Visual feedback system for visually impaired using tACS

a proof of concept study

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Abstract:

Background:Visual system of brain computes the visual details to detect and interpret information in the visible light. This is a complex process that includes reception of light, binocular perception, estimation of distance and categorization of objects. An anomaly in any such process causes blindness or visual Impairment. Most of the blind-aid systems use audio feedback, but this could interfere with one's attention to other environmental auditory cues. Moreover, a non-invasively delivered visual feedback for visual stimuli would be more intuitive and appealing than an auditory feedback.

Hypothesis:tACS non-invasively provides very low electrical simulation (in micro amperes) to the posterior part of brain, which is perceived by the subject as 'flashes of light'. By altering electrical characteristics of the stimulation (such as current and frequency), we hoped a change in the perceived flash rate, which can then be used as the different levels of visual feedback.

Methods:As a proof to this concept, the current work tested a novel approach where different levels of visual feedback were provided using transcranial alternating current stimulation (tACS) to nine blind folded individuals(males=9; age = 20-35yrs) (mimicking visual impairment). In this study, we used three stimulation parameters for slow, medium and fast flash rates and presented them in random sequence and repetition.

Results:Though the current threshold differed between individuals, all participants correctly reported the change in flash rate corresponding to the stimulation frequency.

Conclusion:tACS stimulations that cause perception of flashes could be a viable approach for the development of a wearable visual-feedback blind-aid system.

***IndexTerms* - transcranial Alternating Current Stimulation (tACS), non-invasive visual feedback, blind-aid system**

I. INTRODUCTION

All Visual system of brain is involved in several complex computational processes that includes reception of light, binocular perception, estimation of distance and categorization of objects. An anomaly in any such process causes Blindness or Visually Impairment.

Researchers across the world are looking for an effective visual prosthesis, to improve the vision among the visually-impaired. All bionic eye systems are invasive; i.e. the subject must undergo surgery which is complex and expensive. Surgery can also lead to untoward complications. One solution to this problem will be to provide visual feedback to the visually-impaired individuals through non-invasive visual stimulation from a wearable device. Most of the proposed blind aid systems use audio feedback, but this could interfere with one's attention to other environmental auditory cues. A visual feedback for visual stimuli, would be more intuitive/appealing than an auditory feedback and could also improve usage of the visual system and reducing burden on auditory system. There are not many research and technology development towards enhancing the visual ability of the subjects by electrical stimulation of the visual system. Considering this concept, we plan to develop a novel system where visual feedback would be provided using transcranial alternating current stimulation (tACS) to blind folded or visually disabled individuals.

tACS is an electronic system which externally generates oscillatory electrical stimulation to non-invasively influence the brain oscillatory activity, at specific frequencies [1].It has been used in many applications, ranging from improvement ofmental illness (as in depression) to performance enhancement(as in sports).The parameters such as frequency, intensity influences the outcome of tACS stimulation.

tACS can be applied in wide range of frequencies, but the typical application is in the range of EEG signals(i.e., 0.1Hz to 80Hz). However, tACS over the posterior (visual) brain regions can cause an experience of 'flashes of light' (called phosphenes) when the stimulation frequency is between 8Hz to 20Hz and above a critical intensity. Though stimulation parameters that cause phosphenes are avoided during typical tACS protocols as they may interfere with the relaxation state or visual attention for a visually sound subject, these could be used as visual cues for a visually impaired or blind-folded individual.

To the best of our knowledge, no prior studies have specifically examined if the subjects experiencing phosphenes can consistently discern between the rate of 'perceived flashes' as the tACS frequency is changed, without having any stimulation associated discomfort. The current study aimed to address the above lacunae, and thereby demonstrating a proof of concept for the subsequent development of a closed-loop visual feedback device for visually impaired using tACS.

II. Materials and Methods

All participants were engineering students (n=9; males=9; age = 20-35yrs)blind to the aim of the study. All participants were explained about the procedure and signed informed consent forms, formulated by the institute ethical committee.

Electrode Placement

Conventional Ag/AgCl adhesive foam electrodes with embedded electrolyte gel(5cm^2 conductive area) were used for tACS.Fp1-A1 bipolar configuration was used for left side stimulation and Fp2-A2 for right side stimulation, with electrode placement following the international 10-20 system(Fig. 1). The aboveelectrode sites were chosen as a previous study from our lab had successfully used this configuration and we had also observed phosphenes.

