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Detecting learning disabilities based on neuro-physiological interface of affect (NPIoA)

Nurul Izzati Mat Razi[1], Abdul Wahab Abdul Rahman[2], Norhaslinda Kamarudin[3]
[1,2]Department of Computer Science, International Islamic University Malaysia, Malaysia
[3]Advanced Analytics and Engineering Centre, Faculty of Computer & Mathematical Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia

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ABSTRACT

Learning disability (LD) is a neurological processing disorder that causes impediment in processing and understanding information. LD is not only affecting academic performance but can also influence on relationship with family, friends and colleagues. Hence, it is important to detect the learning disabilities among children prior to the school year to avoid from anxiety, bully and other social problems. This research aims to implement the learning disabilities detection based on the emotions captured from electroencephalogram (EEG) to recognize the symptoms of Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD) and dyslexia in order to have early diagnosis and assisting the clinician evaluation. The results show several symptoms that ASD children have low alpha power with the Alpha-Beta Test (ABT) power ratio and ASD U-shaped graph, ADHD children have high Theta-Beta Test (TBT) power ratio while Dyslexia have high Left-over-Right Theta (LRT) power ratio. This can be concluded that the learning disabilities detection methods proposed in this study is applicable for ASD, ADHD and also Dyslexia diagnosis.

Corresponding Author:

Norhaslinda Kamaruddin,
Advanced Analytics and Engineering Center,
Faculty of Computer and Mathematical Sciences,
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.
Email: norhaslinda@fskm.uitm.edu.my

1. INTRODUCTION

Learning disability (LD) is a neurological processing disorder that affect the individual intellectual ability and can affect individual ability on writing, reading, listening, spelling, speaking, reasoning or even mathematical proficiencies. Since it is a developmental disorder, these difficulties could also affect their higher order thinking skills at the later stage of their life, such as; planning, organizing, long-term and short-term memory and attention. It is important to recognize and be aware of these learning disabilities early in order to have early intervention. Some of the learning disabilities, such as; Dyslexia, Attention Deficit Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD) if detected at an early stage can help improve the individual to lead a more normal life with early intervention.

Overdue learning disabilities intervention can affect individual growth potential thus affecting not only their academic abilities but also influencing their social abilities in interacting with other and their families. Students with learning disabilities if not properly diagnosed can show other similar type of disease instead of learning disorder which if detected early can help children to lead a more normal life and participating effectively in inclusive education. Children with learning disabilities tend to show some sign and symptoms when they are at primary school going age, unless otherwise parents with knowledge can detect them and get such children to be diagnosed with learning disability. In most cases parents ignore such disorder and accept them as part of children learning process which leads to such children having the disability

deteriorate with time. Teacher could also misapprehend them as being low self-confidence, poor self-esteem and incompetent. While some of the late diagnosis which discovered during their post-secondary school or even work may face a lot more difficulties coping their life that may trigger into the psychological and emotional problems, leading to stress anxiety and depression.

Although learning disability cannot be cured or fixed, as it is a lifelong issue, they could go through physical and psychological intervention in order for them to improve their sensory, daily life skills and others training that can allow them to lead a more normal life. Family or parents will be the best helper for the learning disabilities children in order to be successful person with the right support and intervention. Such intervention and training can encourage them to focus on their strengths, understand their learning or working difficulties, know their weaknesses and always support them to overcome their difficulties. Based on the problems and difficulties related with the late diagnosis of learning disabilities, it is top priority to find methods that could provide early identification or detection of the various learning disabilities.

Autism Spectrum Disorder (ASD) is a complex and heterogeneous developmental disorder associated with communication and behaviour difficulties. Generally, the symptom of an ASD appear after the toddler phase or later, as such the early detection could be difficult or almost impossible for parents to detect. An ASD tend to have difficulties in social and communication associated with the sensory problems that include the repetitive behaviour in which they cannot use their body and thoughts properly to respond to the social interaction. The spectrum disorder of autism can range from simple social disorder to even basic learning skills disorder that might affect their ability in learning even basic skills of their life. Children with ASD may have a wide range of problems, which could include attention problems, language processing difficulties, sensory issues, intense fears about ordinary objects and activities or anxiety and others communication skill problems. Recent study estimate ASD children to normal children ratio is often assumed as 4:1, however some systematic reviews and meta-analysis seems to indicate a ratio closer to 3:1 for the relative proportion of males having higher ratio then females due to disproportionate risk for not receiving any clinical diagnosis [1].

