Biometric Evaluation of Anxiety in Learning English as a Second Language

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Abstract
Biometrics is the recognition process based on one or more intrinsic anatomical, physiological and psychological characteristics. Recently, computational bio-electrography based on gas discharge visualization (GDV) technique has been proposed as one of the biometrics tools for investigating physiological and psycho-emotional functional states of an individual. In this paper, we present an application of computational biometrics based GDV for visual and quantitative evaluation of anxiety in the process of learning English as a Second Language (ESL). The integration of biometrics in the education paradigm has been investigated in a pilot study involving foreign students enrolled in the ESL course at the ESL Institute, Jackson State University. We measured the electro-photonic emission (also called GDV-grams) of students' fingertips before and after language activities, specifically listening comprehension tasks and showed that the anxiety index in listening comprehension paradigm corresponds to the increase of entropy level of left hand corresponding to the right hemisphere. Our pilot data confirms the recent findings of correlation of right hemisphere involvement in second language acquisition at the level of language proficiency. Thus, computational biometrics based GDV tool may be used to evaluate and potentially identify anxiety present in ESL learners.

Key Words
Biometrics, Bio-electrography, GDV technique, Anxiety, ESL, Entropy, Right hemisphere

1. Introduction

Biometrics is an automated process of recognizing the individual features based on one or more intrinsic anatomy, physiology and psychological characteristics. A typical biometric system is comprised of 5 components: a sensor, signal processing algorithms, data storage, a matching algorithm and a decision process. The purposes of the biometric models are recognition, identification and verification. Recognition is knowledge of a previously enrolled individual; identification is the process of determining the identity of an individual, where as verification is a process by which the system confirms the existence of an individual. The biometric models existing nowadays are based on fingerprint, face, iris, voice, signature, hand geometry, palm and vascular pattern recognition, performance evaluation and novel sensors [1; 2]. For example, the palm and fingerprint models combine ridge flow, ridge characteristics and a ridge structure of the raised portion of the epidermis. Vascular pattern recognition models use near-far infrared light reflected or transmitted images of blood vessels of a hand or finger for personal recognition. Dynamic models use anatomic and behavioral characteristics for recognition purposes [3]. There exist other biometric models that are based on speaker recognition, dynamic signature measures, key stroke dynamics, retina recognition, gate/body recognition and facial thermography.

The main areas of biometrics applications can be classified into the following four groups: 1) Medical biometrics, which is related to the use of biometrics in medical applications such as medical diagnosis and is based on the extraction of biomedical pattern and its association to possible diseases; 2) Forensic biometrics, which refers to the use of biometrics for criminal and body identification; 3) Convenience biometrics, which is related to maintaining the convenience level during the use of biometric services, 4) Security biometrics to reduce frauds and control the access to restricted areas [4].

Computational bio-electrography has been recently proposed and used as a promising method for complex evaluation of the functional state of an individual using the fingertips and electro-photonic emission in a high intensity electromagnetic field [5]. The method involves capturing and analyzing the electro-photonic emission of fingertips using an electro-photonic impulse analyzer based on gas discharge visualization technique (GDV) [5]. Several studies tried to determine what exactly forms the fluorescent glow (also called GDV-grams) around fingertips. Krizhanovsky et al. [6] determined that the human central nervous system plays a crucial role in the formation of skin glow in a high intensity electromagnetic field. The ATP (Adenosine Tri-Phosphate) molecule acts as a neurotransmitter in the autonomous neuromuscular junctions, the ganglia and the central nervous system. Therefore, in case of normal operation of the organism,

Manuscript received January 5, 2010
Manuscript revised January 20, 2010

the ATP diffusion exchange (and the electron stream) must be regular, thus ensuring the regularity and uniformity of the fluorescence (glow) that occurs during the interaction of the skin (i.e. of a finger) with the high intensity electromagnetic field. Another study conducted by Williams [7] claims that specific structural-protein complexes within the mass of the skin provide channels of heightened electron conductivity, measurable at acupuncture points on the skin surface. Stimulated impulse emissions from the skin are also developed mainly by transport of delocalized electrons. Optical emissions amplified in gaseous discharge, are registered by optical sensors in the electro-photonic impulse analyzer [7]. The areas of application of GDV technique include medicine, sports, psychology and cognitive study. The correlation of GDV data and the data obtained from the other diagnostic devices showed that GDV is a very fast, at the same time, accurate real-time diagnosis technique [8-12].

