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RESEARCH ARTICLE

SCREEN TASK EXPERIMENTS FOR EEG SIGNALS BASED ON SSVEP BRAIN COMPUTER INTERFACE.

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Abstract

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Development BCI system based stay state visual evoked potential (SSVEP), require establish the characteristics of the stimuli presented the user for optimal development of the extraction of signal characteristics; for it is necessary to determine the stimulation system and the evidence perform for detecting events. There are many types of stimulators that can be used to evoke the SSVEP: monitors include cathode ray tube (CRT) and liquid crystal display (LCD) or an array of light emitting diode (LED). This paper aims to show the different tests and methodologies that have been presented in different studies for generating visual stimuli in a short period of time.

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Introduction:-

Brain Computer Interfaces (BCI) are computer systems that translate the electrophysiological brain activity signals that can be measurable by an electro / electronic device. BCI aim to provide a channel of non-muscle communication for sending commands to the outside world using the electrical activity of the brain. Brain interfaces monitor the brain activity of the user and translate this signals into commands without activating any muscle or peripheral nerve [16].

Brain states are the result of different patterns of neural interaction. These patterns result in waves, which are characterized by different amplitudes and frequencies. The human brain electrical activity present due to two causes. The first is internal, that is, due to inadvertent operation and control of respiration, digestion etc. and will of the individual, to move your body, speak or think, etc. The second cause of brain activity is the occurrence of external stimuli, through a bodily sense.

BCI systems can be classified according to their implementation:

- **Invasive systems:** Are implanted directly into the brain and its main application is in the area of prosthesis to restore limb movement.
- **Non-invasive systems:** The signal acquisition is performed using electrodes placed on the scalp surface (Figure 1) [3].

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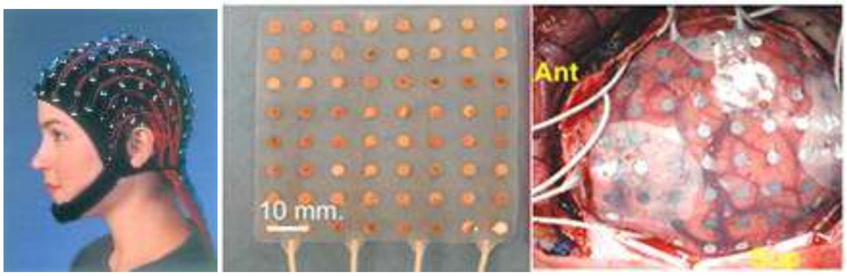

A. (b)

Figure 1:- (a) Invasive System, implemented electrodes directly into the brain. (b) Non-invasive system, EEG cap based on international 10-20 system.

The BCI systems can be classified according to the acquisition of signals:

- **Endogenous Systems:** based on brain rhythms, or systems depend on the user's ability to control their electrophysiological activity, such as EEG amplitude in a specific frequency band over a particular area of the cerebral cortex. We can classify the endogenous systems based on motor imagery (MI), sensorimotor rhythms or based on slow cortical potentials (SCP) BCI systems. Endogenous systems require a period of intensive training.

  A MI-based BCI is a paradigm of two or more classes of motor images (moving left or right hand, feet, tongue, etc.) or other brain tasks (rotation of a cube, performing arithmetic, etc.). MI-based BCI systems have variations for both the execution of a real movement to the imagination of a move or preparing to it.

  A BCI-based on SCP involves slow changes in voltage generated on the cerebral cortex, with a variable duration between 0.5 and 10 seconds. They are typically associated with movement and other functions involving cortical activation. It has shown that people can learn to control these potential.
- **Exogenous Systems:** These are based on event-related potentials (ERP) depend on the electrophysiological activity evoked by external stimuli and do not require intensive training phase systems. We can classify the BCI systems in potential exogenous events P300 systems based on visual events potentials (VEP), based on potential for steady-state visual events (SSVEP) or based on auditory events potentials (AEP) systems.

  BCI systems based on P300. They refer to a peak amplitude on the EEG approximately 300 ms after a rare auditory or visual stimulus occurred. VEP based BCI systems and SSVEP detected in the EEG recorded on the visual area of the cerebral cortex after the user a visual stimulus has been applied. Based AEP BCI systems are detected in the EEG recorded on the auditory area of the cerebral cortex presenting the user with sound sources at different frequencies, the user to focus on any of them, generates a potential of the same frequency as the stimulus [3],[5].

- **Steady State Visually Evoked Potentials (SSVEP):-**

The retina of human eye contains rod and cone cells. The rod cells detect the amount of light and cone cells distinguish the color. There are three kinds of cone cells and are conventionally labeled as Short (S), Medium (M), and Long (L) cones according to the wavelengths of the peaks of their spectral sensitivities (Figure 2). S, M and L cone cells are therefore sensitive to blue (short-wavelength), green (medium-wavelength) and red (long-wavelength) light respectively. The brain combines the information from each cone cells to give different perceptions to different colors; as a result, the SSVEP strength elicited with different colors of the stimuli will be different [14].