Attention Deficit Hyperactivity Disorder (ADHD) is one of the most common medical condition which not only affect children but also adults. In a comprehensive study of ADHD, several researches reported that the pooled estimation prevalence among adults and children who have been diagnosed with ADHD are 2.5 percent and 8.4 percent in United State based on the conducted survey [2, 3]. ADHD is a mental health disorder that can lead beyond the levels of inattentiveness, hyper activeness and impulsive behaviours. Most children may struggle in paying attention, listening and following instruction, sitting still or self-controlling but a child with ADHD tend to struggle even more and most of the time which can lead to other psychological disorder if not intervened at an early stage. ADHD have difference brain development and activities which can affects their attention and behaviour. Most children with ADHD are often diagnosed or identified after the school going aged as they keep making disruptions or problems in their school or even in public, thus delaying diagnosis or intervention. One of the research study highlighted that ADHD diagnosis are more common among male children rather than female which suggest that there is a sex bias in the receiving process of a clinical diagnosis for children with ADHD among female children in which the population show that males got higher scores for all symptoms domains of ADHD compared to females [4]. There are wide range of symptoms that are associated with ADHD which include difficulties to focus and concentrate in doing tasks, often being distracted or forgot about completing tasks, difficulties to sit still and often disrupting others which may cause problems at their school, home or social life. The ADHD diagnosis have been grouped into three types in order to make it more consistent by American Psychological Association (APA) which are predominantly inattentive, predominantly hyperactivity-impulsive, and a combination of predominantly inattentive and hyperactivity-impulsive [5].

Dyslexia is a learning disorder or also known as reading disability in which the language processing area of the brain being affected. Children with dyslexia can vary from mild to severe and often having normal vision, smart and hardworking, but they may have difficulties in spelling, slow in reading and mix-up words or letters. Dyslexia is a condition in which a person could be born with it or genetics. The symptoms of dyslexia could affect the person's ability to read, spell, write and speak. Even some adults may not realize that they have dyslexia as they may have discovered them at an older age and have been able to manage it through accidental exposure of the disorder. Children with dyslexia are often misunderstood of being interpreted as stupid or lazy as they may not be able to read and write well affecting their learning ability. Thus, such situation if not diagnose early may results in student is not able to cope with their studies and labelled as stupid or lazy. As a result, student with dyslexia becomes frustrated and can develop into depression due to their inability to cope with the learning. In addition, most dyslexic children will find difficulties in reading although most of them can achieve the average or high academic performance due to their hardworking and intelligence in overcoming their disabilities. Most dyslexic children who were detected at an early stage with proper intervention are found to lead a better future with the therapy, support and right ways to learn to

cope with their abilities as dyslexia used different parts of the brain compared to typically normal children in learning or reading.

Learning disabilities children with proper and focus intervention could managed and controlled their disabilities if intervention is carried out early could even lead them to have a more normal life. Such intervention although can be carried out at home by parents also need the conducive school environment to support, otherwise children with such learning disabilities can end up with depression, anxiety and stress [6]. Different learning disabilities need different ways of intervention and in some cases require a combination of intervention due to comorbid cases (where a child may be having more than one disability). It is inevitable that every child in preschool should be screened for early learning disabilities detection so that early diagnosis can provide early intervention for better treatment.

2. RESEARCH METHOD

In this paper we introduced the use of neuro-physiological Interface of affect (NPIA) using data from the electroencephalogram (EEG) to detect children with learning disabilities for ASD, ADHD and Dyslexia. NPIA is a frequency domain approach in analysing individual emotions based on the valence (V) and arousal (A) [1]. Data was collected at the Sungai Petani Hospital, psychiatric ward under the supervision of the psychiatrist of the hospital. All data were then analysed, which include pre-processing, feature extraction, labelling of set target, classification and detection. All the methods will be explained in detail in the next sections.

2.1. Data collection

Electroencephalogram (EEG) signals were measured among five years old to eleven years old children with learning disabilities and also typical (normal) developing children. There were altogether eight children participating in the data collection with five learning disabilities children and three typical developing children.