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tACS Stimulation

tACS stimulation produces phosphenes dependingon the ambient illumination and frequency and intensity of the stimulating current. Based on literature review and experience from our prior study,we chose 3stimulation frequencies of (8Hz, 10Hz and 20Hz) for which the flicker rate of phosphenes could be easily made out, with current intensity ranging from 200 µA to 1200µA (in steps of 200µA), forevoking phosphenes in the current study.A portable tACS device with bluetooth interphase (axxStim-tES, Axxonet System Technologies, India) was used in this study. Eachstimulation was software programmedfor30s duration unilateral stimulation with a minimum inter-stimulation interval of 2 mins.

III. Procedure

Participants were blind-folded throughout the stimulations. Stimulations were first given on one side, with all combinations of stimulation frequency and intensity, and then given on the other side (order was counterbalanced across subjects). On each side, the stimulations were done in two stages.

During the first stage, the intensity at which phosphenes can be best perceived is determined separately for the three stimulation frequencies. For this, each participant was instructed to rate the intensity of phosphene perception after each stimulation; scale of '1'for the first perception of a flicker (lowest) to '15' (highest level of perception) and '0' for no perception.

During the second stage, stimulation intensity was fixed to a supra-threshold level and frequency was randomly and repeatedly varied along with some sham stimulations, to assess whether each subject could differentiate between slow (8Hz), medium (10Hz) and fast (30Hz) flicker rates consistently. Stimulations were also randomly swapped between left and right side to see if each subject experienced a side difference in line with the stimulations.All participants were instructed to report if they experience any irritation or discomfort during tACS, and in such case the test would be terminated.

IV. Results and Discussion

The All the participants could perceive phosphenes and were able to distinguish between different frequencies (8Hz, 10Hz and 20Hz). They also perceived left and right phosphenes in accordance with the site of stimulation.Subjective scales given by each subject of their phosphene perception across different stimulation intensities for slow (Left side – Fig 2; Right side – Fig 3), medium (Left side – Fig 4; Right side – Fig 5), and fast (Left side – Fig 6; Right side – Fig 7) flickering rates.

Transcranial Magnetic Simulation (TMS) and Transcranial Electrical Stimulation (tES) have proved to be two powerful noninvasive tools for establishing link between brain region and their functions. tACS, being one of the tES technique, has found several promising responses when applied to the brain's visual areas. One study[2] demonstrated that tACS when applied over the occipital region at specific frequencies and induce visual experiences called phosphenes. Participants perceived continuous 'flickering of light' most effectively for stimulations in the beta frequency (13-20Hz) in an illuminated room. This phenomenon shifted to alpha frequency (8-12Hz) stimulations when provided in darkness. Stimulations in the theta and gamma frequency range did not produce any visual perception. The work clearly demonstrated that low intensity tACS given at specific frequencies can non-invasively evoke a low-level visual perception as flashes of light.

As with many brain function, visual system also has the potential to undergo neural plasticity and recover some of its capabilities after a damage. A study [3] that applied tACS to the visual system of patients with optical nerve damage, demonstrated significant recovery of their visual function. In this double-blind, placebo controlled clinical trial around 12patientswith partial visual impairment were randomly selected for tACS, and visual outcome was measured with EEG before and after treatment. They found significant improvement of visual field detection deficit by as much as 69%. There also found significant improvement in temporal processing of visual stimuli, detection performance in static perimetry, and visual acuity.

The most prominent EEG changewasfound in the alpha frequency, with features suggestive of improved synchronisation in the visual regions. Though the mechanism of this improvement is not yet clear, this study shows that tACS can improve visual processing even after many years of optic nerve damage or neuropathy.

Another study[4] examined the source of generation of phosphenes. They found that phosphenes can be experienced when electrodes are placed away from visual cortex and closer to eye even at lower currents. They found that the frequency tuning of phosphenes is can be related to the properties of primate retinal ganglion cells. They also found no difference in time between phosphenes evoked in retina and that evoked above the visual cortex. The study concluded that phosphenes are primarily originating from retina. Even if this claim is true, the potential for using tACS to evoke phosphenes remains proved. Liebetanz and his colleagues [5] have determined the safety measures and estimation of safety threshold for DC transcranial stimulation for clinical and experimental application.

Thus, tACS hold promise to be used as a safe and non-invasive method to provide visual feedback in terms of flashes of light. The current study will check if this perception can have distinguishable differences depending on the frequency of the stimulation. If so, this would allow the use of tACS to give visual cue to a blind individual based on a sensor output, such as that from a camera.