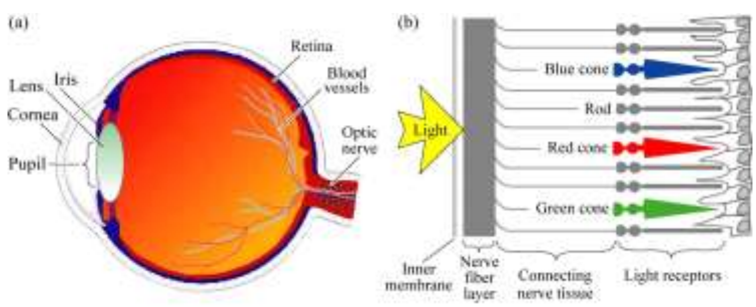

Figure 2:- (a) Cross section through a human eye. (b) Schematic view of the retina including rod and cone light receptors (adapted from Encyclopedia Britannica), 1994-Shubert, 2006.

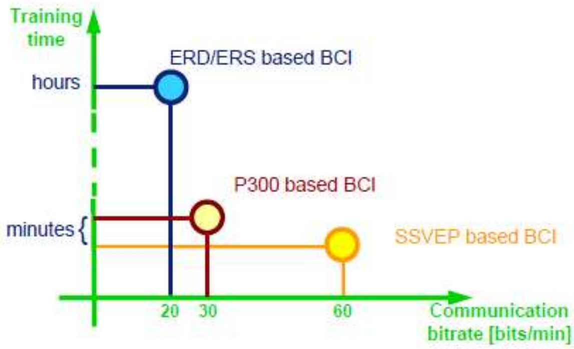

Figure 3:- Training time versus communication bitrate for the three main types of noninvasive BCIs [8].

In SSVEP based BCIs, visual stimulus modulated at different frequencies are simultaneously presented to the user. Each pattern is associated with an action in an output device. When the user focuses attention on a certain pattern, the corresponding stimulating frequency, or its harmonics, dominantly appears in the spectral representation of the EEG signals recorded at occipital sites. The action associated to the dominant frequency is performed [8].

The amplitude of the SSVEP is not the same for different stimulation frequencies or different subjects. In fact, the largest SSVEP amplitude occurs, in average, at a stimulation frequency of about 15 Hz, Figure 4 [8].

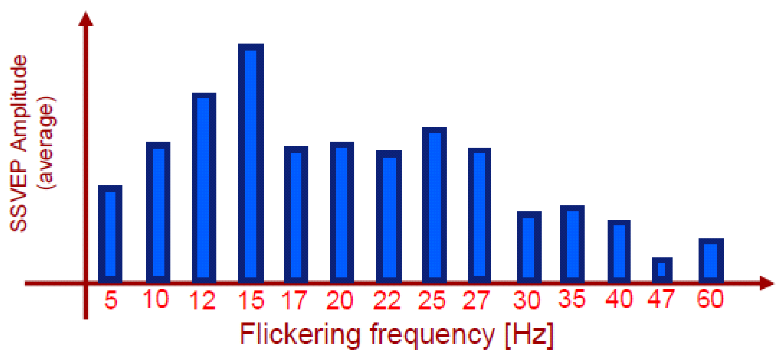

Figure 4:- Average SSVEP amplitude in function of the stimulation frequency [8].

SSVEP-based BCI experiments need to reproduce a flickering stimulus at a constant frequency. We use the computer screen as the flickering device. Thus, a flickering object (or “target”) is represented by a shape which changes color at a constant frequency or/and object to appear suddenly. In order for the SSVEP to work, this change of color/object must occur at precise intervals. It is thus necessary to redraw the targets in a synchronized way with the screen. This means, that the frequencies, which can be achieved, depend on the refresh rate of the screen. In practice, only frequencies that are entire divisions of the screen’s base refresh rate will be possible to achieve [13].

On a screen with refresh rate of 60 Hz, displaying of frequencies of 30, 20, 15, 12, 10 Hz and lower will be possible. On a 50 Hz screen, you will be able to use 25, 16.66, 12.5, 10 and lower frequencies as shown on Figure 5.

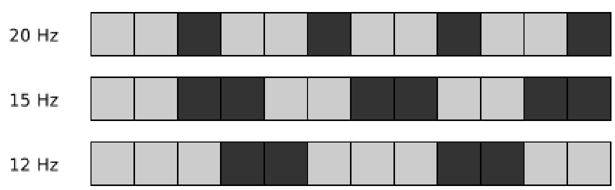

Figure 5:- Stimulation frequencies on a 60 Hz screen [13].

- **SSVEP Task Experiments**
  - **Repetitive Visual Stimulus (RVS)**

In SSVEP research, three main categories of repetitive visual stimuli exist:

- **Light stimuli**.- are rendered using light sources such as LEDs, fluorescent lights and Xe-lights, which are modulated at a specified frequency. These devices are generally driven by dedicated electronic circuitry, which enables them to accurately render any illumination sequence or waveform (Figure 6). The intensity (time integrated luminance) of the light stimulus is measured in candelas per square meter on the second (cd/sm^2 or nits/s) because the light luminance changes over time. An important parameter to quantify the stimulus strength is the *modulation depth* which is defined as *lmax−lmin/lmax+ lmin*, where lmin, lmax are the minimum and maximum luminance, respectively [20].

Figure 6:- Led Light dives for visual stimuli

- **Single graphics stimuli.-** Some geometric figures (e.g., rectangle, square, or arrow) are rendered on a computer screen and appear from and disappear into the background at a specified rate (Figure 7). The stimulation rate is reported as the number of full cycles per second, normally simply referred to as the frequency of the stimulus [20].

