THREE SET CRITERION (3SC)
A common comparison platform for casual Brain Computer Interfaces (BCIs)

[1]Satyajit Sen Purkayastha, [2]V. K Jain, [3]H. K Sardana
[1]Associate Professor, [2]Professor, [3]HRD
[1] Electrical and Electronics Engineering,
[1] Amrapali Institute of Technology and Sciences, Uttarakhand Technical University, Haldwani, India

Abstract: A brain computer interface (BCI) is a communication and control scheme that allows brain signals to command a computer or any other peripheral device directly, without involving the motor units. There has been tremendous focus in this technology in last two decades and as a result, a technology primarily meant for medical purposes has made its shift towards the healthy user segment as well. BCI as a technology is getting wide spread attention and focus for medical usage but since it lacks standardization and a common comparison platform, its impact on the healthy user (Casual) market is not of much significance in spite of its huge potential. In this paper we have attempted to suggest a common comparison platform for casual BCIs and provide a guideline for designing an optimal casual BCI.

***Index Terms* - Brain computer interface (BCI), Casual BCI, Comparison platform**

I. INTRODUCTION

Brain computer interface (BCI) is a device used for communication between brain and a device whose control is independent of the brain's natural output path of peripheral nerves and muscles i.e. it does not require any peripheral muscular activity and enables a user to send instructions to an electronic device only by means of brain signals [1, 2]. The key objective of this system is to function as a unique communication mode for people with severe neuromuscular disorders. But in the recent past, it has been observed that BCI can be of much use to the casual (healthy) users [3]. Thus, keeping in mind this change in the user segment from dependent to healthy, we would be focusing on the BCI segment with casual end users only. The general opinion about BCIs with casual end user, is that it can only allow a user to send some information that one could otherwise convey much more easily and quickly through other interfaces, but this outlook is incorrect and BCIs are useful for casual end users for many specific applications/situations like:

(i). Virtual gaming: - the BCI use has enhanced the associated entertainment and improved the multitasking skills in the virtual gaming world [4]. Moreover, it can also provide a supplementary signal, like an extra key for an extra application or could change instructions transmitted by primary interface or could even provide a blend of information and features that no other gaming input modality can provide [5].

(ii). State of induced disability: - "Induced disability" is a situation in which casual user is in the similar situation as disabled user i.e. under such circumstances casual users are not able to use conventional interfaces effectively. For instance, if verbal communication is not possible due to noise or if user's hands are occupied, in such situations BCI is the best alternative [5].

(iii) Ease of use: - Users find BCI hardware easier to use than other interfaces. Since, BCIs are becoming more wearable and transparent; it is quite possible that they may replace the everyday accessories like wrist watches and mobile phones in the near future [5, 6].

(iv). Informative: - BCI provides added information which is generally unavailable by the use of other means. For instance, real-time error detection and correction [7, 8] or detection of emotion and excitement levels, etc. It helps in modifying the way information is presented to the user and is drawing considerable attention in the field of neuro-marketing [5].

(v). Improves training and performance: - Research results indicate improvement in training and performance, as this training helps to produce specific neural activity patterns, which in turn can help to improve the user's performance [5].

(vi). Confidentiality: - A BCI provides the most secure communication medium as compared to conventional interfaces as no one can spy inside user's brain. Hence, BCIs can be utilized in situations demanding utter secrecy [5].

(vii). Fast signal detection: - Brain activity required for any action is noticeable several hundred milliseconds before the actual action begins and hence it precedes the awareness of the decision to act [9]. Thus, BCIs could possibly provide early prediction of any action with greater precision and accuracy [5].

(viii). Novelty: - People uses BCIs, simply because it is new, modern, innovative and exciting [5].

Generally, BCIs are defined as the amalgamation of few functional segments namely: - Brain activity measurement (signal acquisition), Feature extraction, Feature translation, Control interface, Device controller and Commands execution by the device [10, 11]. The objective of this paper is to provide a common platform for comparison of different casual BCIs and to provide a guideline for designing an optimal casual BCI. Thus, in this paper, Section II reviews different set of criterions / rules considered for formulation of the comparison platform. Section III enlists the implications of these criterions/ rules on a casual BCI and suggests the "3SC factors" for comparison. Section IV determines the various statuses of the "3SC factors" and assigns weights with the help of a process depicted in a flowchart. Section V Details the "Three Sets Criterions (3SC)" comparison platform and its guidelines for designing optimal casual BCI. Section VI discusses the future utility of 3SC and conclusion.