Our results provide sufficient evidence towards the feasibility of using tACS to non-invasively provide visual cues to individuals without visual access, in terms of flicker rate and laterality of perceived phosphenes.

V. FUTURE WORK.

Providing visual feedback directly to the brain of visually impaired individuals through implantable stimulators has been a very complex and challenging task to researchers across the globe. Use of tACS to indirectly and non-invasively achieve the visual system, can simplify this task and reduce the development cost by many folds. We would next explore if our findings can be replicated in visually impaired individuals with varying degrees of vision damage. Subsequently, closed-loop wearable tACS devices could be developed that can help the visually impaired to pick an object or reach the destination using visual feedback based on multiple sensors or camera. Moreover, the weakened visual system of visually impaired individuals could undergo long-term changes over the usage of such tACS device and improve their vision.

FiguresandTables

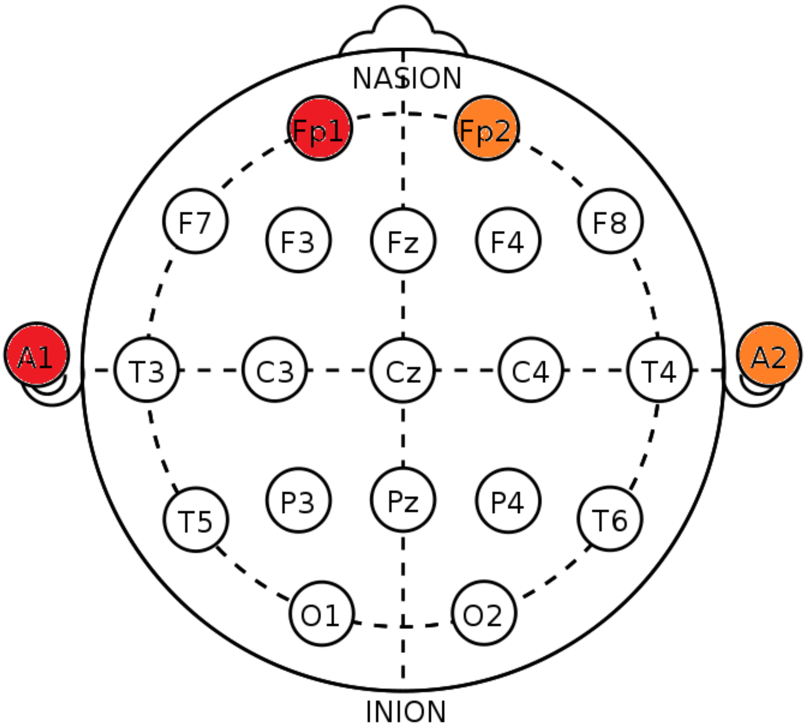

Fig. 1. Electrode placement for tACS stimulation. Fp1-A1 pair used for left side stimulation and Fp2-A2 pair used for right side stimulation.

