Kolb's Learning Style correlate to Extraversion using EEG and Clustering Analysis

N. Abdul Rashid, M.N. Taib, Z. H. Murat, R. S. S. Abdul Kadir, S. Lias, N. Sulaiman

Abstract—**Individual Learning style (LS) had gained an enormous attention as learning process became more independent and student-centered. Furthermore, studies had shown that a congruence learning and teaching style could lead to a successful learning process. One of the frequently used instruments to determine student's LS is Kolb's Learning Style Inventory (LSI). According to the Kolb's model, the LSI would establish the LS of Diverger, Assimilator, Converger or Accommodator. On the other hand, Personality Traits had been considered as one of the student's important attribute. As such, several studies had been embarked to find the relationship between LS and Personality Traits but it were always confined to the usage of traditional instruments mostly adopting questionnaire-based methodology. In this research, the LS and Personality Traits were correlated using Electroencephalogram (EEG) technology. Initially, the participants' LS (N=41) were determined using Kolb's LSI. Then their brainwaves were recorded at baseline resting condition of Open Eyes and Closed Eyes using EEG. The EEG Alpha band was selected and analyze using SPSS 2Step Cluster analysis module. The findings show that 100% clustering had been achieved and Converger and Accommodator had been correctly detected as the Extraversion-bound LS in most experiment.**

Index Terms— **Learning style, Personality Traits, Extraversion, EEG, Clustering**

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N. Abdul Rashid is with the Faculty of Arts, Computing and Creative Industry, Sultan Idris Education University (UPSI), Tg. Malim, 35900, MALAYSIA (phone: +6103-6226224; e-mail: nazre.rashid@gmail.com)

M.N. Taib is a Professor and Dean at the Electrical Engineering Faculty, Universiti Teknologi MARA, Shah Alam (UiTM), MALAYSIA. He is the founder and leader of UiTM's Advanced Signal Processing Research Group (ASPRG). (e-mail: nasir@ieee.org)

Z. H. Murat, R. S. S. Abdul Kadir, S. Lias, N. Sulaiman are with Electrical Engineering Faculty UiTM Shah Alam.

I. Introduction

A. What is Learning Style?

Learning style (LS) refers to a wider scope that includes cognitive performance and bespeaks general orientations for ways and environments for learning. The attributes of cognition, affection, psycho-motor, and physiological were all covered in LS [1]. LS additionally delineated as the method students onset to ponder on, procedure, internalize, and recall new and tough intellectual data. [2]. On the same note, LS mentions to the believed that learners differ in assuming the appropriate mode of education for them. Advocates of learning-style appraisal asserted that optimal instruction needs examining individualize LS and adjusting instruction accordingly. Although the highly heterogeneity of the assessment materials are observed, LS ordinarily assessed by inquiring participants to measure what kind of available information they favor and/or what kind of mental task they determine most suitable [3]. Furthermore, the LS instance is established in a several educational psychology textbooks. Learning styles and tendencies do effect on the ways and the contents of what students learn. Verbal learners

look to learn better when instruction is disseminate through words while visual learners appear to learn better when pictures are introduced to them [4]. Thus ambitious learners and educators are being informed that students bear unique learning styles and that these properties should be taken into account by adjusting the pedagogical content and mode of instruction to those learning styles[3].

B. The importance of Learning Style

Studies in the field of education show dynamic approaches whereby students play more active roles, bear the responsibility of learning and are obligated to exploit their cognitive skills when its matter most. These approaches put forward that students' environment to the existing preliminary information which decided the new information they will obtain to their memories. This relation causes information shifting where learners will accommodate the existing and new information in their unique style. This situation also leads to the concept of individual differences which include LS as one of the reference term in educational research[5]. One of the factors that influence student's achievement is the match between learners' LS and teachers' teaching styles. It has been found that matching between teaching and LS have a significant impact on achievement and satisfaction[6]. Matching and mismatching between both styles happened in any academic setting, at least to a certain cases. A mismatch is taken place when students' preferred way of handling information is not coordinated with the teachers' preferred styles of teaching. This could caused student's poor performance as they might facing boredom and low motivation [7]. Students might perform below-par on examinations; show opposition to the courses and the curriculum and in some unfortunate events may shift to other curricula or leave the academic institutions prematurely. Thus, providing instructors with the necessary information about students' LS preferences could enable them to include more preferred LS methods into their teaching [8].