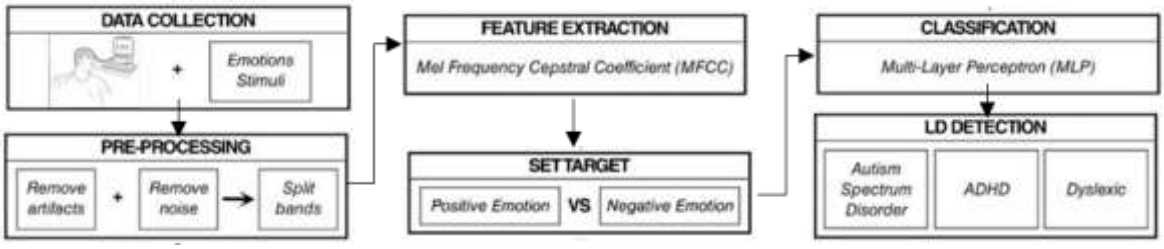

Figure 1. Research Methods

The learning disabilities children who participated are two ASD, two ADHD and one dyslexic children. The data were collected in a room at the Learning Disabilities Centre, of the psychiatric ward. The children need to fulfilled all the protocol given while watching the emotion stimuli which were positive emotions and negative emotions. The emotions stimuli were obtained from the International Affective Picture System (IAPS). Figure 1 shows the flow of the research methods, which start with data collection followed by data analysis. Data analysis will be explained in sub section 2.2.

2.2. Data analysis

The EEG data were analysed by using MATLAB software. All data were pre-processed to make sure that artifacts and unwanted noise were removed, and the EEG data were then split into five bands as shown by Figure 2. The artifacts may occur in the EEG signals due to involuntary muscle movement or eye blinking, jaw movement and making small movement with their cheeks. These will create the unwanted spikes and distortion in the interpretation of recorded signals [7] and must be eliminated. Elliptic filters were used to smoothen the raw EEG signals and also deriving the band pass filtering for the five different bands.

The frequencies implemented in this research study are delta (1-3Hz), theta (4-8Hz), alpha (9-13Hz), beta (14-25Hz) and also gamma (26Hz-40Hz). The processed EEG data were then used to extract features based on the Mel Frequency Cepstral Coefficients (MFCCs) technique which has been applied in several studies for brain signals analysis [8-10]. After features were extracted, at each instance target was labelled based on the emotions data used indicating positive emotion calm with labelled (1, -1) and for negative emotion (fear) with labelled (-1, 1) for valence and arousal (V, A) respectively.

There are also several proposed machine-learning methods for the EEG sub bands in assisting the diagnosis of learning disabilities based on different focus and analysis based on Discrete Wavelet Transform (DWT), Shannon Entropy Vector and also Artificial Neural Network (ANN) classifier [11]. Since our earlier work using the multi-layer perceptron (MLP) were suggested and has shown to be viable in this paper we will propose the use of MLP as the classification methods to identify the EEG emotions, addiction, behavior and others [8, 12, 13].

2.3. EEG learning disabilities detection

The affect analysis of the EEG data based on emotion differs greatly for different learning disabilities. As shown by Figure 2 different learning disability will used different method of detection depending on the previous study. Thus, it is important in this paper that all the three different type of learning disabilities of ASD, ADHD and dyslexia be detected. These will also be in line with the different intervention requirement for different learning disabilities.