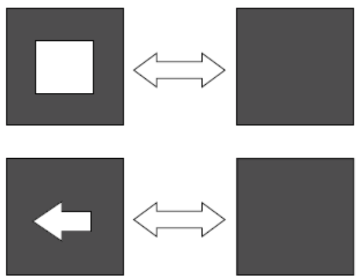

Figure 7:- Single graphic stimuli, the graphical object alternately appears and disappears in the background [20].

- **Pattern reversal stimuli.-** Are rendered on a computer screen by oscillatory alternation of graphical patterns, for example, checkerboards. They consist of at least two patterns that are alternated at a specified number of alternations per second. Frequently used patterns include checkerboards and line boxes (Figure 8). Patterns are usually colored in black and white. A checkerboard stimulus is characterized by the subtended visual angle of each tile (spatial frequency), the number of reversals per second, the mean luminance, the field size, and the pattern contrast. It is worth noting that single graphic stimuli could be viewed as a special case of pattern reversal stimuli where the graphic is the first pattern and the second pattern is the background. An important difference is that single graphic stimuli elicit an SSVEP response at the frequency of one full cycle (e.g., two alternations), whereas real pattern reversal stimuli elicit an SSVEP response at the frequency of one alternation. All repetitive visual stimuli have various properties such as frequency, color, and contrast. Both the type and properties of stimuli affect the elicited SSVEP response [20].

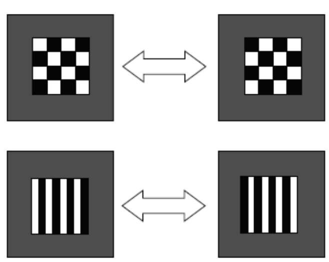

Figure 8:- Pattern reversal stimuli, at least two patterns are alternated at a specified frequency [20].

Light and Dark:-

In this test, the targets are flickering by switching between two colors. The name “Light and Dark” were selected arbitrarily and the tester can choose any colors you. Blinking objects are achieved by switching between two colors (Rennes et al 2015 and Nakanishi et al 2014). In order to achieve better SSVEP response try to choose contrasting colors (such as red and black). The basic scenario uses three stimulation frequencies, however will be able to use more frequencies.

Processing EEG signal is set small cycles over a period of time to later extract the amplitudes of brain waves in each of the frequency bands stimulated.

The training scenario will present a window that displays (default) three places called *training objectives*. An additional box is added to represent an object without stimulation, which will not blink at any time of the experiment, this is shown on Figure 9.

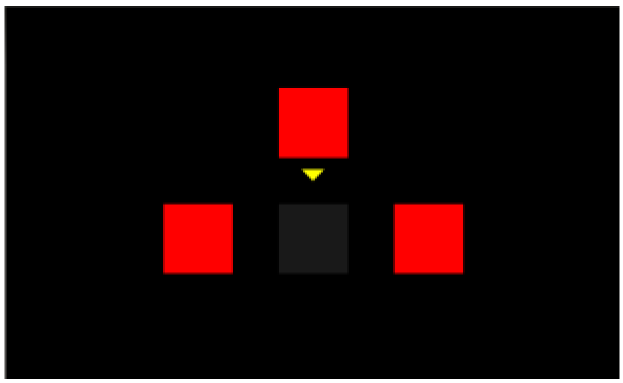

Figure 9:- The initial training scenario for Light and Dark test [13].

During the training, periods of stimulation (when the targets will flicker, each at its predefined frequency) will repeat with break periods (no flickering) in between. Before each stimulation period, a yellow arrow will mark one of the squares. The subject must then focus his visual attention at the marked square for the whole stimulation period. Each square will be marked several times during the whole experiment. At the end of the procedure, a file containing an annotated EEG signal will be produced. The duration of the stimulation period is 7.0 s, the break duration of the break period is 4.0 s each period, the flickering delay (time between the appearance of the arrow marking the square to stimulate and the beginning of the flickering) is 1.0 s.

The size of the target is given as a proportion to the viewport’s size. Thus a size of 0.5; 0.1 will mean that the target will be a rectangle with a width equal to a half of the viewport’s width and height equal to 1/10 of the viewport’s height. The viewport (the area used for display), is the largest square which fits the window, this means that a target with same width and height ratio will always be a square (default value 03, 0.3). Positions of the middle of the targets are N+1 targets, considering N as the number of frequencies. The first one is the blank target mentioned before [13].

Square Flickered:-

In 2012 Zhang et al, propose “Square Flickered Experiment” for the extraction of more discriminative features of SSVEP used of the sparsity constraint of the least absolute shrinkage and selection operator (LASSO). In 2014 used a similar experiments “Command icon Flickered” to determine the optimal time Window Length (TWL) in order to estimate the dominant frequency components in EEG signals on SSVEP-BCI.

During both experiments, the subjects were seated in a comfortable chair 50 cm from a standard 17-inch CRT monitor (85 Hz refresh rate, 1024 × 768 screen resolution). In the first experiment, command icons as stimuli were used as shown on Figure 9. The first row in Figure 8 shows four command icons (‘Volume ON’, ‘Volume +’, ‘Volume−’, ‘Volume OFF’). The frequencies of the four flickering squares in the second row were 6.1, 7.1, 8.5 and 10.6 Hz corresponding to the four commands, respectively. These four commands could be used to adjust the volume of a device [18]. The second experiment, use red squares, which are presented on the screen (Figure 10), the stimuli and flickered at 6, 7, 8.5 and 10.6 Hz, respectively. Each subject performed six runs and each run contained four trials. In each trial, a target cue first appeared for 1 s. The subject was then indicated to focus attention on the cued stimulus for 4 s [19].