II. CONSIDERATIONS FOR FORMULATION OF THE COMPARISON PLATFORM:

The term BCI- Brain Computer Interface is in itself the combination of three different words and in simplest of its interpretation is the interface between the brain and a computer. Hence our first set of criterion evaluates the BCI in terms of an interface and for doing so we make use of the eight golden rules of interface design by Ben Shneiderman.

In the year 1987 Shneiderman merged known practice guidelines, tacit and knowledge into a set of eight general guidelines for the use of specialist, who were being introduced to the work of designing interactive interfaces. Since then there is ample empirical evidence published which consolidates the applicability of these eight guide lines. By using these guidelines, it is possible to differentiate a good interface design from a bad one especially from the Human-User interaction point of view and obviously it became our first set of considerations. The rules are [12]:

Rule 1. Strive for consistency: Consistent sequences of actions should be required in similar situations; identical terminology should be used in prompts, menus, and help screens; and consistent color, layout, capitalization, fonts, and so on should be employed throughout. Exceptions, such as required confirmation of the delete command of no echoing of passwords, should be comprehensible and limited in number.

Rule 2. Cater to universal usability: Recognize the needs of diverse users and design for plasticity, facilitating transformation of content. Novice to expert differences, age ranges, disabilities, and technological diversity each enrich the spectrum of requirements that guides design. Adding features of novices, such as explanations, and features for experts, such as shortcuts and faster pacing can enrich the interface design and improve perceived system quality.

Rule 3. Offer informative feedback: For every user action, there should be system feedback. For frequent and minor actions, the response can be modest, whereas for infrequent and major actions, the response should be more substantial. Visual presentation of the objects of interest provides a convenient environment for showing changes explicitly.

Rule 4. Design dialog to yield closure: Sequence of actions should be organized into groups with a beginning, middle, and end. Informative feedback at the completion of a group of actions gives operators the satisfaction of accomplishment, a sense of relief, a signal to drop contingency plans from their minds, and an indicator to prepare for the next group of actions. For example, e-commerce web sites move users from selecting products to the checkout, ending with a clear confirmation page that completes the transaction.

Rule 5. Prevent error: As much as possible, design the system such that users cannot make serious errors; for example, grey out menu items that are not appropriate and do not allow alphabetic characters in numeric entry fields. If a user makes an error, the interface should detect the error and offer simple, constructive, and specific instructions for recovery. For example, users should not have to retype an entire name- address form if they enter an invalid zip code, but rather should be guided to repair only the faulty part. Erroneous actions should leave the system state unchanged, or the interface should give instructions about restoring the state.

Rule 6. Permit easy reversal of actions: As much as possible, actions should be reversible. This feature relieves anxiety, since the user knows that errors can be undone, and encourages exploration of unfamiliar options. The units of reversibility may be a single action, a data- entry task, or a complete group of actions, such as entry of a name-address block.

Rule 7. Support internal locus of control: Experienced users strongly desire the sense that they are in charge of the interface and that the interface responds to their actions. They don't want surprises or changes in familiar behavior, and they are annoyed by the tedious data-entry sequences, difficulty in obtaining necessary information, and inability to produce their desired result.

Rule 8. Reduce short-term memory load: Human's limited capacity for information processing in short – term memory requires that designers avoid interfaces in which users must remember information from one screen and then use that information on another screen. It means that cell phones should not require re-entry of phone numbers, web-site locations should remain visible, multiple-page display should be consolidated, and sufficient training time should be allotted for complex sequences of actions.

The implementation of above set of rules would lead to a good interface but for a specific casual BCI, it not only has to compete with other casual BCIs but also with other general purpose interfaces and their general properties. So in the second consideration, the casual BCI would be reviewed as a product, which is not the case with medical BCIs, as users are not dependent on it for vital functions. Hence to compete as a product it has to consider itself being pleasurable, without which its chances of getting associated with the user is bleak. Thus, the use of casual BCI as a product is pleasurable or not would have a significant impact on the users and therefore we would consider the set of product attributes which makes a product pleasurable or dis-pleasurable described by Patrick Jordan in the year 1998 as our second set of consideration. The attributes are [13]:

ATTRIBUTE 1. Features: This was the issue most commonly mentioned in association with pleasurable products - helpful features supporting the operation of the product. Some people simply commented that their pleasurable product contained the appropriate features to do what it was supposed to do efficiently. However, if the product contained unnecessary features or did not have sufficient features, this could lead to it being perceived as dis-pleasurable.