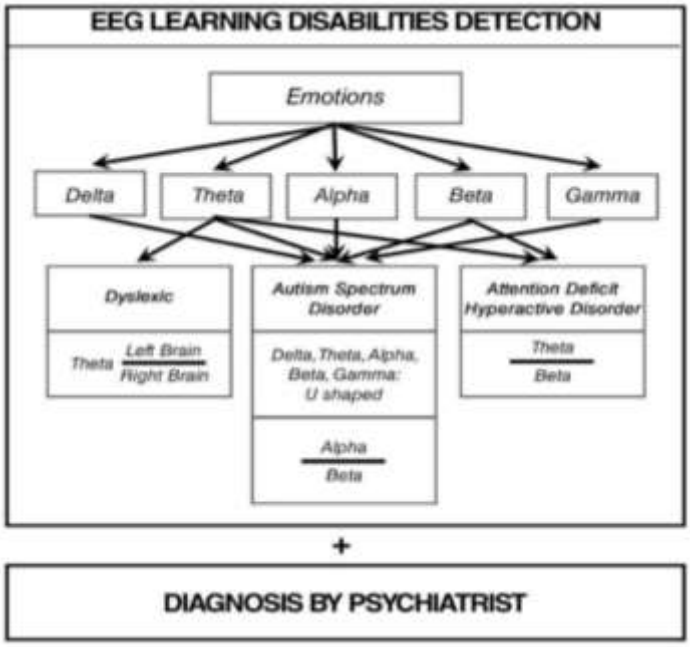

Figure 2. EEG learning disabilities detection

2.3.1. Autism spectrum disorder (ASD)

According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV), people with ASD not only have difficulties in communication and interaction with other people, but also have restricted interests and repetitive behaviours in which the disorders may hurt their ability to function properly in the right place and time in their daily activities [6]. An ASD children may react excessively or not given any reaction over the information received through their senses. This is because their brain could not respond properly to the information received by them in order to have an appropriate response and may create behavioural problems later.

For individual where one of the family members has autism spectrum disorder (ASD) tend to have the tendencies to develop this disorder more than others. Previous research has suggested that the reducing power of infants with familial risk for autism as an atypical brain function marker which is the high-alpha frontal power of the infants who have siblings with autism had reduced between every 3 months old of developmental assessment compared to the infants who have typically developing children [14]. In the same argument, a study has been distinguished an early biomarker for ASD infants with low risk control (LRC) and infants with high risk ASD (HRA) begins from 3 months old by computing the nonlinear features analysis of EEG resting state signals which extracts the information that the children who develop ASD are significantly different in the left temporal and right temporal parietal regions at an early stage and in the frontal regions after 18 months later [14].

Based on the previous studies, it has conclusive evidence shown by several researchers that the children with ASD or the potential ASD children with high familial risk showed an alleviate in their alpha power compared to the typically developing children [14-16]. Similarly, one of the studies has been determined that the theta over beta ratio has been decreased while the relative power of gamma have been increased among the high- functioning ASD children [17]. Thus, it can be summarized that ASD children show the lowest alpha power among the frequencies applied in which this study applied the u-shaped graph which includes delta, theta, alpha, beta and gamma, and also the alpha over beta ratio as shown in Figure 2.

2.3.2. Attention deficit hyperactive disorder (ADHD)

ADHD children may have difficulties to focus especially their attention on a single task and to sit still for a long time, which they cannot move excessively in certain setting or while waiting to do a given tasks. Children with ADHD displayed different brain waves compared to typically developing children. The National Institute for Health and Care Excellence (NICE) highlighted several problems that the ADHD must encounter with, for example, teacher unaware with their symptoms, negative impact on their academic achievement or even employment and bad impacts on their emotions, social communication and life [18].

In the previous study on ADHD children, the EEG signals have been integrated with the theta over beta ratios and a clinician`s evaluation which aimed to improve the criterion evaluation of ADHD children [19]. The short neuro-feedback sessions based on the theta over beta ratio show that the ADHD children learned to reduce their theta over beta ratio, complemented by a depletion of theta activity in a reading task for the good regulator group of ADHD [20]. In contrast to these study [19, 20], the theta over beta ratio are greater for the ADHD children compared to ADHD adults and typically developing group recorded during the resting state at eyes open [21]. Conversely, it was reported that there are no changes in the theta power while the beta power has increased slightly within the neuro-feedback training sessions in which it is not significantly correlated with the behavioural changes [22]. As there are several perspectives on the theta over beta ratio for the EEG signals and our study implemented the theta beta ratio based on the EEG emotions data to see the possibility of the ratio in detecting the symptoms of ADHD.

2.3.3. Dyslexia

Dyslexic children show several symptoms before the school years include late talking, slow learning of new words, difficulty to form words or, problems in remembering or naming letter, numbers and colors. Even though dyslexia cannot be cured, but early diagnosed can help them to get early assessment and early intervention can help them to cope better resulting in an excellent outcome for their future. Refer to the previous study by Harshani et al. [23], it is observed that the writing and typing task classifiers show the higher sensitivity percentages on the left hemisphere of the brain compared to the right hemisphere of the brain.