The GDV technique has been successfully used in psychology and cognitive studies mainly to assess the psycho-emotional state of an individual and evaluate the changes that take place in a human organism over a period of time. Based on GDV parameters such as form and size of electro-photonic emission, symmetry and relationship of the captured image with the rest of the GDV-grams of all fingertips, the presence or absence of aggressive signs and defects with the organs/organ systems can be predicted and hence it becomes possible to conclude about the functional state of an individual at the moment of study [13; 14].

Second language learning is a process by which a person learns a language in addition to his/her native language. English is the current lingua franca for communication in the modern era of globalization and has been widely studied for adaptation as an international language [15]. In the United States of America, a majority of the population speak English as their native language. International students usually experience cultural shock when they are exposed to a native English environment, such as the United States, and it takes time for them to overcome the language barriers. It has been demonstrated that native English speakers perform significantly better than non-native English speakers in all the major subtests (on Writing, Reading and Listening) of an English Language Proficiency test [16]. The relatively poor performance of non-native speakers of English is mainly attributed to anxiety, which is a prominently documented psychological phenomenon in second language learning. It has been recently reported that one third to one half of international students experience debilitating levels of anxiety while performing in their second language [17].

The anxiety phenomenon in the field of second language learning has been the focus point of different studies and research projects. It has been established that (i) anxiety can occur at any stage of language acquisition and can influence speed and accuracy of learning, (ii) language anxiety can be one of the predictors of language proficiency, (iii) learners with higher language anxiety avoid interactive communication more often than less anxious learners, (iv) anxiety arousal can negatively influence the communication output as it can be interrupted by the “freezing up” moments which learners experience when they are anxious, (v) language learning under anxious circumstances can become traumatic to the identity of a learner [18]. Young [19; 20] determined several aspects as potentially interrelated sources of anxiety from the perspective of the learner, the teacher and instructional process. Therefore, he claims that the possible causes of anxiety may be (i) personal and interpersonal anxiety, (ii) learner beliefs about language learning, (iii) instructors beliefs about language teaching, (iv) instructor-learner interactions, (v) classroom procedure and (vi) language testing.

In this paper, we hypothesize that language activities such as listening comprehension, speaking, reading and writing may involve anxiety factor which can be quantified and visualized using the GDV method. The psycho-emotional aspects of language learning and performance, such as anxiety and stress, are manifested at the physiological level by increased sweating of palms and fingers and muscle tension. An electro-photonic impulse analyzer based on GDV can make use of these manifestations, especially those revealed through the fingertips, for quantifying and visualizing the anxiety level of an ESL (English as a Second Language) learner. The GDV technique is non-invasive and provides a real-time measurement of the signals of the sympathetic and parasympathetic nervous system [21]. Thus, using this biometric model of GDV, one will be able to quantify and visualize unique biological features in psychological and physiological parameters pertaining to anxiety with respect to ESL learning. The rest of the paper is organized as follows: Section 2 reviews the literature on relationship between learning English as a second language and anxiety. Section 3 provides an overview of the origin of computational bio-electrography based on the GDV technique and describes the actual procedure used to obtain the GDV-grams. We also describe the analysis of the GDV-grams using the built-in GDV software of the Electro-photonic impulse analyzer. Section 4 describes a pilot study, the first of its nature, which has been conducted by us to quantify and visualize the anxiety levels of the student learners of English as a second language at Jackson State University. Section 5 concludes the paper.

2. English as a Second Language and Anxiety

With the increase of popularity of English language in the world and its usage in almost all spheres of social, economic and cultural life, the need to learn English as a Second Language (ESL) has increased among the populace whose native language is other than English. The education goals pursued by non-native students in English speaking countries, like the United States of America, require certain level of English language proficiency which can be achieved through preparation and taking a TOEFL test. Some students have to start English study from the beginner's level and advance slowly due to the peculiarities in their cultural background. For example, it has been established that English language learners from Confucian Heritage Cultures (CHCs), such as China, Korea and Japan, are more anxious when learning, performing and communicating in ESL [22]. It is a very challenging task for teachers and counselors in U.S. schools to address the specific needs of the students for whom English is not a native language.

Scovel [23] was the first to associate the inconsistency in second language learning with anxiety. Horwitz was the first to clearly define the concept of foreign language anxiety. Horwitz's Foreign Language Classroom Anxiety Scale (FLCAS) was the major contribution to the field of second language learning and acquisition [24]. The major ways of anxiety measurement include behavioral observation, physiological assessment such as heart rates and blood pressure, learners' self-report on their internal feelings and reactions as well as structured interviews, follow-up interviews and questionnaires [25; 26]. The negative relationship between anxiety and achievement or performance has been confirmed in several subsequent studies involving all four language skills: speaking [27-29], writing [30], reading [31] and listening [32; 33].