ATTRIBUTE 2. Usability: Usability seemed to be a major issue, both as a contributor to pleasure and as a factor whose absence might cause displeasure.

ATTRIBUTE 3. Aesthetics: Appearance strongly contributed to the pleasure which some users took in their products. Both style and color were important to users. Equally, lack of aesthetic appeal could contribute to making a product dis-pleasurable to use.

ATTRIBUTE 4. Performance: This refers to a product performing its primary task to a particularly high level.

ATTRIBUTE 5. Reliability: Reliability is central to enabling users to form a ‘bond’ with a product. Interviewees indicated that they had become attached to products which had given them years of good service. Unreliable products could leave the user feeling cheated.

ATTRIBUTE 6. Convenience: Some products gave pleasure though their convenience--being particularly appropriate for certain contexts of use.

ATTRIBUTE 7. Size: People mentioned that the size of their pleasurable product was optimal--either in respect of enhancing the product’s performance or in terms of suiting the product’s context of use.

ATTRIBUTE 8. Cost: The level of negative feeling associated with dis-pleasurable products could be exacerbated if the product had been expensive to buy in the first place. No one mentioned low cost as a contributing factor to making a product pleasurable.

ATTRIBUTE 9. Gimmick: Products could be regarded as dis-pleasurable because they were seen as being ‘gimmicks’.

By the implications of the above mentioned criterions, the designing of the good interface with good product characteristics could be planned but practically to have such a casual BCI it has to overcome some of the critical technological challenges. Hence for the purpose of designing a technically sound Casual BCI we would consider the crucial technical challenges for a non-medical BCI stated by Van Erp et. al. in the year 2012. The casual BCI has to overcome these challenges so as to be accepted by the users as a next generation interface. Hence we will focus on these factors which are not necessarily crucial for medical applications but which are crucial challenges for development of casual BCIs [14]. The factors are:

FACTOR1 Usability: A typical user of a non-medical BCI will want to operate the BCI without the help of a caregiver and without extensive training. Generally, the user will have high demands regarding the usability and the comfort of the system. Users will not appreciate having to wash their hair after the use of gel, as required with most current EEG sensors, or a cap that is too tight or that harms the scalp due to friction. Users must be able to mount the EEG cap and set up the equipment fast and intuitively. In order to reach optimal performance, BCI systems require a calibration session which consists of recording examples of EEG signals from the user, in order to tune the parameters for this specific user. The length of a Typical BCI calibration session is about 5-20 minutes at best, which is still too long for most non-medical applications. Furthermore, the system must be safe and maintenance should be minimal. In particular, BCI applications should be easy, intuitive and fast to learn and to use, without being too cognitively demanding. Additionally, user experience aspects must be taken into account including subjective aspects such as the user's feelings, emotions, and beliefs. Also, to ensure a good acceptance of non-medical BCI applications, they should be ethically sound, in particular with respect to mind privacy issues and long-term effects of BCI use.

FACTOR2 Hardware: The hardware improvements required to develop usable non-medical BCI applications are probably among the most challenging but also among the most important ones. First, sensors have to be dry in order to be comfortable, convenient and easy to mount. Second, these sensors must offer a good signal quality even in very noisy environments and/or with moving users. The development of better active electrodes with active shielding could prove very useful. Another issue that needs to be tackled is the optimal number and placement of electrodes and how to achieve a consistent placement of the electrodes while ensuring an easy mounting without external help. Furthermore, an ideal BCI device (sensors, amplifier and possibly computer) is wearable, light, unobtrusive, comfortable, wireless, and visually appealing. Finally, for many non-medical applications, reducing the cost of the BCI hardware is a prerequisite.

FACTOR3 Signal processing: Usable non-medical BCI applications require progress in the following four areas: (1) robustness to noise and changing signal characteristics (non-stationarity) of brain signals, (2) asynchronous and continuous operation instead of synchronous and discrete, (3) minimal calibration time, and (4) algorithms to classify signals from novel sensors and new BCI paradigms to extract mental states.

FACTOR4 System integration: Non-medical BCIs require quick, easy and seamless integration with existing systems.

The above mentioned considerations are almost covering all the expectations and limitations of a good interface, a pleasurable product and a next generation non-medical BCI. However, in the next segment we would be discussing the combined implications of these considerations in the designing of an optimal casual BCI.