Previous research found that the presence of the atypical linguistic network was featured by a dominance of theta power spectra activity in the left of the frontal regions compared to typically developing children [24]. The theta power is common power of EEG activities that involved Dyslexia. While one of the research studies underlined that the theta activities consistently increase as the mental workload rise, which also refer to the level of mental effort [25]. Therefore, in this research study, we have used the theta of the left hemisphere, which include the channels of Fp1, F3, F7, C3, T7, P3, P7 and O1 over the theta of the right hemisphere, which include Fp2, F4, F8, C4, T8, P4, P8 and O2.

Table 1. Selected channels for theta of the left and right hemisphere

Left Hemisphere Channels	Right Hemisphere Channels
Fp1, F3, F7, C3, T7, P3, P7, O1	Fp2, F4, F8, C4, T8, P4, P8, O2

3. RESULTS AND ANALYSIS

Four different type of analyses were carried out as shown by Figure 2, namely; one for ADHD, one for Dyslexia and two for ASD. All the analyses were carried out using the arousal extracted from the emotion classification based on the neuro-physiological interface of affect (NPIA). Detail discussion of the analyses will be discussed in the aforemention sections.

3.1. EEG learning disabilities detection

Electroencephalogram (EEG) is one of the most convenient techniques used to represent behaviors of the brain and helped to explore valuable insights through the measurement of brain electrical activity [20]. Recent development of the EEG devices has made it easier to use for analyzing brain wave patterns and even the data collections is fairly robust. In addition, the portability of EEG devices allows it to be used easily in a

classroom environment for analysis and it is reasonable cost of measurement allow monitoring of atypical brain development that have been increasingly inspected as a prospective clinical tool [13]. In this study EEG emotions data of the learning disabilities for children to detect the differences of the frequencies in their signals based on the emotion stimuli were used. Table 2 shows the Learning Disabilities Detection for positive emotion of calm and Table 3 shows the Learning Disabilities Detection for negative emotion of fear.

Table 2. Learning disabilities detection for positive emotion

Subject No	Autism Spectrum Disorder		ADHD	Dyslexic	Diagnosed by Psychiatrist	Potential EEG Detection
	Alpha Beta Test	U-shape Detection	Theta Beta Test	Left-over-Right Theta Test		
A	0.26	U	0.26	0.41	Autism Spectrum Disorder	Pure Autism Spectrum Disorder
B	0.54	U	0.55	0.79	Mild Autism Spectrum Disorder	Pure Autism Spectrum Disorder
C	1.52	n	1.23	1.26	ADHD	ADHD with Dyslexia
D	1.10	n	1.15	0.24	ADHD	Pure ADHD
E	1.25	n	1.09	1.76	Dyslexia	Dyslexia with ADHD
F	1.59	n	0.63	0.75	Normal	Normal
G	1.26	n	0.97	0.73	Normal	Normal
H	1.34	n	0.89	0.78	Normal	Normal

Table 3. Learning disabilities detection for negative emotion

Subject No	Autism Spectrum Disorder		ADHD	Dyslexic	Diagnosed by Psychiatrist	Potential EEG Detection
	Alpha Beta Test	U-shape Detection	Theta Beta Test	Left-over-Right Theta Test		
A	0.69	U	0.32	0.32	Autism Spectrum Disorder	Pure Autism Spectrum Disorder
B	0.55	U	0.68	0.65	Mild Autism Spectrum Disorder	Pure Autism Spectrum Disorder
C	1.25	n	1.20	1.14	ADHD	ADHD with Dyslexia
D	1.01	n	1.33	0.22	ADHD	Pure ADHD
E	1.59	n	1.02	1.32	Dyslexia	Dyslexia with ADHD
F	1.51	n	0.58	0.77	Normal	Normal
G	1.18	n	0.80	0.86	Normal	Normal
H	1.34	n	0.89	0.78	Normal	Normal

3.2. Autism spectrum disorder

Based on Table 2 and Table 3, the Subjects A and B which have been diagnosed as ASD by the psychiatrist, seems to produce consistent result in the case of the U test for ASD. There was a significant difference results between the ASD, other learning disabilities and typically developing children for both tables. The ASD children present the lower Alpha Beta Test (ABT) compared to others which also show the consistency between the positive emotion and negative emotion detection. For both emotions, the ABT and ASD U-shape Detection have shown a regularity in their detection. The ASD U-shape Detection interpret the U as ASD symptom and n as typically developing or without ASD symptom. Based on the experimental result for both positive and negative emotion, Subject A and B yielded u pattern. Therefore, it can be concluded that children with ASD shows the consistency lower alpha power as supported by previous studies on the reducing of alpha power for ASD cases [5, 10].