A student who suffers from reading anxiety can exhibit a variety of symptoms that result from the inhibition of their intellectual curiosity, aggression or independence. It has been shown [34] that (1) reading anxiety shows a stronger negative correlation with reading achievement compared to general anxiety; and (2) although general anxiety and reading anxiety correlate substantially, reading anxiety measures something beyond general anxiety. Listening anxiety is a type of anxiety that comes from listening to others, such as in a foreign language situation. Thus, listening anxiety may negatively influence the learning process and affect performance [35].

Foreign language learners typically experience considerable anxiety about taking listening tests. The results in [36] indicated that foreign language anxiety and listening anxiety are separate but related phenomena that both correlate negatively with achievement. An English Writing Anxiety Scale was developed in [37] and it identified four contributing factors for writing anxiety in English: fear of writing tests, anxiety about making mistakes, fear of negative evaluation and low confidence in English writing. The results have showed that the scale has adequate psychometric properties. Another study [38] evaluated the anxiety of students over a ten year period, using FLCAS. The FLCAS scores measured the students' perception about their language learning skills and showed that anxiety plays a primary role in performing and successfully accomplishing using a foreign/second language.

The first attempt [39] to use GDV technique in education was realized in the experiment to teach listening skills in English as a foreign language. The eyes of the student participants in this experiment were closed. The GDV technique was used to assess the functional state of the individuals and the biological dynamics in the process of perception and processing the information in English [39]. In 2007, Bulatova et. al. [40] reported the results of investigation of school children with GDV technique. According to the interpretation of the GDV-grams obtained in their studies, only 36% of children had normal psycho-emotional and physiological state; 42% have shown deficiency in electro-photonic emission and 17% were in a critical state. A positive correlation was found between the level of performance of the students and the results of GDV test. Children with deficiency in electro-photonic emission had lower performance level. Due to the active effort of psychologists, family, teachers and children themselves, over a five month period of counseling, regime, daily exercise and correct nutrition, 82% of children had their electro-photonic emission in the normal range. This experience has established that GDV technique can be helpful in education process, mainly because of instant and real-time assessment of the functional state of an individual and also anxiety and stress that accompany a learning process. Taking cue from this research, we will employ the GDV method to identify the unique physiological and psycho-emotional signatures associated with anxiety in ESL learning process.

3. Computational Bio-electrography Based on Gas Discharge Visualization Technique

The first world-wide discoveries of the phenomenon of bright fluorescence around human body in a high frequency electrical circuit belong to Nicola Tesla in 1880. The understanding of the significance of this discovery began in 1939 when Russian technician Semion Kirlian noticed the florescence around his fingers when repairing the high frequency equipment in the hospital. He and his wife Valentina investigated this "mysterious glow" till 1978 and it became famous under the name of "Kirlian Photography". During the 1980s, different approaches for the applications of bio-electrographic technique in medicine were developed (e.g., by Dumitresku I. in Romania, Mandel P. in Germany, Milhomens N. in Brazil, Lerner A. in France, Oldfield H. in England, Konikevich A. in the USA and many others). Many books and research articles have been published on Kirlian Photography and statistical correlations with interesting observations worldwide. In 1995, the Gas Discharge Visualization (GDV) technique, based on optical methods, modern electronics and computer processing of data, gave a new dimension to Kirlian Photography and lead to the foundation of a new scientific field called computational bio-electrography.

Figure 1: A Setup of the Electro-photonic Impulse Analyzer Operated through a Laptop