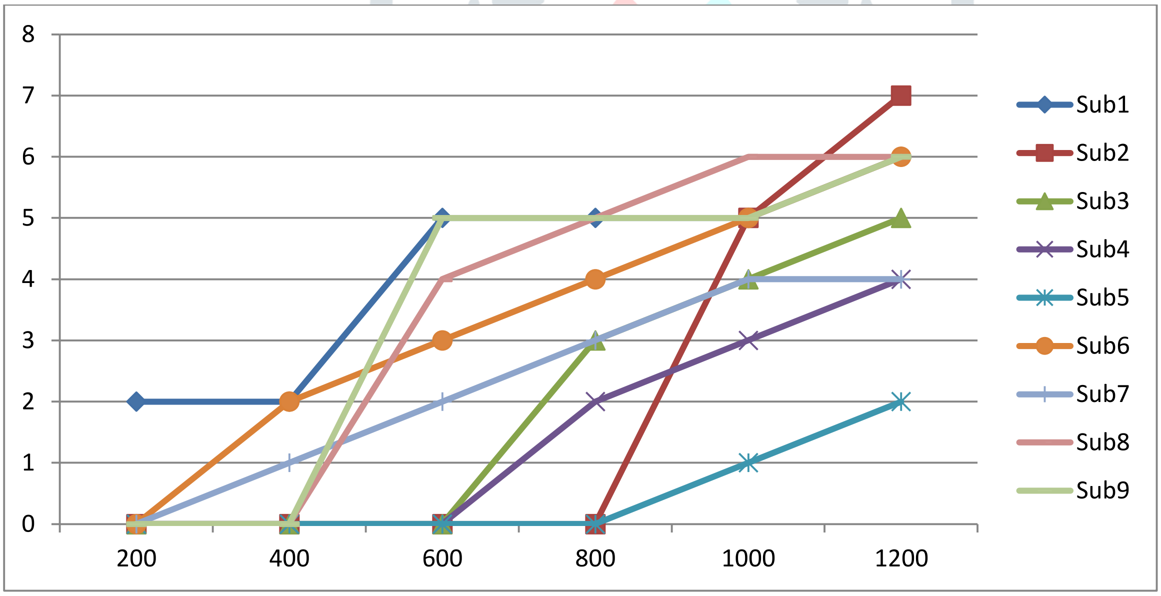

Fig 2. Subjective scale for left brain stimulation with frequency 8Hz for different current intensity

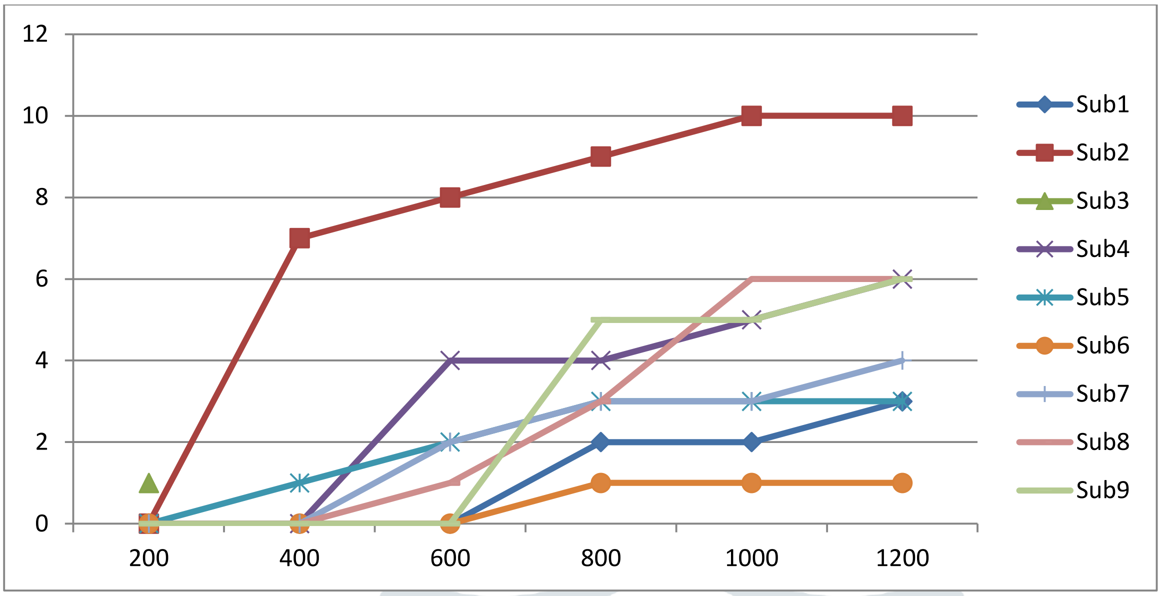

Fig 3. Subjective scale for right brain stimulation with frequency 8Hz for different current intensity