III. IMPLICATION OF THE ABOVE CONSIDERATIONS FOR DESIGNING AN OPTIMAL CASUAL BCI

The generalized considerations to design a good interface, to design a product which is pleasurable to the users and to design a future non-medical BCI which can overcome the present technical challenges could be combined to formulate the road map for designing an optimal casual BCI, this work can even be used for comparison of different casual BCIs present in the market, for designating them as optimal in the present scenario. Here each of the generalized considerations would be evaluated in terms of designing an optimal casual BCI and "3SC factors" would be suggested. "3SC factors" are the comparison factors whose status would decide the superiority of one BCI over other in the casual context.

Implication of Rule 1 "Strive for consistency":

S. No.	Implications	3SC Factors
1	BCI design should support users to perform a specific task the same way they have been performing it every time.	Operational consistency
2	BCI design should have identical terminology throughout the process	Consistent salutation
3	BCI design needs to exhibit consistent visual quality across the screens.	Visual consistency
4	BCI design needs to exhibit consistent behavioural quality across the applications.	Behavioural consistency

Implication of Rule 2 "Cater to universal usability":

5	BCI design should be universally usable to cater a wide range of users from different age, culture, educational level and disability.	Universally usable
6	BCI design should have the option of transformation of contents	Content transformation
7	BCI design should cater the needs of diverse users classified as Novice, Intermediate and Experts.	Expertise levels
8	BCI design should have special features for novices like "explanation", etc.	Novice features
9	BCI design should have special features for experts like "Shortcuts", "Fast pacing", etc.	Expert features

Implication of Rule 3 "Offer informative feedback":

10	BCI design should have a system feedback for every user's action.	Action feedback
11	BCI design should have variations in feedbacks depending on the kind of user action, like minor or major action, frequent or infrequent action, etc.	Variations in feedbacks
12	BCI design should have provision to exhibit changes in a visual form i.e. visual feedback.	Visual feedback

Implication of Rule 4 "Design dialog to yield closure":

13	BCI design should have all the actions grouped as beginning, middle and end of action.	Action categories
14	BCI design should have informative feedbacks for completion of each group of actions	Group completion feedback

Implication of Rule 5 "Prevent error":

15	BCI design should have techniques to prevent users from making errors.	Error prevention
16	BCI designs should have error detection techniques	Error detection
17	BCI design should have simple, constructive and specific error correction techniques.	Error correction
18	BCI design should have option of system state restore.	System state restore

Implication of Rule 6 "Permit easy reversal of actions":

19	BCI design should have action reversal option.	Action reversal

Implication of Rule 7 "Support internal locus of control":

20	BCI design should allow the user feel "in control" of the system and situation.	User controlled
21	BCI design should support the system behaviour familiarity of the user	Behaviour familiarity
22	BCI design should have techniques to avoid tedious data entry sequences	Techniques to avoid data entry
23	BCI design should have necessary information accumulation method for the convenience of user	Information accumulation method
24	BCI design should support the user to produce his/her desired results	Support for desired output

Implication of Rule 8 "Reduce short-term memory load":

25	BCI design should support to reduce the short term memory load.	Short term memory load reduction
26	BCI design should support the consolidation of multiple page display	Multi-page display consolidation
27	BCI design should have provision of sufficient training time for complex sequence of actions	Training time provision

Implication of Attribute 1 "Features":

28	BCI as a product should have helpful features supporting its operations	Helpful features
29	BCI as a product should have efficient features.	Efficient features
30	BCI as a product should have sufficient number of features.	Sufficient number of features
31	BCI as a product should not have unnecessary features	Unnecessary features

Implication of Attribute 2 "Usability":

32	BCI as product should be highly usable	Usability

Implication of Attribute 3 "Aesthetics":

33	BCI as product should have aesthetic appeal.	Aesthetic appeal

Implication of Attribute 4 "Performance":

34	BCI as a product should have high level of performance for the primary task.	Product Performance

Implication of Attribute 5 "Reliability":

35	BCI as a product should be reliable	Reliable

Implication of Attribute 6 "Convenience":

36	BCI as a product should be convenient for users	Convenient

Implication of Attribute 7 "Size":

37	BCI as a product should have a optimal size for a user	Optimal size

Implication of Attribute 8 "Cost":