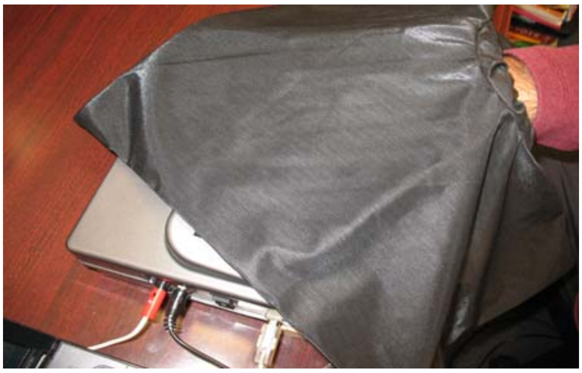
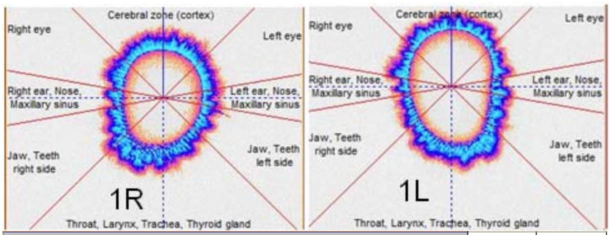
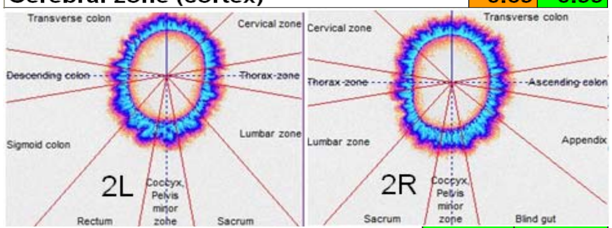


Figure 2: Actual Procedure of Covering the Hand with a Black Cloth for EPE Capture

The GDV assessment of the functional state of an individual comprises of static snapshots (also called GDV-grams) of the electro-photonic emission (EPE) of the 5-fingers from each hand (a total of 10 finger EPE snapshots) which are collected with and without using filters on the glass surface of the Electro-photonic Impulse Analyzer. The filter is a thin plastic film that prevents the direct contact of the skin of the fingertip on the glass surface of the analyzer. The rationale behind using the filter is to capture the EPE that represents the physiological parameters of the person; whereas, the EPE captured without using the filter represents the psycho-emotional parameters of the person. Figure 1 demonstrates a setup of the Electro-photonic Impulse Analyzer operated through a laptop and Figure 2 illustrates the actual procedure of covering the hand with a black cloth to prevent the penetration of light onto the glass surface. A GDV-camera underneath the electrodes captures the EPE (i.e., GDV-grams) of the fingertips placed on the glass surface of the analyzer.



Organs/ Body Systems	Left	Right
Right eye	0.05	0.11
Right ear, Nose, Maxillary sinus	-0.03	0
Jaw, Teeth right side	-0.18	0.28
Throat, Larynx, Trachea, Thyroid gland	-0.12	0.11
Jaw, Teeth left side	0.03	-0.08
Left ear, Nose, Maxillary sinus	-0.02	0.06
Left eye	-0.1	0.04
Cerebral zone (cortex)	-0.69	0.99



Sacrum	0.03	0.07
Coccyx, Pelvis minor zone	0.09	-0.06
Blind gut		0.04
Appendix		0.02
Ascending colon		0.16
Transverse colon	0.21	1.39
Descending colon	0.09	
Sigmoid colon	0.11	
Rectum	0.16	

Figure 3: Sample GDV-grams of the Thumb and Index Fingers on the Left and Right Hands illustrating the Different Sectors representing the Organ Systems and their Energy Coefficients (L – Left, R – Right)