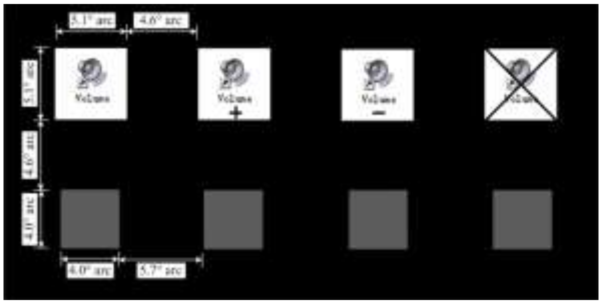

Figure 10:- Experimental images and layout. The colors of the four flickering squares in the second row are red in the experiment [18].

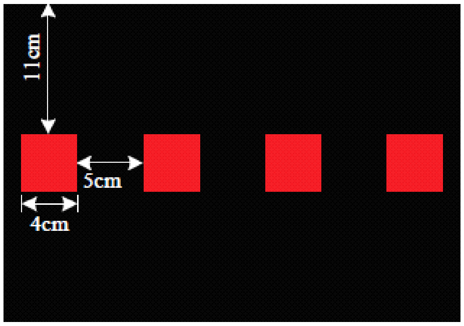

Figure 11:- Square flickered experimental layout [19].

Four Square:-

This RVS experiments can be presented on a set of Light Emitting Diodes (LEDs) or on a Liquid Crystal Display (LCD) monitor. In this case, LCD monitor was used due to the flexibility in changing the color of flickering bars. Four colors: green, red, blue and violet were included in the experiment; background color is selected as black. Four frequencies 7, 9, 11 and 13 Hz, in the low frequency range were selected, as the refreshing rate of LCD monitor is 60 Hz rate and the high amplitude SSVEPs are obtained at lower frequencies. The visual stimuli were squares of (4 cm × 4 cm) in shape and were placed on four corners of the LCD screen Figure 12). Firstly, the SSVEP data is collected. The SSVEP data for all the four frequencies with green color and the experiment is repeated for both red and violet colors in separate sessions. The interval between sessions was 10 minutes. Initially the subjects were required to close their eyes for 2 minutes to record the baseline signal and then given 5 minutes to adapt to the flickering stimulus placed in front of them.

During these experiments, the subjects were directed to focus on a particular frequency for 5 s duration followed by 5 s rest period. The subjects were instructed to avoid eye movements or blinking during focusing period. The event markers were used to indicate the starting and ending time of each frequency. In a single trial, all the four frequencies were performed three times and the same procedure was repeated for another three trials, keeping a five minutes break between each trial. The time for completing one session for each subject was about 30 minutes [14].

Figure 12:- Four Square repetitive visual stimulus configuration [14].

Visual Search Within Natural Images

In this test, the is asked to look to a series of natural images in black and white of 800 × 600 pixels, which are presented in the center of the screen of 1366 × 768 pixels. At one moment, a stimulus appears at a random location of a screen, whilst the subject is still looking at the black and white image. The stimulus is a yellow circle with a percentage of the screen of 4%.

The stimulus appears between 8 and 16 seconds after the start of the image on a random location within the image, the subject must not take any action to the stimulus appear only locate your position on the screen at him. A dark screen with a duration of 3000 ms replaces 1000 ms after the image and the test is repeated five times [7], Figure 13.

(a) (b) (c)

Figure 13:- (a) Initial screen. (b) Wait screen. (c) Random stimulus position over wait screen.

Visual Discrimination Five Box Task:-

In this test, the aim is to obtain data related to stimuli in the brain signals during an exercise in simple attention. Visual Discrimination using the Five Box Test consists of finding the difference between stimuli related to the care and unrelated to care. Unlike the visual test, the subject must discriminate between different types of stimuli that are presented at high speed.

The stimuli that occur inside this box are attended stimuli. Stimuli within the blue boxes are known as unattended stimuli. All tests contain 100 stimuli in total; 80 attended and 20 not attended. The stimuli are presented to the subject in a random position to 250 ms, 500 ms, 750 ms, 1 s. Spurs last 200 ms on the screen before disappearing.

- **Discrimination Simple Description:** Spurs are red circles within 5 boxes. 120 (25%) attended 480 events (75%) events unattended.
- **Variant Discrimination Composed:** Spurs are filled boxes of its original color. 120 (25%) attended 480 events (75%) events unattended
- **Discrimination Combined Variant:** Test considers both previous tests. Half of the stimuli are simple variant and the other half consists variant. Attended stimuli are just the red circles. 35 (25%) attended 105 events (75%) events unattended.