38	BCI as a product should have low cost	Low product cost

Implication of Attribute 9 "Gimmick":

39	BCI as a product should not be seen as a gimmick.	Not having a gimmick image

Implication of Factor 1 "Usability":

40	BCI operator should operate it without any external human support	External human support
41	BCI operator should operate it without any extensive training	Extensive training
42	BCI should have high usability	Usability
43	BCI should be comfortable to operate	Comfortable use
44	BCI should have dry electrodes	Dry electrodes
45	BCI should have easy mounting head gear	Head gears
46	BCI should have minimal calibration time	Not having large calibration time
47	BCI should be safe to use	Safety
48	BCI should have minimal maintenance	Not having large maintenance
49	BCI should not be cognitively demanding	Not having tedious cognitive demand
50	BCI should be ethical sound	Ethical issues
51	BCI should not have long term effects of use	Long term effects

Implication of Factor 2 "Hardware":

52	BCI should have dry electrodes	Dry electrodes
53	BCI should have high signal to noise ratio (S/N)	S/N
54	BCI should have active electrodes with active shielding	Active electrode
55	BCI should have optimal number of electrodes	Having optimal electrode numbers
56	BCI should have optimal placement of electrodes	Having optimal electrode placements
57	BCI should have easy mounting	Easy electrode mounting
58	BCI should not require external help	External human support
59	BCI should be a wearable system	Wearable system
60	BCI should be light in weight	Light weight

61	BCI should be unobtrusive	Unobtrusive
62	BCI should be comfortable	Comfortable
63	BCI should be wireless	Wireless
64	BCI should be visually appealing	Aesthetic appeal
65	BCI should be cheap	Cost

Implication of Factor 3 "Signal processing":

66	BCI should exhibit robustness to noise and changing signal characteristics	Robustness
67	BCI should be asynchronous operation	Asynchronous operation
68	BCI should have continuous operation	Continuous operation
69	BCI should have minimal calibration time	Calibration time
70	BCI should have algorithms with high classification accuracy	Classification accuracy
71	BCI should recognise more number of classes i.e. mental states	Classes

Implication of Factor 4 "System integration":

72	BCI should be quick i.e. should have high information transfer rate (ITR)	ITR
73	BCI should easily and seamlessly integrate with other systems	Seamless integration

Note: Some of the 3SC factors were coloured in red, because these factors are repeated and hence not taken into account again.

IV. Statuses of the 3SC factors and weights assignment:

In this section the "3SC factors" would be assigned various statuses. The statuses would be assigned, depending on the nature, type and way of determination of the "3SC factors" in the closest possible way. Statuses are primarily categorised into four groups, namely:

1. Available/ Unavailable: It is assigned to those "3SC Factors" whose presence or absence in a casual BCI could be judged easily by the user or the product manufacturer. The status "Available" is considered as a preferred status because it represents those groups of qualities which are essential for a casual BCI and therefore it is also given higher weighted value then status "Unavailable".

2. Percentage %: It is assigned to those "3SC Factors" whose measurement is a combined effect of various sub factors and is represented as a percentage. It can also be defined as the approximate average percentage of the 3SC factor from different sources (Manufacturer / Group of users / Individual user/ Research labs / etc.). Here a 3SC factor with a value closer to 100% is considered more preferred and hence has higher weighted value assigned to it.

3. Numbers: It is assigned to those "3SC Factors" which could be represented specifically by a numerical value. Here a 3SC factor with higher value is considered more preferred and so higher weighted value is assigned to it.

Most of the 3SC factors will not have any units but if it has units then for the purpose of forming a base line, a smaller unit would be considered and others would be converted for the purpose of comparison.

4. Exist/ Doesn't exist: It is similar to the 1st status group i.e. Available / Unavailable except for the fact that here the status "Exist" is considered as a non - preferred status because it represents those groups of qualities which are unwanted for a casual BCI and therefore the status "Doesn't exist" is given higher weighted value then status "Exist".