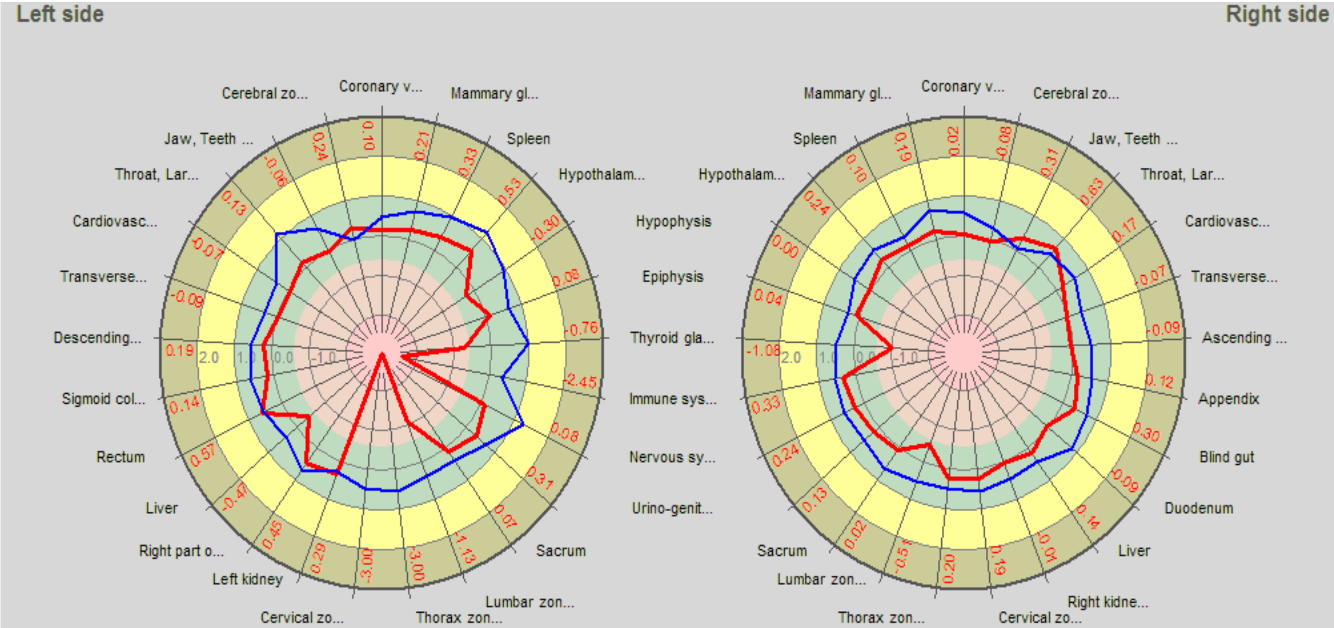


Figure 4: A Sample GDV-diagram obtained using the static GDV-grams of the 10 fingertips

The electro-photonic impulse analyzer has an in-built GDV-software to analyze the GDV-grams. The GDV-software quantifies the activity status of the different organs/organ systems in the form of energy coefficients. The energy coefficient of an organ/ organ system in a GDV-gram is characteristic of the energy state (i.e., the activity) of the organ/ organ system and is obtained by normalizing the image to the standard GDV-grams. The GDV software that computes these numerical energy coefficients has been pre-calibrated with the standard GDV-grams collected from about 10,000 people with normal health. The range of the energy coefficient values for an organ/organ system in normal state is [-0.6, … , 1.0]; whereas, the organs/organ systems with energy coefficient values below -0.6 are said to be hypo-functional (low energy) and organs/organ systems with energy coefficient values greater than 1.0 are said to be hyper-functional (excess energy). Figure 3 illustrates the GDV-grams obtained for the (1) thumb and (2) index fingers on the left (L) and right (R) hands for a human subject. The energy status observed for the organs/organ systems has been visualized (in Figure 3) by highlighting their energy coefficient values in green, pink and yellow colors – representative of the normal, hypo-functional and hyper-functional states respectively.

Using the energy coefficients obtained from the GDV-grams of all of the fingertips from the left and right hands, the GDV-software constructs a GDV-diagram that presents a comprehensive view of the energy states of all the organs/organs systems. The GDV-diagram of a person (a sample is shown in Figure 4) is represented using two curves (of red and blue color) and each of these curves is divided into different sectors whose radius correspond to the energy coefficient values observed for the sector. Each sector in the GDV-diagram is characteristic of a particular organ/organ system. The curve with the red color represents the GDV image taken without using the plastic filter and it captures the functionality of the organs/organ systems characteristic of the psycho-emotional status of an individual. The curve with the blue color represents the GDV image taken using the filter and it captures the functionality of the organs/organ systems characteristic of the physiological status of the individual. For better visualization of coefficient distribution, the circles are presented in three colors: pink, green and yellow corresponding to the levels below norm (i.e., hypo-functional), norm (normal) and above norm (hyper-functional) respectively.

In addition to static snapshots of the fingertips, one could also collect dynamic GDV-grams to monitor the changes in the physiological and psycho-emotional states of a person while performing a particular activity. The dynamic GDV-grams can be used to monitor an individual over a period of time during certain activities such as watching a video, test, public speaking; investigate the psycho-physiological dynamics that may take place and correlate them with the content. The GDV-grams are a series of static snapshots of the fingertips collected at a regular interval. In Figures 5 and 6, we show a sequence of GDV-grams (collected for every minute), illustrating the energy status changes of non-native and native speakers while watching a 3-minute movie in English. A visual interpretation of the two sets of GDV-grams indicates that the non-native speakers undergo serious changes in their energy states while watching a movie that affects their emotional anxiety, while there are no significant changes in the energy states of the native speakers watching the same movie.