In the test, users set their sights on a cross, above which five boxes which are exhibited constantly (Figure 14). Each test block is 76 s, one of the boxes was a different color (green). The location of this was randomly shown during test periods. A series of circles are briefly presented in any of the five boxes in a random order. It is asked the user to concentrate whenever a disc appear on one of the pictures were recorded from subjects who attended the random sequences of full disks appear briefly within one of the five empty seats that were shown (Townsend Courchesne and 1994). The 1.6 cm square contours are shown on a black background in horizontal viewing angles of 0 ° ± 2.7º and 5.5º ± fixing. For each block of 76 s trial, one of the five generally was green and four blue. Green Square marked the location to be attended. This location was varied in order to counterbalance randomly across blocks. In each block, 100 stimuli (full red disks) with a duration of 117 ms is shown for one of the five empty seats in a pseudo-random sequence with inter-stimulus intervals of 250 to 1000 ms (in four steps of 250 ms equiprobables) [10].

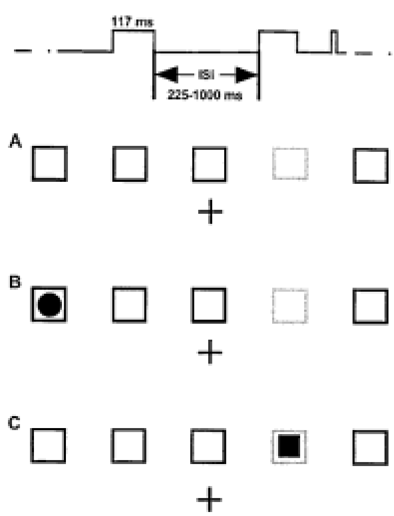

Figure 14:- Five box configuration task. *A* initial state, *B* stimulus, *C* not stimulus [10].

Classification Task:-

The experimental protocol has been divided in two phases: training and testing. The training phase has the purpose of establishing the parameters of the typical SSVEP activity of every subject (maximal amplitude) in order to fix the threshold for the classification part. The subject sits at 70 cm distance from the screen and the electrodes (Oz, O2, PO8) are used. In this first phase, during which the feedback signal is not given to the subject, the subject has to focus his/her attention for 20 s on the left flashing symbol, after 2 s at the center of the screen and finally for 20 s at the left flashing symbol. To check the exact moment in which the subject changes direction, the subject has to press one of the three buttons according to which flashing light the subject is looking at.

In the second phase, the subject has been told to focus his/her attention on the flashing arrows, following the sequence of the directions to look at on top screen (D for Right, S for Left as it can see on the Figure 15). The current letter (corresponding to a direction) will change colour if the subject manages to keep the amplitude (according to the magnitude bar) of the brain wave corresponding to the frequency of the stimulus he is looking at, for at least 2 seconds. For each trial, the correct selections, the errors, the null events (defined as the event when both the amplitude bars reach the top for two seconds) and the time to complete the trial are measured. After each trial, the subject's amplitude thresholds are recalculated adaptively in order to track the changes on the individual behaviour. This simple game is an easy trick to keep the subject always engaged [4].

Figure 15:- Checkboard layout configuration [4].

Newton's Rings:-

The visual stimulation of non-direction-specific motion reversals was introduced in the design of the spatial selective attention based steady-state BCI system. Here the "steady-state" brain responses were evoked by *mirror movements*, which oscillated in two opposite directions (Xie 2012, Ding 2006). Newton's ring, which is an optical interference pattern widely existing in the natural world, was adopted as the template for motion reversal stimulation. It appears as a series of concentric and alternate bright and dark rings, where the outer rings are spaced more closely than inner ones. The phase of the Newton's ring was temporally sinusoidal shifted so as to produce the motion reversal procedure, which included the inward contraction and outward expansion motions alternately. Here the contraction of Newton's ring was implemented by its phase shift from 0 to , and then expansion motion was achieved with phase shift from back to 0. The position of the rings was not exactly repeated before and after a reversal and one displacement was inserted to maintain consistency of motion. Newton's ring based stimulator and its motion reversal procedure in one stimulus period showed in Figure 16.

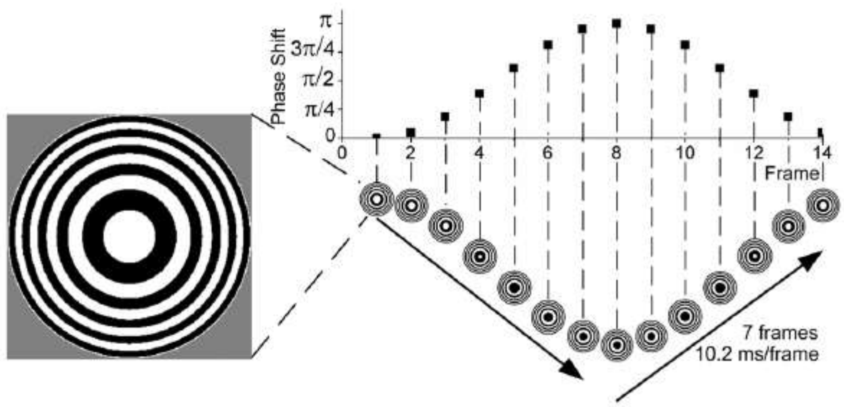

Figure 16:- (a) Newton's ring based stimulator. (b) The motion reversal procedure of the rings. It was illustrated with a 14 Hz motion reversal frequency and each reversal contained 7 frames. The phase of the Newton's ring was modulated by a sinusoid of 7 Hz in [0,] to produce motion reversals [17].