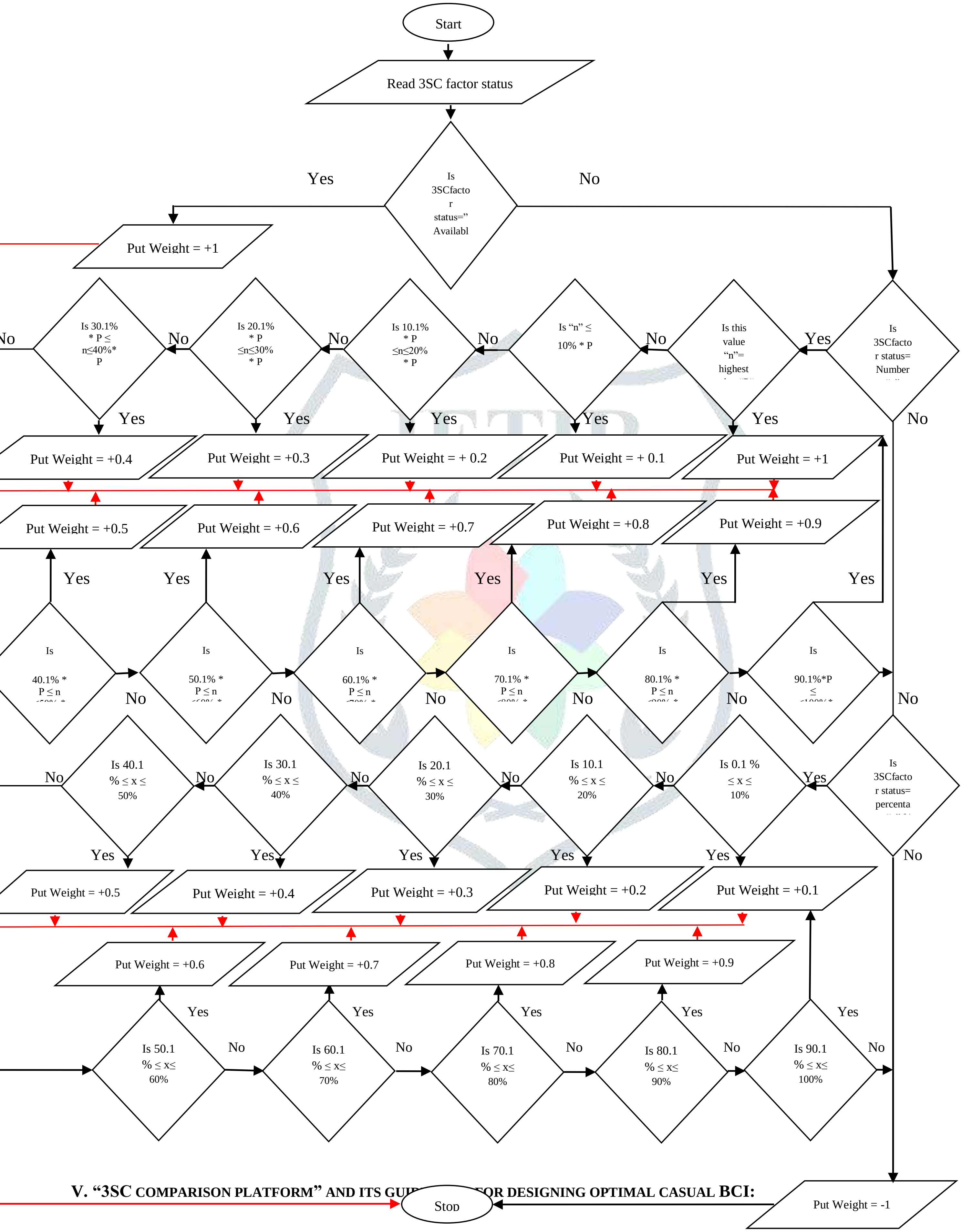
Table 4.1: It shows the status assigned to each of the 3SC factors

Serial No	3SC Factors	Status	
1	Operational consistency	Percentage %	
2	Consistent salutation	Available	Unavailable
3	Visual consistency	Available	Unavailable
4	Behavioural consistency	Percentage %	
5	Universally usable	Percentage %	
6	Content transformation	Available	Unavailable