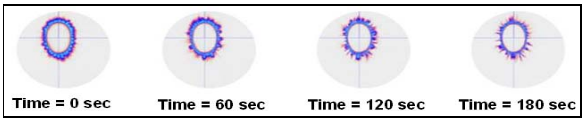


Figure 5: Dynamic GDV-grams of a Non-native Speaker while Watching a Movie in English

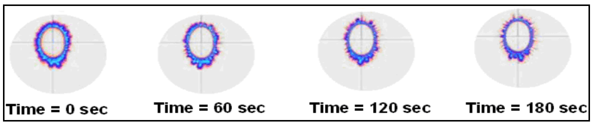


Figure 6: Dynamic GDV-grams of a Native Speaker while Watching a Movie in English

4. Pilot Study of ESL Learning Process Using GDV Technique

Four international students of Turkish, Vietnamese and Chinese origin (right hand dominant) at the English as a Second Language Institute (ELSI), Jackson State University, volunteered to participate in our study. We have chosen to initially study auditory comprehension anxiety because of our conjecture that listening skill is the hardest to master in second language learning. Our hypothesis in this pilot study is that being non-native speakers, these individuals will have increased expression of anxiety associated with language tasks in English, especially with the listening comprehension section. All the students were enrolled in the medium level of English as a Second Language course at ELSI. The students signed the consent form in compliance with the human Institutional Review Board (IRB) and the purpose of the procedure was explained to them according to the guidelines of the human IRB. Seven individuals were recruited and participated in the first phase of GDV recordings; however, only four participants completed the experimental protocol. Three students did not show up because of lack of understanding of instructions given in English language.

We recorded two sets of the static images of electro-photonic emission around the students' fingertips in a high intensity electromagnetic field generated by electro-photonic impulse analyzer, before and after the listening comprehension tasks.

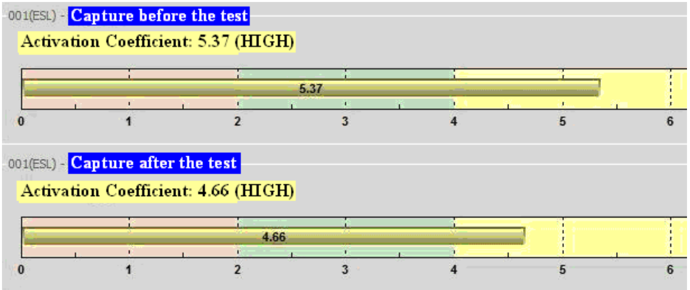


Figure 7.1: Activation Coefficient for Student 1

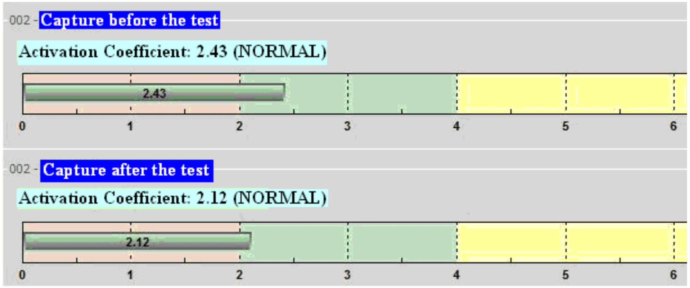


Figure 7.2: Activation Coefficient for Student 2

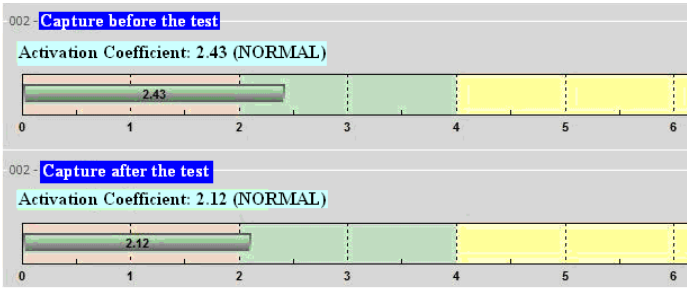


Figure 7.3: Activation Coefficient for Student 3

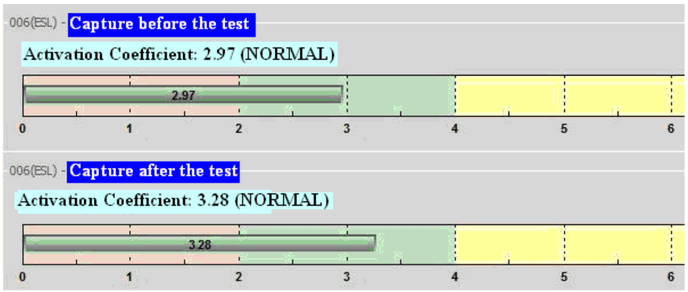


Figure 7.4: Activation Coefficient for Student 2

Figure 7: The Distribution of the Activation Coefficient in the Four ESL Participants Before and After Taking the Listening Test

The recording of the images was done with and without filter. Two integral parameters, activation coefficient and integral entropy, were analyzed and were considered as potential indicators for the measure of anxiety of the student participants. According to Korotkov

[5], activation coefficient is an average of the absolute magnitude of difference of the energy coefficients of diagrams created using GDV images captured with and without filter taking corresponding dispersions.