C. Kolb's Learning Style

Many dissimilar LS assessment frameworks and tools could be found commercially. Several models are multi-dimensional which built-up with cognition, affection and psychological features as the main perspectives. Others are limited to a exclusive variable, ordinarily from the base on cognition or psychological area [9]. However, this section solely focuses on the LS model and the related learning style appraisal instrument developed by David A. Kolb which was used throughout the study. According to prior research on LS, 71 LS models were recognized by which 13 were reckoned as a greater importance [10]. One of them is the exceedingly prominent model pioneered by cognitive theorist, David Kolb and his associates, Fry in 1975 based on Kurt Lewin's model [11].

Kolb's experiential learning theory (ELT) provides substitute to conventional instructive and behavioral schoolroom advancements, furnishing modification and development on oneself well-being as a learning cycle function [12]. Kolb's idea comprised of three major elements : a theory of experiential learning; a graphical presentation of the learning cycle framework; and the documents for determining the participants' LS that has since published in different versions called the Learning Styles Inventory (LSI) [13].

Kolb presented the cyclic model of learning process in a graphical form containing four learning proportions came from a pair of bi-polar perspective of apprehension, the comprehending of information from experience, which represented Concrete Experience-Abstract Conceptualization (CE-AC) and transformation, the processing of grasped information represented by the combination of Active Experimentation-Reflective Observation (AE-RO) (see Fig. 1)[13].

Interactions between the four dimensions

managed Kolb to discriminate four LS delineated as Divergers, Assimilators, Convergers and Accommodators. The accommodators favor CE and AE and study effectively from practical experience. Accommodators are proficient at materializing plans with the skill to adapt to varying situations. Divergers utilize CE and contemplation to see concrete circumstances from various views angle and delighting to come out with alternative ideas. Convergers depend on AC and AE by disclosing how things function and employing thoughts or theories for tackling problems practically. Converger prefer technical jobs and seldom encountering with emotion. Assimilators use AC and RO to comprehend, coordinate, and fuse colossal numbers of data into a compact, coherent model .

Research data suggested that Kolb's experiential learning theory might shows LS standard within academic areas. Accommodators may be drawn to activity-oriented jobs such as marketing executive, sales executive, or manager. Divergers lean toward service type careers, such as in arts, social sciences, or the humanities. Engineers are instance of Convergers, whereas scientists and academicians were in the family of Assimilators [13-15].