3.3. Attention deficit hyperactive disorder (ADHD)

Based on the result Theta Beta Test (TBT), ADHD children have higher TBT value as compared to others. Subject C and Subject D have been diagnosed by the psychiatrist to suffer from ADHD and both subjects yielded Theta-Beta Test (TBT) ratio of more than 1.0 value as opposed to the other group. However, Subject E shows higher than 1.0 TBT value in both positive emotion (1.09) and negative emotion (1.02). It that may indicate that Subject E may experience slight ADHD that is overlooked by the psychiatrist.

3.4. Dyslexia

Since there is only one dyslexic child, it is difficult to discover the symptoms without any clinician evaluation. The experimental result shows that Left-over-Right Test value for children with dyslexia reached up to 1.76 for positive emotion and 1.32 for negative emotion as compared to the other group of children. It is interesting to observe that Subject C may also have potential of dyslexia as the subject scored 1.26 and 1.14 for positive and negative emotion LRT values respectively.

4. CONCLUSION

There has been numerous study using EEG devices to detect learning disabilities based on just the power of the different band signals. In this paper we use the EEG signals in the affective domain to analyse and detecting three types of learning disabilities of ASD, ADHD and dyslexia. The neuro-physiological interface of affect (NPIA) uses the emotion analysis based on valence and arousal to detect the various learning disabilities. The consistencies of results using the positive and negative emotions indicate potential of using NPIA for detecting such learning disabilities. Nonetheless much work needs to be done to ensure a larger sample size for consistent evaluation. Nonetheless with one minute of emotion detection it results in 500 instances of the emotion data use for the analysis indicating a large enough sample for initial work.The use of EEG with NPIA in this study show good potential for future in detecting brain development among children especially learning disabilities children. The results show that the ASD children tend to have the symptom, which is low ABT and U shape graph, the ADHD tend to have the symptom which is high TBT and Dyslexia tend to have the symptom that is high LRT. This can be concluded that the Learning Disabilities Detection based on NPIA can be used to study the learning disabilities symptoms in helping to assist the clinician diagnosis. Thus, the NPIA as a detection tools can aid psychiatrist and medical practitioner in providing pre-screening to primary school teacher and educators.

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BIOGRAPHIES OF AUTHORS

Nurul Izzati Mat Razi received her degree in Information Technology in 2015, Master of Computer Science by Research in 2018 and currently doing PhD in Computer Science at the International Islamic University Malaysia (IIUM) Malaysia. Prior to that, she assisted several EEG project at the Pervasive Computing for Brain Development Research Group as the data collector. She is done her master with the research of Neuro-finance and currently worked on the research of learning disabilities detection among children.

Prof. Dr. Abdul Wahab received the Degree from the University of Essex, Essex, U.K., in 1979, the M.Sc. degree from the National University of Singapore, Singapore, in 1987, and the Ph.D. degree from Nanyang Technological University, Singapore. His research has been in the areas of telecommunication, signal processing, and artificial intelligence. He was with Hewlett Packard Singapore, Singapore, as a Research and Development Project Manager both in CO, USA. He joined Nanyang Technological University in 1990, where he was an Associate Professor, before joining the International Islamic University of Malaysia, Malaysia, as a Professor, in 2009. He has authored over 100 conference papers, journal papers, patents, and book chapters in the areas of digital and optical computing, signal processing, and artificial intelligence.

Assoc. Prof. Ts. Dr. Norhaslinda Kamaruddin currently holds a post of associate professor in Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA (UiTM), Malaysia. She served UiTM since 2011. She received her bachelor's degree in Information Technology (Computer Science) from Universiti Kebangsaan Malaysia in 2001 followed by her Master of Software Engineering from Malaya University in 2006. In 2013, she is awarded with Doctor of Philosophy (Computer Engineering) from Nanyang Technological University (Singapore) focusing on computational intelligence especially on Affective Computing. She is very active in research fields of affective computing, speech emotion recognition, neuro-cognitive informatics, big data analytics and driver behavioral study.