The proposed 0-10 scale of anxiety based on the activation coefficient is divided into four main parts: 0-2 (low level of anxiety), 2-4 (normal level of anxiety, 4-8 (high level of anxiety) and 8-10 (distress, altered state of consciousness). The activation coefficient of the four ESL participants before and after taking the listening comprehension test is shown in Figure 7. As seen in this figure, the activation coefficient of three of the four participants was high before the test and low after the test. The activation coefficient of these participants decreased from 5.37 to 4.66 (a 13% decrease), 2.43 to 2.12 (13% decrease) and 5.42 to 2.06 (62% decrease). For the fourth participant, the activation coefficient increased after the test (from 2.97 before the test to 3.28 after the test – 10% increase). We would expect the anxiety to go up after the listening comprehension activities. However, for 3 out of the 4 ESL participants, we do not observe an increase in the activation coefficient after the listening test.

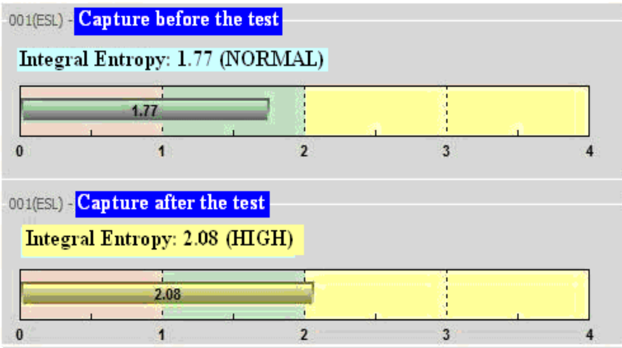


Figure 8.1: Integral Entropy for Student 1

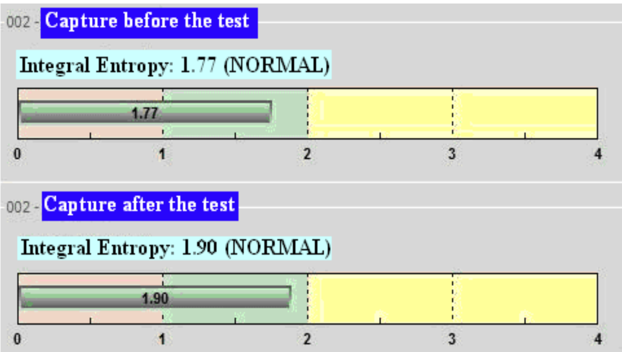


Figure 8.2: Activation Coefficient for Student 2

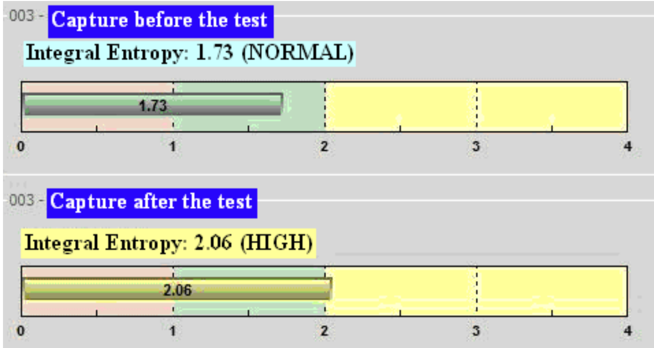


Figure 8.3: Integral Entropy for Student 3

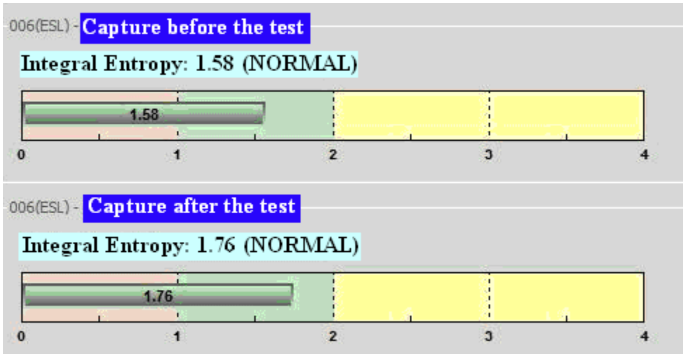


Figure 8.4: Activation Coefficient for Student 4

Figure 8: The Distribution of the Integral Entropy in the Four ESL Participants Before and After Taking the Listening Test

Thus, the proposed anxiety scale 0-10 after Korotkov cannot be used for the evaluating anxiety in the ESL listening comprehension task, though we do not exclude the possibility of using the activation coefficient as a measure of evaluating anxiety for other language activities such as speaking, reading and writing.