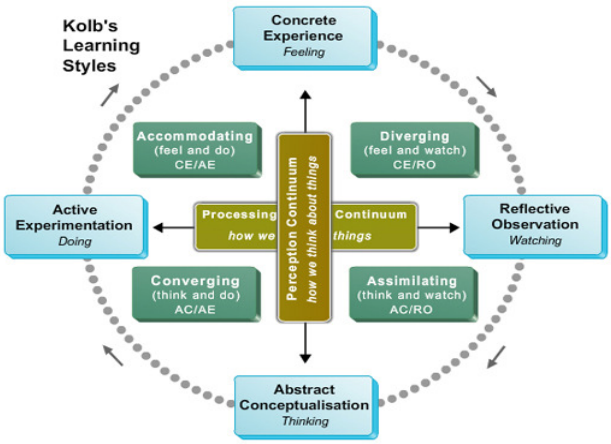

Fig. 1: Kolb's Experiential Learning Style Model

D. Personality Trait, Extraversion and Kolb's Learning Style

Studies had been conducted to find the relation between LS and personality for instance, Furnham looked into the association between three learning style models of Honey and Mumford learning style questionnaire (LSQ), the Whetten and Cameron cognitive style instrument (CST), the Kolb learning style Inventory (KLSI) and the personality traits extraversion, neuroticism, psychoticism and lie which measured using Eysenck personality questionnaire (EPQ) [16]. In Honey and Mumford's LSQ, Furnham discovered positive correlations between extraversion and the learning styles ``Activist'' and ``Pragmatist''. The opposite situation detected whenever extraversion tested with the learning style ``Reflector''.

As for the Whetten and Cameron's CST, Furnham established that the extraversion correlated positively to active cognitive style, while it correlated negatively with the more reflective cognitive style.

For the Kolb's LSI, Furnham encountered a positive relation on extraversion with the LS ``Converger'' and ``Accommodator''. Neuroticism correlated negatively with the learning styles ``Assimilator'' and ``Accommodator''. Psychoticism correlated positively with the learning style ``Diverger''. The research questions had been replicated by several researchers and they are in-line with Furnham's findings[17].

According to Kolb, the outlines of behavior connected alongside his four LS are forged by deals amid people and their nature at disparate levels encompassing personality, educational differentiation, expert occupation, present job act, and adaptive as depicted in Table I. Nevertheless, ELT defines LS as a human psychological format which merely in part determined by personality. Personality wields a scope but meaningful influence yet the LS was also influenced by the demands of educational needs, occupation, and tasks competencies[15].

TABLE I. RELATIONSHIP BETWEEN LEARNING STYLES AND FIVE LEVELS OF BEHAVIOR [15]

Behavior Level	Diverging	Assimilating	Converging	Accommodating
Personality types	Introverted Feeling	Introverted Intuition	*Extraverted Thinking*	*Extraverted Sensation*
Educational Specialization	Arts, English, History, Psychology	Maths, Physical Science	Engineering,Medicine	Education, Communication, Nursing
Professional Career	Social Service, Arts	Sciences, Research, Information	Engineering, Medicine, Technology	Sales, Social Service, Education
Current Jobs	Personal jobs	Information jobs	Technical jobs	Executive jobs
Adaptive Competencies	Valuing skills	Thinking skills	Decision skills	Action skills

The resemblance of ELT framework to Carl Jung's statements of individuals' favor in his/her surrounding adaptation had been duly recognized by many researchers. Several research works linking the LSI with the Myers-Briggs Type Indicator (MBTI) by presenting the connection between Jung's Extraversion/Introversion dialectical attribute to ELT's Active/Reflective and the Feeling/Thinking attribute associates with Concrete Experience/Abstract Conceptualization. The MBTI Sensing type is connected with the LSI Accommodating learning style, and the Intuitive type with Assimilating style. MBTI Feeling types relate to LSI Diverger, and Thinking types to Converger. The above discussion entails that the Accommodator is the Extraverted Sensing type, and the Converger is the Extraverted Thinking type while the Assimilator links to the Introverted Intuitive personality type, and the Diverger to the Introverted Feeling type [15].

As such, the personality domain of Extraversion was commonly adopted to relate between students' preferred learning styles and personality traits [18, 19] . The importance of Extraversion in learning field has been widely documented such as in the execution of self-directed social learning and self-efficiency [20] and shaping the Learning Style preferences among learners [15]. Extraversion is defined as a predisposition to confirming or enjoyment stimulus and Extraverts were always associated to positive affect [21]. Based on Eysenck's arousal hypothesis, extraverted persons are pretended to exhibit a lower cortical arousal compared to introverted persons [22].