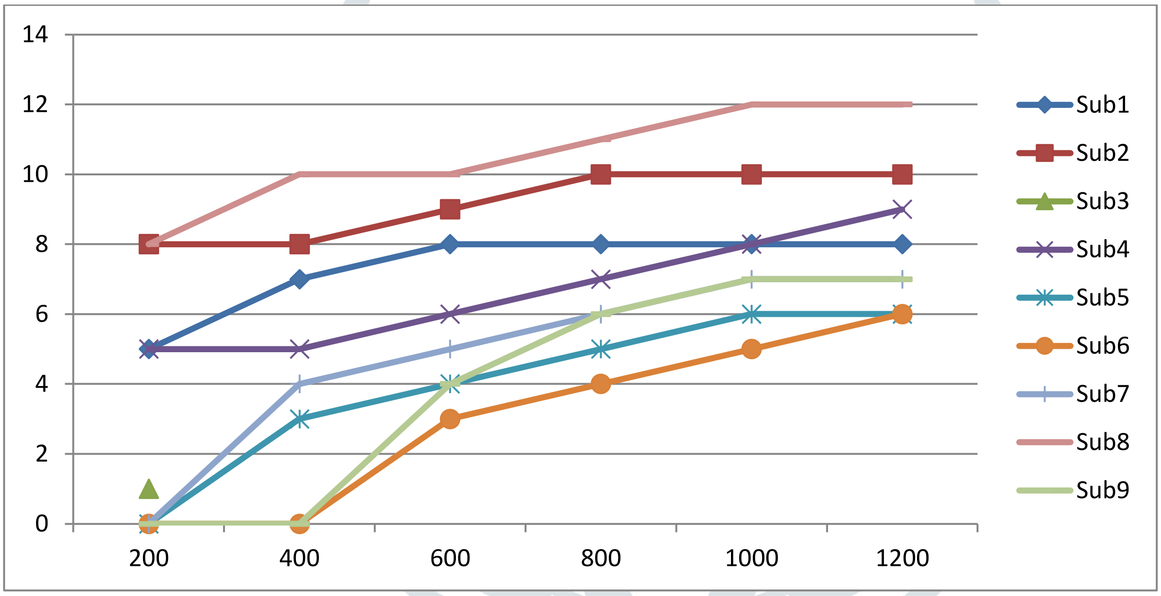

Fig 4. Subjective scale for left brain stimulation with frequency 10Hz for different current intensity

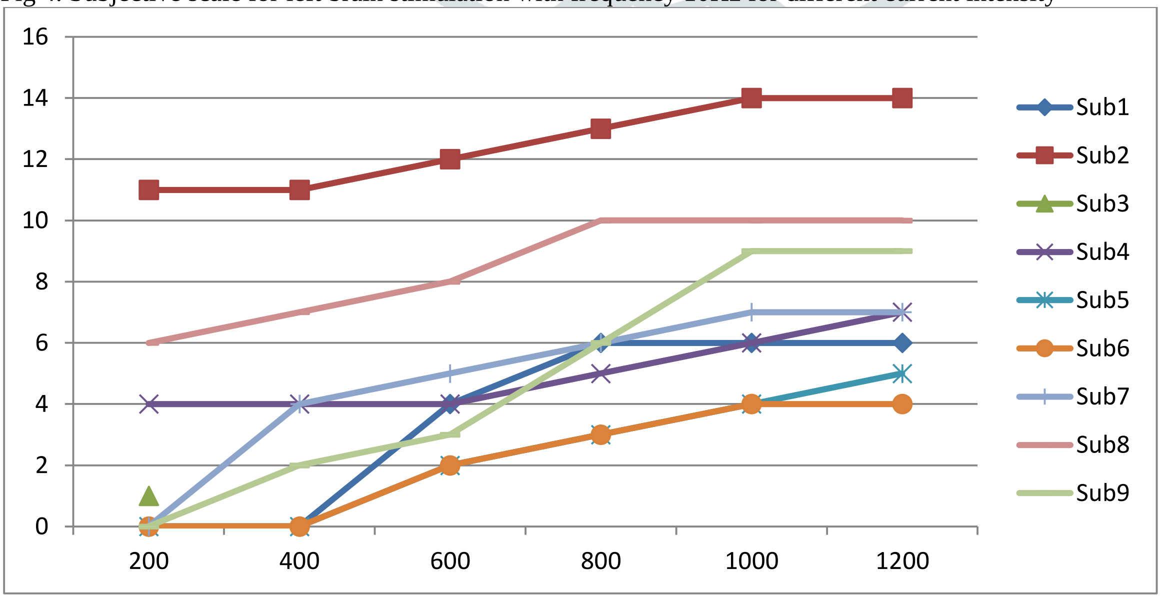

Fig 5. Subjective scale forright brain stimulation with frequency 10Hz for different current intensity

