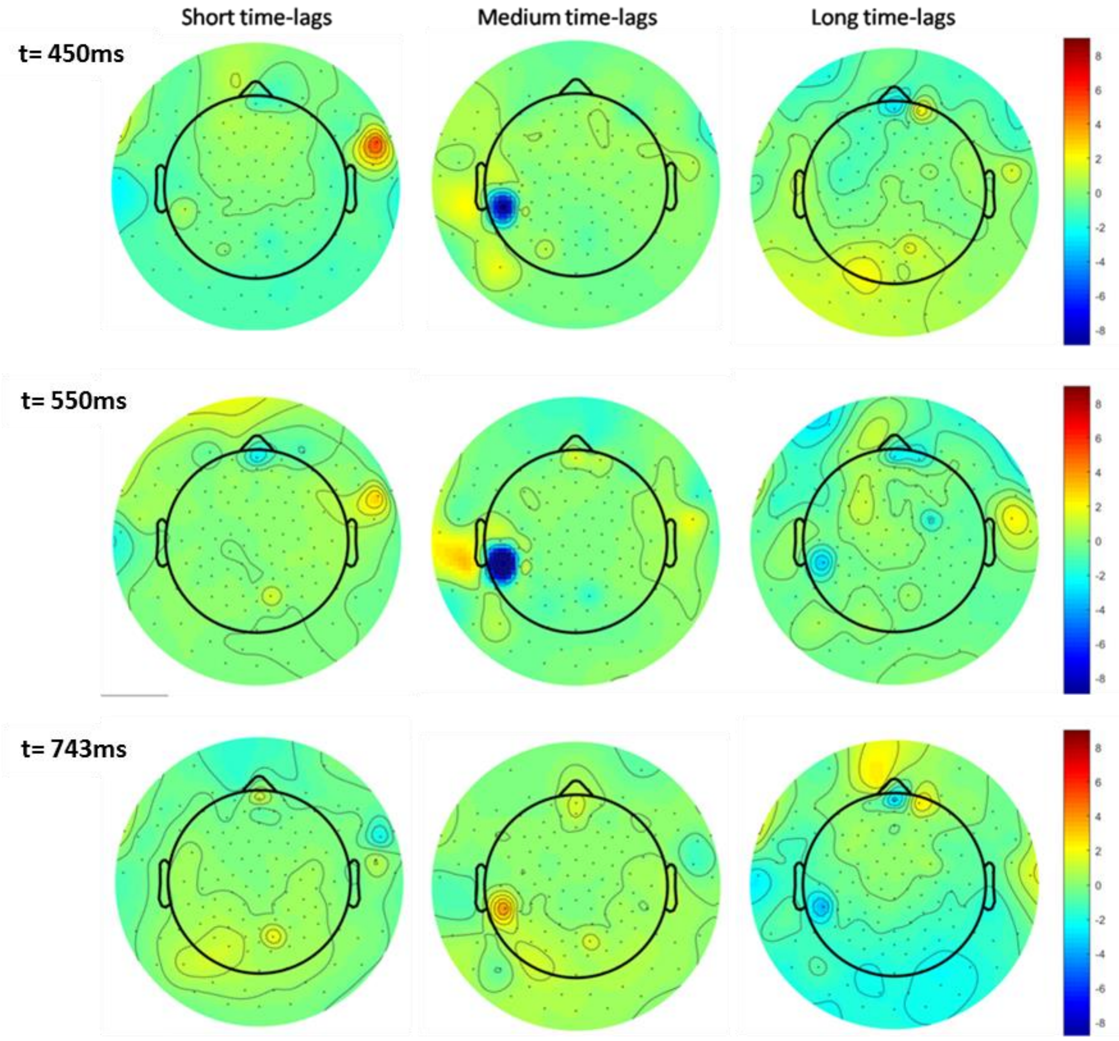


Figure 32: Topoplots for t=450ms (first row), t= 550ms (second row), t= 743ms (last row) where t= 0 is 300ms before the T2 onset for correct rejection trials. First column has the plots for short time-lags, second, the medium time-lags and third, the long-time lags.

The topoplots shows the electrode activity across the head. From the above plots, it can be comprehended that, T2 processing happens in the occipital region with a latency of 50ms after the T2 offset. It can be seen that the activity in the case of long time-lags is greater as compared to short time-lags at t=450ms. Although an intermediate activity is expected for medium time-lags, activity is seen to be the lowest.