E. EEG Technology

Electroencephalography (EEG) is a medical imaging method that takes head skin electrical activity yielded by brain system. EEG is entirely non-invasive routine that can be practiced several time to participants with virtually no hazard or restriction [23]. The common classification of EEG frequency is Delta band waves at 0.5 to 4 Hertz with variable amplitude are always associated to deep sleep. Theta band waves which originate from aroused annoyance or dissatisfaction ranged at 4 to 8 Hertz. The frequency of Alpha band waves is set in the range of 8 to 13 Hz. Alpha which linked to relaxed awareness, reflecting and inattention is the most prevalent wave in the brain. Beta waves exhibit at the range of 13 to 30 Hz and are always associated to active thinking, alert and busy state (See Fig. 2). Meanwhile Gamma waves have the highest frequency range of 30 to 40 Hz [24, 25].

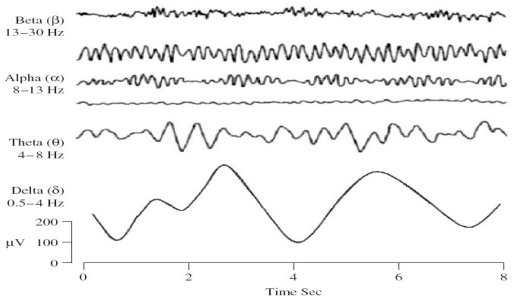

Fig. 2: The Typical Dominant Brain Waves in Specified Frequencies Range

The electroencephalogram (EEG) enabled the connection amid brain characteristics and personality domains to be examined whereas studies discovered an affirmative association amid EEG alpha attention and extraversion generally in the frontal span of the brain [7] [8]. In analyzing the EEG band power, extraverted persons always displayed the highest measure while in introverted, lower measure was detected [7]. Meanwhile, for those with higher extraversion scores, a relatively large left frontal activity was predicted for them. In such a way, extraverted persons in a state of repose showed a raised blood stream in the left frontal region [9].

II. The Methodology In Action

The methodologies adopted in this research mainly to cater for the participants' data collection in term of their Learning Style and EEG. Along the way, the signal processing exercise such as a single EEG band analysis and feature extraction of Brain Asymmetry were introduced. Statistical analysis was carried mostly to support the clustering process. The methods embraced have proven efficacy as being demonstrated in previous studies [26, 27].

A. Participants

The participants (N=41) comprised first year students who were pursuing undergraduate degree at Sultan Idris Education University (UPSI), Malaysia. Participation was brought in by voluntarily basis. The participants are divulged across the hardware and procedure individually and were presented with result on their scores subsequently when the whole participants had been examined.

B. Kolb's Learning Style Inventory

The instrument used to determine participants' LS in this study is Kolb's Learning Style Inventory (KLSI) which comprised a 12-item self-report questionnaire based on KLSI Workbook version 3. The KLSI established in 2005 as an upgraded instrument to the previous KLSI versions. [15]. Participants are needed on each of the questions to rank (1, 2, 3 or 4) to statements tallying to each of the four learning. The rank scales are contemplative of CE, RO, AC and AE score. LSI scores may be combined in particular pairs to derive a new score for each learning style bi-polar proportion as AC-CE (AC minus CE) and AE-RO (AE minus RO), hence providing individual emplacement on these two proportion, to be plotted and grouped in agreement to the particular learning style of Diverger, Assimilator, Converger or Accommodator.

C. EEG Acquisition

EEG recordings were made in dedicated room where participants were seated in a comfortable armchair. The room temperature was set at ranged of 22 to 23 degree Celsius. MindPeak's WaveRider and its corresponding hardware (See Fig. 3) and WaveWare software were used for EEG data acquisition (See Fig. 4) EEG was recorded from the positions Fp1and Fp2 according to the international 10–20 system and referenced to the left earlobe. The recording was in 0.15 – 40 Hz band range with a sampling frequency of 128 Hz. All electrodes impedances were less than 5 kΩ. Each participant was put through a baseline recording (Open eyes and closed eyes, 5 minutes respectively) [28]. They were given 30 seconds break between sessions and were continuously monitored in order to ensure that

they were following the instructions to minimize the eyes and body movement to avoid unnecessary EEG artifacts. The EEG bands Power Spectrum Density (PSD) values were then processed off-lined using MATLAB.