A typical stimulation protocol used four visual stimulators and displayed them on a CRT monitor and the viewing distance was 70 cm. Each stimulator subtended a circular field of 4.8 degrees diameter and was composed of five symmetrical black and white rings. The stimulus luminance was 118 cd/m^2 for the white rings, and 0.7 cd/m^2 for the black ones. The squared values of the relative radius of all rings constituted an arithmetic progression and then each ring shared the same size except the most inner circle. When the stimulator moved, its mean luminance kept almost the same throughout the entire stimulus period but litter jitter would appear due to the area change of the inner circle. In the whole experiment, spatially homogeneous grey background with a luminance of 38 cd/m^2 was displayed in pauses and around the stimulators. The four stimulators were uniformly spaced in left, right, up and down directions to the center of the monitor. The distance from the center of each stimulator to the center of the monitor was 7.2 degrees of visual angle (see Figure 17). Four distinct motion reversal frequencies of 8.1, 9.8, 12.25 and 14 Hz, which were compatible to the measured refresh rate of 98 Hz, were presented as the fundamental frequencies of the four stimulators (left, right, up and down). Each frequency was obtained from dividing the refresh rate by the frame values in half cycle period (i.e. 12, 10, 8 and 7 frames), respectively, Figure 17 [17].

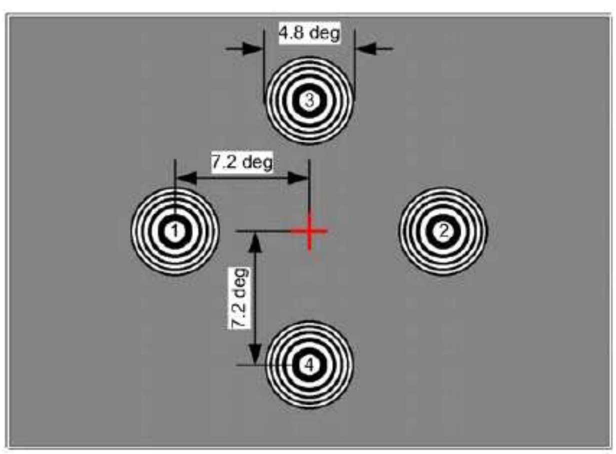

Figure 17:- Schematic diagram. Distribution of four stimulators on the computer screen. The cross indicating the center of the monitor was not presented on the screen [17].

For each subject, four experimental tasks were carried out where the aim of Task 1 to Task 4 was to focus attention on the visual stimulator of 8.1, 9.8, 12.25 and 14 Hz, respectively. Each task contained two runs and each run had twenty trials inside. Subjects were instructed to fixate on a specific stimulator throughout the task and Task 1, 2, 3 and 4 were performed one by one in random order (Figure 18). In the experiment of each run, 2 s of grey screen was first displayed, and then the four stimulators were simultaneously presented 4 s as a single trial. Two adjacent trials were isolated by grey screen and the interval time was fixed to 1 s.

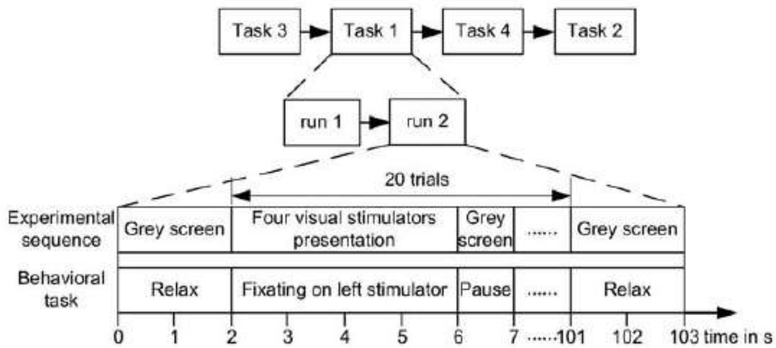

Figure 18:- The timing of the experimental sequence and behavioral task [17].

Video Stimuli:-

In the experiment participants had to watch a series of 51 videos, divided into three runs (20 + 15 + 16). Between each run, there was a break of about 10 min, to give the participants the chance to relax and stretch. Each video had a length of 114 s, followed by a pause of 5 s. Each video began with a fixation cross that was displayed for 3 s at the center. In order to minimize artifacts, participants were instructed to not move their eyes during the presentation of the video and to blink as little as possible [1].

Six gray-level texture images were chosen as the basis for stimulus generation (Figure 19). The size was 512 × 512 pixels and they all had the same average luminance. In order to make the measurement independent of the image statistics and of the actual gaze position during the experiment, the texture images were spatially roughlystationary. The quality of each texture image was then degraded in six different levels. The distortions were introduced by coding the textures using the HM10.0 test model of the emerging high efficiency video coding (H.265/MPEG-HEVC) standard (Sullivan et al 2012). In this standard, statistical redundancies are exploited by block-wise temporal and spatial linear prediction.