7	Expertise levels	Numbers	
8	Novice features	Numbers	
9	Expert features	Numbers	
10	Action feedback	Available	Unavailable
11	Variations in feedbacks	Numbers	
12	Visual feedback	Available	Unavailable
13	Action categories	Available	Unavailable
14	Group completion feedback	Available	Unavailable
15	Error prevention	Available	Unavailable
16	Error detection	Available	Unavailable
17	Error correction	Available	Unavailable
18	System state restore	Available	Unavailable
19	Action reversal	Available	Unavailable
20	User controlled	Percentage %	
21	Behaviour familiarity	Percentage %	
22	Techniques to avoid data entry	Available	Unavailable
23	Information accumulation method	Available	Unavailable
24	Support for desired output	Percentage %	
25	Short term memory load reduction	Percentage %	
26	Multi-page display consolidation	Available	Unavailable
27	Training time provision	Available	Unavailable
28	Helpful features	Numbers	
29	Efficient features	Numbers	
30	Sufficient number of features	Available	Unavailable
31	Unnecessary features	Exist	Doesn't exist
32	Usability	Percentage %	
33	Aesthetic appeal	Percentage %	
34	Product Performance	Percentage %	
35	Reliable	Percentage %	
36	Convenient	Percentage %	
37	Optimal size	Percentage %	
38	Low product cost	Percentage %	
39	Not having a gimmick image	Percentage %	
40	External human support	Exist	Doesn't exist
41	Extensive training	Exist	Doesn't exist
42	Comfortable use	Percentage %	
43	Dry electrodes	Available	Unavailable
44	Head gears	Available	Unavailable
45	Not having large calibration time	Percentage %	
46	Safety	Percentage %	
47	Not having large maintenance	Percentage %	
48	Not having tedious cognitive demand	Percentage %	
49	Ethical issues	Exist	Doesn't exist
50	Long term effects	Exist	Doesn't exist
51	S/N	Numbers	
52	Active electrode	Available	Unavailable
53	Having optimal electrode numbers	Percentage %	
54	Having optimal electrode placements	Percentage %	
55	Easy electrode mounting	Available	Unavailable
56	Wearable system	Available	Unavailable
57	Light weight	Percentage %	
58	Unobtrusive	Percentage %	
59	Wireless	Available	Unavailable
60	Robustness	Available	Unavailable
61	Asynchronous operation	Available	Unavailable
62	Continuous operation	Available	Unavailable
63	Classification accuracy	Numbers	

64	Classes	Numbers	
65	ITR	Numbers	
66	Seamless integration	Available	Unavailable

After the status is assigned to a 3SC factor as shown in Table 4.1, the next process is weight assignment to these 3SC factors, which is depicted by the flow chart given below. The maximum value of weight is “+1” and the minimum value is “-1”. Here “n” is the numerical value of a parameter with status “Number” and “p” is the highest value of this parameter in the present market. Also “x” is the percentage value of a parameter with status “Percentage %”.



V. "3SC COMPARISON PLATFORM" AND ITS GUI… OR DESIGNING OPTIMAL CASUAL BCI:

"Comparison matrix or 3SC comparison platform" (shown in Table 5.1) is a simple comparison matrix prepared by taking all the 66 "3SC factors" in the first column. The next columns represent the corresponding weighted values of different "3SC factors" of a particular BCI, let us suppose BCI 1. The weighted values of the "3SC factors" were found out by the application of the flowchart mentioned in the previous section. Similarly, the rest of the columns will represent the weighted values of "3SC factors" of the other BCIs like BCI 2, BCI 3 etc. The number of columns would depend upon the number of BCIs one wishes to compare, whereas the total number of rows will be fixed i.e. 66 which is the total number of "3SC factors". The maximum value of the weight for a particular "3SC factor" is "+1" and the minimum value is "-1". To select the optimal casual BCI in the present scenario we have to compare all the competing BCIs on the basis of the "3SC Factors" and complete the comparison matrix. Once the matrix is complete, simply add all the weighted values in a column. This is the total weighted sum (TWS) of a particular BCI. Calculate the total weighted sum of all the competing BCIs. The BCI with maximum value of total weighted sum is the most optimal casual BCI in present scenario.

Table 5.1: Comparison matrix or 3SC comparison platform

Casual BCIs / **3SC Factors**	**BCI 1**	**BCI 2**	**BCI 3**	………	………
1. Operational consistency					
2. Consistent salutation					
3. ….					
……					
……					
66.					
Total Weighted Sum (TWS)					

For designing an optimal casual BCI one needs to take care of all the "3SC factors" and should try to have a total weighted sum (TWS) value of 66, which is the maximum value. Till then the BCI with TWS nearest to this value is the casual BCI which could be considered to be a good interface, a good product and a next generation non-medical BCI.