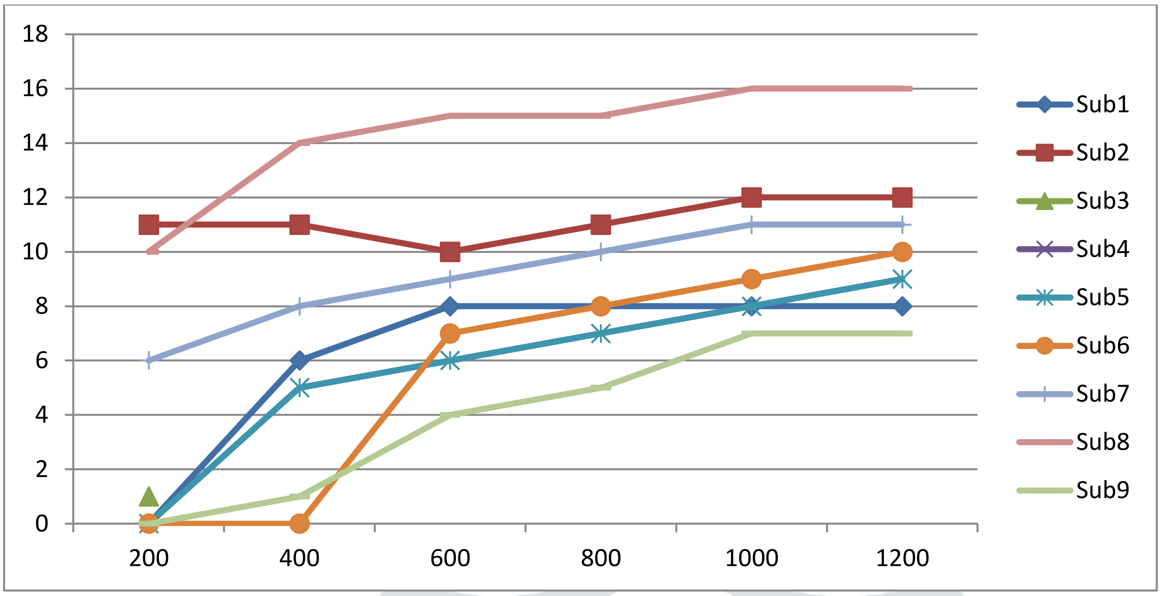

Fig 6. Subjective scale forleft brain stimulation with frequency 20Hz for different current intensity

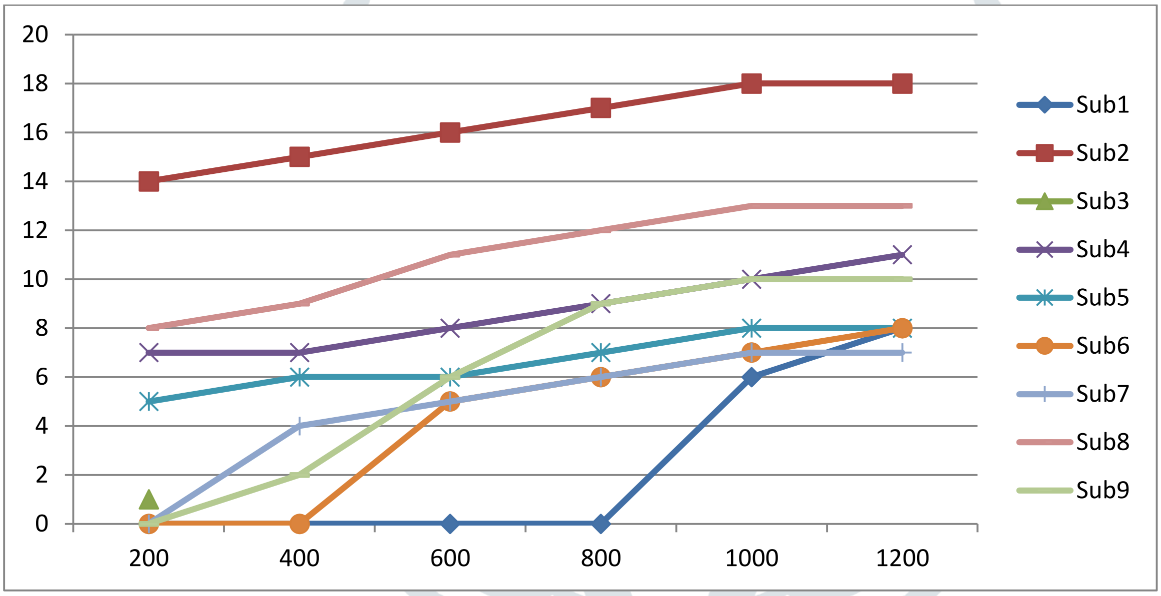

Fig 7. Subjective scale forright brain stimulation with frequency 20Hz for different current intensity

VI. ACKNOWLEDGEMENT

We acknowledge the support from BMS Engineering College and Axxonet Technologies Ltd Bengaluru.

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