At t =550ms, an activity in the occipital-parietal region is observed and it increases from short to long time-lags. The activity is lower in the short time-lag trials as compared to long at t=743ms in the frontal region. Traces of activity is seen in the occipital region as well which is decreases to 0 when time-lag is short.

This implicates that the activity recorded in the electrodes is lower, possibly because of lower brain activity, when the ITI is in the attentional blink region, in the occipital, parietal as well as the frontal regions, when subjects are asked to report orientation feature of two targets.

In the case of correct rejection, such an activity is absent at all the three time-points. This is possibly the absence of the processing of the orientation feature that is happening in the case of hit trials.

Chapter 4

Conclusion and future scope

A variety of studies happen in the decrease in the 'detection' ability during the 'attentional blink' period. But the neuronal mechanism of the second target being suppressed when two of them come in close in the temporal domain is yet to be found out.

Through this study, we aimed to find out the combination of targets and distractor, which have a simple orientation feature, for which 'Attentional blink' happens. It is an important observation made through the study that the ability of discriminating between the two orientations of the second of the two targets also gets impaired during the 'blink period'. Behavioral correlates of attentional deficit are obtained by fitting the data collected with the m-ADC model developed by Sridharan et. al. The psychometric analysis results show that the sensitivity (d') gets impaired as opposed to the bias (cc) during the 'blink period' which suggests that, the decline in the performance accuracy is associated with a deficit in attention

The ERP analysis and the assessment of topoplots clearly show that there is a decrease in the ERP amplitude for the hit responses when time-lag is shorter indicating that the processing in the brain becomes weaker during the 'blink period'. The data collected doesn't have enough number of trials with miss, false alarm and mis-identification which prevents us from obtaining the actual neural signals for such trials when averaged out. This can be overcome by having a task with a greater number of total trials so as to get more such types of trials.

An approach of taking the study further is to study the relation of the deficit in the detection and discrimination ability with the ERP amplitude by finding the correlation between the two. The EEG cohort doesn't have enough number of subjects to study the correlation between the d' deficit and the decrease in the ERP amplitude since not all of the subjects are good blinkers in the cohort. This could be circumvented by collecting more data from the blinkers.

EEG doesn't have enough spatial precision to locate the locations in the brain which are involved in this phenomenon. fMRI is a technique which helps in that but because of the less temporal precision, the technique can't be used in temporal search tasks. Thus, a way to go about it is to do a decoding analysis to find out the level at which the sensory evidence of the orientation information is lost in the brain.

Chapter 5

References

Brisson B1, Spalek TM, Di Lollo V. (2011). On the role of intervening distractors in the attentional blink.Atten Percept Psychophys. 73(1):42-52.

Cameron, E.L., Tai, J.C., Eckstein, M.P., and Carrasco, M. (2004). Signal detection theory applied to three visual search tasks -- Identification, yes/no detection and localization. Spat. Vis. 17, 295–325.

Carrasco, M. (2011). Visual attention: The past 25 years. Vis. Res. 51, 1484–1525.

Gold, J.I., Law, C.-T., Connolly, P., and Bennur, S. (2008). The relative influences of priors and sensory evidence on an oculomotor decision variable during perceptual learning. J. Neurophysiol. 100, 2653–2668.

Hermann J. Müller and John M. Findlay (1987). Sensitivity and criterion effects in the spatial cuing of visual attention. Perception & Psychophysics, Volume 42, Issue 4, pp 383–399

Kimron L. Shapiro, Karen M. Arnell and Jane E. Raymond (1997). The attentional blink. Trends in Cognitive Sciences - Vol. 1, No. 8.

Mulder, M.J., Wagenmakers, E., Ratcliff, R., Boekel, W., and Forstmann, B.U. (2012). Bias in the brain: A diffusion model analysis of prior probability and potential payoff. J. Neurosci. 32, 2335–2343.

Sander Martensa and Brad Wybleb (2010). The attentional blink: Past, present, and future of a blind spot inperceptual awareness, *NeurosciBiobehav Rev. 34(6): 947–957*

Steven J.Luck, Edward K. Vogel &Kimron L. Shapiro (1996). Word meanings can be accessed but not reported during the attentional blink. *Nature- Vol 383*

Sridharan, D., and Steinmetz, N. (2014). Distinguishing bias from sensitivity effects in multialternative detection tasks. *J. vis 14, 1–32.*