Fig. 3: (L-R) WaveRider, Head Electrodes and Ear Electrodes

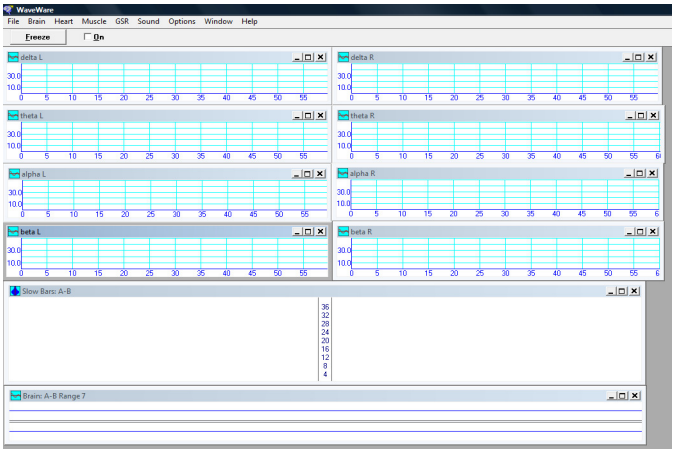

Fig. 4: WaveWare Interface With Pre-set Configuration

D. *Brain Asymmetry*

The brain asymmetry score was used to indicate greater left or right hemisphere activation of the human brain. Several approaches are adopted by researchers to infer the brain waves asymmetry scores, for instance by using the transformation log of brain power in the left hemisphere minus the power in the right hemisphere [log(Pleft) – log(Pright)], natural log of left power minus the natural log of right power [ln(Pleft) – ln(Pright)] [29] and by calculated the asymmetry relation ratio (ARR), [(Pleft-Pright)/(Pleft+Pright)] [30, 31]. The ARR formula was selected to be used in this research. The positive value of ARR indicated left brain hemisphere dominant whereas negative value shows right brain hemisphere dominant [32].

E. *Statistical Analysis*

SPSS TwoStep clustering utilized mainly for the analysis of large data sets was introduced by Chiu, Fang, Chen, Wang and Jeris [33]. The statistical module consists of two steps :

- Pre-clustering of cases. A successive approach is used to pre-cluster the cases. The objective is to calculate a new data matrix with lesser case for the next step. In order to reach this aim, the computed pre-clusters and their features are used as new cases. The pre-clusters are defined as dense regions in the analyzed attribute space. The number of pre-clusters relies on three parameters of mxbranch, mxlevel and inittreshold.
- Clustering of cases. A model based hierarchical technique is implemented. Correspond to agglomerative hierarchical techniques, the pre- clusters are unified stepwise until all clusters are in one cluster.

III. RESULT AND DISCUSSION

A. *LS Grouping*

The participants' LS grouping after the execution of Kolb's LSI is shown in Table II.

The participants were distributed almost equally in each LS which Assimilator with 12 persons, followed by Diverger (11 persons), Accommodator

(10 persons) and the least was Converger with 8 persons.

TABLE II. PARTICIPANTS' LS GROUPING USING KLSI

LS	No. of Participants
Diverger	11
Assimilator	12
Converger	8
Accomodator	10

B. EEG Analysis

The EEG bands were analyzed statistically using SPSS 2 Steps Cluster analysis module mainly for two purposes : 1. To obtained the clustering of LS and 2. To compare the cluster's mean value. The clusters were fixed into two based on the groups of personality traits stated by Kolb[15].

From the literature, Alpha band is shown to be positively correlated to Extraversion [35]. This finding leads to a reliable prevision that based on EEG, the highest mean Kolb's LS is related to Extraversion. Meanwhile, the positive value obtained from the LS's ARR shown left hemispheric dominant which also related to the condition of Extraversion [36].