VI. Discussion and conclusion.

This is the simplest and elaborate comparison platform for the casual BCIs till date. Prior to this the comparisons were based on few factors like ITRs, cost, complexity etc. but this platform is almost covering all the expectations and limitations of a good interface, a pleasurable product and a next generation non-medical BCI. Above all this is the only platform which is considering the human factors, which in spite of being important was always missing. Moreover, it is flexible and simple, which means it could adjust easily to the advancements of the technology and new benchmarks. For now, it could serve as a comparison platform for all the casual BCIs and could serve as a guideline for making an optimal casual BCI.

But advancement in the related technologies like electronics, sensor efficiency, biotechnology, signal processing, classification algorithms, etc. in future may lead to inclusion of more considerations in the above list. Moreover, there is scope of further improvement in the method of weight assignment, as we have assumed 10 intervals for the "Percentage %" and "Numbers" and assigned weighted values accordingly, but in a more practical scenario the intervals should be more and even may vary continuously. This would minimize the dichotomization errors. However, this method is first of its kind comparison platform which takes into account the Human Factor as well as the technical parameters in a balanced way. Further research in this direction may led to a more accepted, efficient and useful casual BCI in future.

VII. Acknowledgement

Competing interests: None declared
Funding: None
Ethical approval: Not required

VIII. References

[1]. J. R. Wolpaw, N. Birbaumer, D. J. McFarland, G. Pfurtscheller and T. M. Vaughan (2002), Brain computer interfaces for communication and control, Clinical Neurophysiology, 113, 6, pp. 767-791.

[2]. T. M. Vaughan, W. J. Heetderks, L. J. Trejo, W. Z. Rymer, M. Weinrich, M. M. Moore, A. Kubler, B. H. Dobkin, N. Birbaumer, E. Donchin, E. W. Wolpaw and J. R. Wolpaw (2003), Brain-computer interface technology: a review of the second international meeting, IEEE Transactions on Neural Systems and Rehabilitation Engineering, 11, 2, pp. 94-109.

[3] B. Graimann, B Allison and G Pfurtscheller(2010), Brain–Computer Interfaces, The Frontiers Collection, 1 DOI 10.1007/978-3-642-02091-9_1, C _ Springer-Verlag Berlin Heidelberg

[4]. Allison, B.Z., Wolpaw, E. W., Wolpaw, J. R. Brain computer interface systems: Progress and opportunities. In Poll, E. ed. British Review of Medical Devices, In Review.

[5]. Allison B, Graimann B and Graser A 2007 Why use a BCI if you are healthy? ACE Workshop on Brainplay: Brain–Computer Interfaces and Games (Salzburg, Austria, 2007)

[6]. Pfurtscheller, G., Müller-Putz, G.R., Schlogl, A., Graimann, B., Scherer, R., Leeb, R., Brunner, C., Keinrath, C., Lee, F., Townsend, G., Vidaurre, C. and Neuper, C. 15 years of BCI research at Graz University of Technology: Current projects. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 14, 2 (2006), 205-210.

[7]. Buttfield, A., Ferrez, P.W. and Millan, J.D. Towards a robust BCI: Error potentials and online learning. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 14, 2 (2006), 164-168.

[8]. Parra, L.C., Spence, C.D., Gerson, A.D. and Sajda, P. Response error correction--a demonstration of improved human-machine performance using real-time EEG monitoring. IEEE Trans Neural Syst Rehabil Eng, 11, 2 (2003), 173-177.

[9]. Pineda, J.A., Allison, B.Z. and Vankov, A. The effects of self-movement, observation, and imagination on mu rhythms and readiness potentials (RP's): Toward a brain-computer interface (BCI). IEEE Transactions on Neural Systems and Rehabilitation Engineering, 8, 2 (2000), 219-222.

[10]. L. F. Nicolas-Alonso and J. Gomez-Gil "Brain computer interfaces, a review", Sensors, vol. 12, pp.1211 -1279 2012

[11]. Mason, S. and G. Birch.Ageneral framework for brain-computer interface design. IEEE Transactions on Neural Systems and Rehabilitation Engineer., 11: 70.2003.

[12]: B Shneiderman and C Plaisant 2003-Designing the User Interface, PearsonEducation, fourth Edition, 92-93.

[13]. Jordan, P.W. "Human factor for pleasure in product use", Applied Ergonomics, Elsevier Science Ltd, 29,1(1998), 25-33.

[14]. Jan B.F. Van Erp, Fabien Lotte, Michael Tangermann. Brain-Computer Interfaces: Beyond Medical Applications. Computer -IEEE Computer Society-, IEEE, 2012, 45 (4), pp.26-34.