On the other hand, the distribution of integral entropy has shown very promising results. Integral entropy is a measure of the deviation from the physiological and psycho-emotional balance. The proposed scale of anxiety based on integral entropy is divided into four main parts: 0-1 (low level of anxiety), 1-2 (normal level of anxiety, 2-4 (high level of anxiety) and > 4 (very high level of anxiety). As presented in Figure 8, the integral entropy level of all the four ESL participants, measured using the GDV-grams for the left hand corresponding to the right hemisphere of the human brain, increased after the test when compared to the values obtained before the test. The integral entropy level of the student participants increased from 1.77 to 2.08 (18% increase), 1.77 to 1.90 (7% increase), 1.73 to 2.06 (19% increase) and from 1.58 to 1.76 (11% increase). Hence, we contemplate on using integral entropy as a measure of the anxiety of learning English as a Second Language, at least for the listening tasks, vindicated by the results in our pilot study.

Our preference for integral entropy as a measure of anxiety is also justified by the following observations from the literature on Chaos/ Complexity Science and Second Language Acquisition [41] and the recent discovery in the literature that the right hemisphere is more involved in second language learners who are less familiar and less trained in the language [42].

According to Larsen-Freeman [41], language learning is a dynamic, complex, open, self-organizing, feedback sensitive task, and is constrained by strange attractors. It is complex, because a multitude of interacting factors are involved in the ESL learning process. Learning new vocabulary is a nonlinear process, for example, the student can listen to the text with familiar words and feel comfortable in performance, but the moment the teacher introduces new words, rather than making progress, the student's performance becomes less proficient, because after the introduction of new unfamiliar words, the system the student has constructed in his mind implodes. Therefore, orderly periods are very frequently followed by periods of chaos, especially when something new is introduced and students have to adjust a new content to their understanding and awareness. Order, eventually, can be restored through interaction with others. The integral entropy metric captures the fluctuations in the physiological and psycho-emotional parameters of the individual from an orderly status to a disorderly status and vice-versa.

The results of a very recent study demonstrated the significant difference between the proficiency level and hemisphere involvement in language processing. It has been shown that the right hemisphere of the human cerebrum is more involved and hence contributes to an increase in the entropy in second language learners with less experience and less training [42]. The results of our pilot study provide empirical evidence to the above finding and show that listening comprehension tasks in English as a Second Language activate functioning of the right hemisphere of the human brain, which is responsible for parsing and analyzing the semantic and phonetic characteristics of the language.

5 Conclusions and Future Work

Biometrics are used in the identification of unique features based on anatomical, physiological and psychological parameters of an individual. Computational Bio-electography based on GDV technique is a biometric tool to identify unique signatures expressed by individuals at physiological and psycho-emotional levels. Learning of English as a second language (ESL) is a process that is accompanied by anxiety, which can negatively influence the performance of students. In this paper, we have demonstrated the use of GDV to measure, quantify and visualize the anxiety levels of ESL learners. We identify the integral entropy measured by GDV as the appropriate parameter to quantify and visualize the increase in anxiety. As observed from the results of our pilot study, the integral entropy of an ESL learner who has gone through a listening comprehension task increases by 7%-18%. Our conclusion of the use of integral entropy, based on the images collected from the left hand corresponding to the right hemisphere, is also substantiated by recent findings on EEG (Electro-encephalogram) synchronization in the literature. Thus, GDV as a biometric tool may be used to study anxiety associated with ESL learning and in other areas of education.

We anticipate that the integral entropy can also be used to capture the anxiety levels of ESL learners for other language activities such as reading, writing and speaking and this will be verified in our future work. As part of future work, we would also develop computational models that can identify unique biological signatures that are characteristic of the anxiety level of an ESL learner for a particular language activity.

Acknowledgments

HC and RI acknowledge grants from National Center for Research Resources, National Institutes of Health (G12RR013459); and EPSCoR, National Science Foundation (EPS-0903787). The content is solely the responsibility of the authors and does not necessarily represent the official views of the funding agencies.

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