1) Open eyes : Alpha Left and Alpha Right

TABLE IV. CENTROID VALUES FOR RESPECTIVE CLUSTER

EEG bands	Cluster	Mean	Std. Deviation
Open Eyes Alpha Right	1	310.0459	189.03556
	2	259.8495	192.30176
Open Eyes Alpha Right	1	317.9599	173.84000
	2	285.8440	258.31383

Table III shows the LS clustering using EEG Alpha Left and Right at Open Eyes. 100% clustering achieved for each LS. In Open Eyes Alpha Left, Converger and Accommodator were in Cluster 1 and Diverger and Assimilator were in Cluster 2. The same clustering pattern found in Open Eyes Alpha Right condition.

Table IV shows the centroid value for every cluster. In both condition, Cluster 1 was determined with the higher mean value of 310.0459 and 317.9599 respectively. This situation indicated that for both condition, LS in Cluster 1, Converger and Accommodator are the Extraversion- bound LS.

TABLE III. LS CLUSTERING BY EEG

EEG bands	LS	Cluster #	Count	% of Classification
Open Eyes Alpha Left	Diverger	2	11	100
	Assimilator	2	12	100
	Converger	1	8	100
	Accommodator	1	10	100
Open Eyes Alpha Right	Diverger	2	11	100
	Assimilator	2	12	100
	Converger	1	8	100
	Accommodator	1	10	100

* Shaded – Extraversion LS

2) Closed eyes : Alpha Left and Alpha Right

LS clustering using EEG Alpha Left and Right at Closed Eyes is shown by Table V. In both EEG bands, 100% clustering had been achieved for each LS. In Closed Eyes Alpha Left, Diverger and Assimilator were in Cluster 1 whereas Converger and Accommodator were in Cluster 2. Meanwhile in Closed Eyes Alpha Right, Assimilator and Converger were grouped in

Cluster 1 and Diverger and Accommodator in Cluster 2.

The centroid value for every cluster is shown in Table VI.. In both condition of EEG Alpha Left and Right, Cluster 2 was found with the higher mean value of 294.5367and 269.1211respectively. These findings evidenced that for Closed Eyes Alpha Left, Converger and Accommodator are the Extraversion-bound LS. On the other hand, Diverger and Accommodator are the LS concerned for Closed Eyes Alpha Right condition.

TABLE V. LS CLUSTERING BY EEG

EEG bands	LS	Cluster #	Count	% of Classification
Closed Eyes Alpha Left	Diverger	1	11	100
	Assimilator	1	12	100
	Converger	2	8	100
	Accommodator	2	10	100
Closed Eyes Alpha Right	Diverger	2	11	100
	Assimilator	1	12	100
	Converger	1	8	100
	Accommodator	2	10	100

Shaded – Extraversion LS

TABLE VI. CENTROID VALUES FOR RESPECTIVE CLUSTER

EEG bands	Cluster	Mean	Std. Deviation
Closed Eyes Alpha Left	1	182.8705	179.46837
	2	294.5367	270.89122
Closed Eyes Alpha Right	1	211.9895	237.36241
	2	269.1211	212.86263

3) Open Eyes and Closed Eyes : Alpha ARR

Table VII shown the clustering of LS using EEG Alpha ARR in both condition of Open Eyes and Closed Eyes. Each LS had been successfully 100% grouped into two clusters. In Open Eyes Alpha ARR, Diverger and Accommodator were classified in Cluster 1 whereas Cluster 2 consisted of Assimilator and Converger. Meanwhile in Closed Eyes Alpha ARR, Diverger and Converger were grouped in Cluster 1 and Assimilator and Accommodator were sorted in Cluster 2.

The centroid value for every cluster is shown in Table VIII.. In both condition of ARR, Cluster 2 was found with the higher mean value of 0.0053and 0.1410 respectively. This findings evidenced that for Open Eyes Alpha ARR, Assimilator and Converger are the Extraversion-bound LS. Meanwhile for Closed Eyes Alpha ARR, Assimilator and Accommodator are the LS considered as Extraversion-bound.