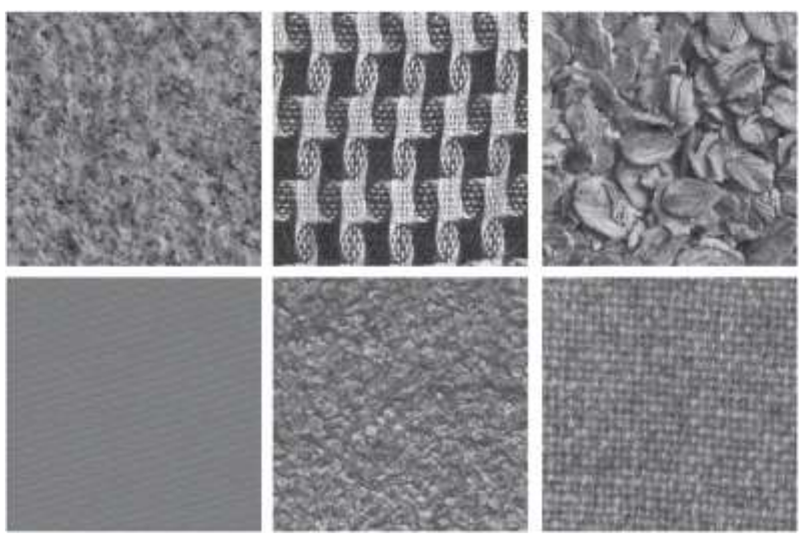

Figure 19:- Stimuli. The textures in the upper row represent stone, scarf and oatmeal, in the lower row gray rubber, gray flakes and blanket, all in their undistorted form. They have been degraded in six levels of quality coded with the HM10.0 test model HEVC standard and grouped together to form videos with a frame rate of 3 Hz [1].

The residual signal is transformed block-wise, and coefficients are quantized in the transform domain. The quantization is controlled by the quantization parameter (QP). Coding artifacts, which are perceived by the human observer as a loss of visual quality, are introduced by the quantization of the transform coefficients. In order to investigate how the visual cortex responds to distortions at the threshold of perception, the first three distortion levels are chosen to be perceived as high quality. The QP-values used in the experiment were estimated in a pilot study in order to meet consistent mean opinion scores (MOS). All the texture images in all the different levels of degradation were displayed as videos, 114 s long. Figure 20 depicts the structure of one video (trial); each trial comprises all six textures and degrees of quality, presented in random order.

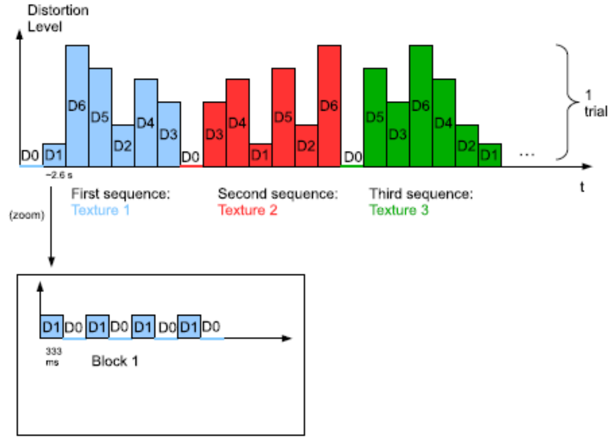

Figure 20:- Video structure (trial). Each trial comprised the six textures presented in all the levels of distortion (D1 ... D6) in a random order. Each texture was displayed distorted for 333 ms, followed by the undistorted form for 333 ms (D0) and the same succession was repeated four times for each level [1].

The stimulus onset asynchrony (SOA) was 333 ms, that is, each texture image was displayed for 333 ms. At the beginning, the texture was presented in its undistorted form (D0) for 2664 ms (333 ms × 8). Then, the first quality change occurred and the distorted texture was displayed for 333 ms, followed by 333 ms of the same texture in its undistorted version. This cycle “distorted-undistorted” was repeated four times for a total of 2664 ms. Then, the same texture was displayed with another level of quality change for a cycle “distorted-undistorted” of the same length.

This procedure was performed until all the distortion levels were displayed for that texture (in a randomized order). After that, the texture was switched and the new one was displayed at the beginning in its undistorted version for 2664 ms, before starting the cycle of quality changes.

This presentation elicits SSVEPs if the changes due to altered quality are processed in the visual cortex. A SOA of 333 ms results in a flickering frequency of 3 Hz. Before starting the main EEG recording, some additional measurements were performed, comprising a relax measurement and an artifact measurement. In the relax measurement, EEG was acquired during rest alternating with eyes open and eyes closed (10 s each) in order obtain a standard measure of the participant’s occipital alpha rhythm. In the former phase, they had to look at a simple colored geometrical shape moving in the center of the display. The cycle “eyes closed-eyes open” was repeated ten times.

In the artifact measurement, five crosses were displayed: one in the center, the others respectively at the left and right side, upper and below the central one. The distance of the four external crosses matched the size of the videos. Participants were instructed to fixate the central cross and then promptly move the eyes to one of other four, according to the instructions of a recorded voice. In the behavioral part of the experiment, participants had to evaluate the perceived quality of the textures, following the standardized degradation category rating quality assessment in a presentation mode. Each texture was presented in the display in pairs for 10s: on the right-hand side in its original undistorted version (reference) and simultaneously on the left-hand side with changed quality (Figure 21).

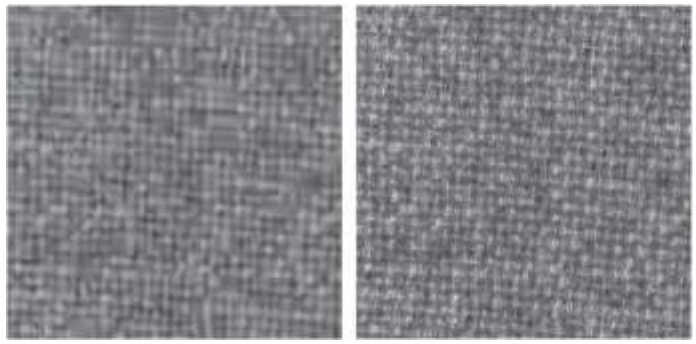

Figure 21:- Behavioral assessment. Textures were presented in a random order, the distorted form on the left side of the display and the undistorted on the right (here an example of blanket with degradation level D6). [1].