TABLE VII. LS CLUSTERING BY EEG

EEG bands	LS	Cluster #	Count	% of Classification
Open Eyes Alpha ARR	Diverger	1	11	100
	Assimilator	2	12	100
	Converger	2	8	100
	Accommodator	1	10	100
Closed Eyes Alpha ARR	Diverger	1	11	100
	Assimilator	2	12	100
	Converger	1	8	100
	Accommodator	2	10	100

Shaded – Extraversion LS

TABLE VIII. CENTROID VALUES FOR RESPECTIVE CLUSTER

EEG bands	Cluster	Mean	Std. Deviation
Open Eyes Alpha ARR	1	.0015	.11331
	2	.0053	.32900
Closed Eyes Alpha ARR	1	-.2496	.37119
	2	.1410	.26641

IV. CONCLUSION

EEG Alpha band and its asymmetry score were chosen to relate between the Kolb's LS and Personality Traits of Extraversion. Throughout the experiment, 100% LS classification achieved in all conditions of the EEG band mentioned. The Extraversion LS is decided upon the cluster with highest means and inclined towards left brain hemisphere dominant condition.

Table VII shows the result summary attained from the study. It has been found that comparing to Kolb [15], the first three EEG Alpha experiments had precisely detected Converger and Accommodator as the LS correlated to Personality Traits of Extraversion. As for the rest of the experiment, Accommodator correctly specified as Extraversion LS for Closed Eyes at Alpha Right and Closed Eyes ARR. Meanwhile, Converger was correctly detected as Extraversion LS using Open Eyes Alpha ARR. As such, Converger and Accommodator pair are the best Extraversion-bound LS detected throughout the experiment where only the Alpha ARR giving an exception.

In conclusion, Open Eyes Alpha Left, Open Eyes Alpha Right and Closed Eyes Alpha left were the best EEG bands for detecting Kolb's Extraversion LS as its gave perfect match to Kolb's hypothesis. So, this study was successful in giving a clearer benchmark for the selection of EEG bands to relate both domains. Larger number of participants should be the next target for continuity of this study to achieve better generalization. The LS of Assimilator which surfaced twice during the experiment should be investigated further as to ascertain its relation to Extraversion.

TABLE IX. OVERALL RESULTS SUMMARY

#	EEG/ARR	Cluster %	LS
1	Open Eyes Alpha Left	100	Converger, Accommodator
2	Open Eyes Alpha Right	100	Converger, Accommodator
3	Closed Eyes Alpha Left	100	Converger, Accommodator
4	Closed Eyes Alpha Right	100	Diverger, Accommodator
5	Open Eyes Alpha ARR	100	Assimilator ;Converger
6	Closed Eyes Alpha ARR	100	Assimilator, Accommodator

Shaded – match to Kolb's

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Nazre bin Abdul Rashid received his Bachelor and Masters degree in 1996 and 2004 respectively, both in Computer Sciences field. Mr. Nazre works as a lecturer and attached to the Computing Department at the Faculty of Arts, Computing and Creative Industry, Sultan Idris Education University, Malaysia. He is one of the recipient of Malaysian government prestigious scholarship prize and currently working toward PhD degree at Advanced Signal Processing Research Group (ASPRG), Universiti Teknologi Mara, Malaysia under the tutelage of Professor Dr. Hj. Mohd. Nasir bin Taib. Mr. Nazre is a reviewer for several conferences and has published a number of papers, including one that had received university and Ministry of higher learning sponsorship to be presented at Istanbul, Turkey in 2011. Mr. Nazre research interests lie predominantly in Electroencephalogram (EEG) technology, Brain signal processing, Learning Style and Personality Traits. He is enthusiastic about researching new frontier to link the domains which he believed could impart a huge benefit to mankind.