A new window was displayed, with the nine-grade degradation (distortion) scale. The scale was displayed in German language, and in English may be translated as follows: 1- very annoying; 3- annoying; 5- slightly annoying; 7- perceptible, but not annoying; 9- imperceptible. Grade 8 is commonly interpreted as the perceptibility threshold that is the distortion level where the observer is not completely sure to perceive the distortion. Participants had up to 10 s to decide about the level of distortion of the previously displayed left image compared to the reference one on the right, scrolling a bar until the selected grade and confirming by button press. The presentation switched to the next pair of textures. If the person did not make any choice within the 10s, the presentation automatically went ahead with the next comparison. In the behavioral assessment, each texture image was presented in all the level of distortions (comprising the comparison reference–reference).

For each level, there were three evaluations. The order of the evaluations was randomly shuffled. At the beginning of the assessment, a calibration block was displayed in order to make the participants confident with the test: each texture was displayed for just two evaluations, worst quality level versus reference and reference versus reference, for a total of 12 calibration evaluations. Like in the actual behavioral assessment, in this short test participants were not aware of the quality level of the displayed textures. The data of this calibration block were not considered in the analysis [1].

The stimuli shown on a 23-inch screen (Dell U2311H) with a native resolution of 1920 × 1080 pixels at a refresh rate of 60 Hz. The stimuli resolution was 512 × 512 pixels (128 × 128 mm), which corresponds to 7.15 visual angle. The size of the images in the behavioral part of the experiment was the same as in the videos. The viewing distance was 110 cm. Subjects sat in front of the display in a dimly light room. Acqualagna et al, 2015 to studied measurement of perceived video quality used this experiment.

The Table 1 shows a summary of the evidence discussed above, it is important to highlight the column on the objectives of the tests.

Task Experiments	**Test**	**Test objective**	**Author(s)**	**Year**
Repetitive Visual Stimulus	Light stimuli	Frequency band detection	Zhu et al	2010
			Parini et al	2009
			Müller-Putz et al	2008
			Müller-Putz and Pfurtschelle	2008
			Wu and Yao	2008
			Wu et al	2008
			Bin et al	2008
			García Molina	2008
			Huang et al	2008
			Ruen et al	2007
			Lüth et al	2007
			Valbuena et al	2007
			Leow et al	2007
			Materka et al	2007
			Scherer et al	2007
			Jia et al	2007

			Friman et al Maggi et al Materka and Byczuk Piccini et al Müller-Putz et al Wang et al Wang et al Gao et al Calhoun et al	2007 2006 2006 2005 2005 2005 2004 2003 1996
	Single graphics stimuli	Frequency band detection	Zhu et al Bin et al Wu et al Wang et al. Ren et al Cecotti and Graeser Touyama and Hirose Lin et al Wang et al Nielsen et al Kelly et al Sami and Nielsen Beverina et al Wahnoun et al Cheng et al Cheng et al Cheng and Gao	2010 2009 2008 2008 2008 2008 2007 2007 2006 2006 2005 2004 2003 2002 2002 2001 1999
	Pattern reversal stimuli	Frequency band detection	Zhu et al Vazquez et al Oehler et al Martinez et al Krusienski and Allison Allison et al Bakardjian et al Kluge and Hartmann Martinez et al Mukesh et al Trejo et al Jaganathan et al Lalor et al Kelly et al	2010 2008 2008 2008 2008 2008 2007 2007 2007 2006 2006 2005 2004 2004
Light and Dark		Frequency band detection	Rennes et al Nakanishi et al	2015 2014
Square Flickered		Frequency band detection	Zhang et al Zhang et al Zheng-Hua et al	2014 2012 2009
Four Square		Frequency band detection	Singla et al Abtahi et al	2013 2010
Visual Search Within Natural Images		Events detection	Emmerling et al Simola et al	2016 2013
Visual Discrimination Five Box Task	Discrimination Simple Description	Events detection	Townsed et al Makeig et al Townsed et al	2001 1999 1996
	Variant Discrimination Composed	Events detection	Townsed et al Makeig et al Townsed et al	2001 1999 1996

	Discrimination Combined Variant	Events detection	Townsed et al Makeig et al Townsed et al	2001 1999 1996
Classification Task		Target Identifications	Camfield Wang et al Bin et al Beverina et al	2011 2010 2009 2003
Newton's Rings		Frequency band detection	Xie et al Ding et al	2012 2006
Video Stimuli		Target Identifications	Acqualagna et al Sullivan et al	2015 2012

Table 1:- Task experiments classification

Conclusion:-

In this paper, we referred to some critical aspects of BCI SSVEP, mainly the characteristics that must have the stimulation system for detection and feature extraction of events presented to the user visually based. The scientific foundations that support the visual condition were presented. Display systems were presented, the characteristics to be considered when selecting the stimulus frequency and detail the characteristics of the different tests, we believe that this document is aid that will allow researchers interested in this area to develop testing tools that meet the characteristics required by BCI based SSVEP.

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