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RESEARCH ARTICLE

Haptic Feedback: An Experimental Evaluation of Vibrations as Tactile Sense in Autistic People

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ABSTRACT One of the most prevalent behavioral impairments in autistic people is difficulty processing sensory information. People commonly observe this phenomenon as either hypersensitivity or hyposensitivity to tactile stimuli. To rectify this irregularity, numerous researchers have suggested wearable sensor-based systems and applications within the realm of virtual environments. However, they have neglected to carry out an adequate evaluation and proof of its feasibility for autistic people. Hence, this study compares three methods to identify the most effective approach to understanding tactile sensory processing in autistic people using haptic technology. The evaluation included behavioral response analysis, which involves observing autistic people; statistical analysis on tactile sensory patterns (TSP), which analyzes data from 9-axis IMU sensors and EMG sensors; and machine learning models, such as recurrent neural networks (RNNs), trained on tactile sensory sensitivity data. The study demonstrates that behavioral response analysis is limited by subjectivity and variability in responses, despite its capacity to provide useful qualitative perspectives. Meanwhile, statistical analysis reveals limitations in its ability to predict sensory outcomes, despite its capacity to provide quantitative measurements of variations in tactile sensory processing. Comparative analysis using machine learning, on the other hand, outperforms both behavioral response analysis and statistical analysis in tactile sensory processing classification and prediction. In particular, the RNN model exhibits remarkable accuracy and correctness in detecting tactile sensory processing among autistic people. This study demonstrated that machine learning can be advantageous for autistic people to analyze tactile sensory processing, explore, and develop touch sensitivity to improve their quality of life.

INDEX TERMS Autism, haptic feedback, tactile sensitivity, vibrations, sensory evaluation.

I. INTRODUCTION

The skin contains a sensory system that is capable of processing and delivering information based on human stimuli such as touch, temperature, vibrations, pain, and pressure [1]. This pattern of sensory reception has existed since birth. The human nervous system is responsible for classifying and developing reactions to information that the human body obtains from its surroundings. This process can be done through its neurological system [2]. In addition, every person has their own unique set of feelings and the capacity to comprehend the information that they have obtained. In a typical scenario, when a person does anything, such as touching an object, the skin or surface of the body begins to receive and process the stimulus in the brain, producing a reaction that is dependent on the sensation that

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was received [3]. This does not apply to every individual, as there are some with sensory processing disorders. Autistic people are not exempt from this type of disorder [4], [5].

Autism can be defined by impairments in a variety of areas, such as social and communication difficulties and restricted and repetitive behaviors, and some research suggests that it may also be related to spatial understanding and awareness [6], [7]. Autistic people are well defined by these impairments. Furthermore, it has been reported that autistic people experience differences in their response to sensory stimulation as well as difficulties in neural development in the brain [8], [9]. Therefore, because of these challenges in neural development in the brain, the process of sensory integration in the brain can become disorganized. To put it another way, this group of individuals has difficulty correctly processing the sensations or stimuli that they are exposed to as well as responding in a manner that is appropriate to the sensations that they are exposed to [10] and [11]. These challenges not only have a common behavioural component that influences children's day-to-day lives, but they also have an effect on adolescents and adults [11].

Sensory seeking, emotional response, low endurance, oral sensory sensitivity, inattention/distractibility, poor registration, sensory sensitivity, sedentary behaviour, fine motor and perceptual dysfunction, and poor oral motor function are all symptoms of sensory integration disorder [12], [13]. These sensory symptoms can also be accommodated using four distinct response patterns: low registration, sensation seeking, sensory sensitivity, and sensation avoiding [14]. Autistic people are characterised by two important characteristics that are commonly referred to as having atypical responses to sensory input: sensory seeking and sensory sensitivity [13], [14]. This abnormal sensory response may influence the feedback received through multiple modalities, such as haptic, visual, or auditory [15]. In addition, hypo-responsiveness, which refers to being unaware of changes in the environment, particularly painful stimuli, and hyper-responsiveness, which refers to showing distress in response to loud noises or textures, are both common types of sensory feedback for autistic people [9]. Even there, people have reported experiencing abnormal sensory responses when touched [16]. As was mentioned earlier, dysfunctional tactile processing is very related to an individual's emotional and social distress [17]. This distress can have an impact on someone's day-to-day activities as well as their learning abilities, such as their awareness of their spatial surroundings [18]. Aside from the effect, the relationship between autistic people and abnormalities in tactile processing in autistic people is still not clear, and the underlying biological mechanisms are not well studied [19]. This is in addition to the fact that the impact of autism is unknown.

In addition to the limited clinical and scientific studies that have been conducted on the dysfunction of tactile processing, there has also been a limited amount of testing and evaluation carried out to provide evidence for possible underlying mechanisms of tactile dysfunction, particularly when it comes to activities such as learning about spatial relationships. When discussing issues with the somatosensory system, it is essential to have a solid understanding of the way in which tactile sensory processing is related to the force that is involved. This somatosensory system is also capable of being linked with haptic feedback during the course of one's interaction with a haptic device [20]. As the interaction with an object begins, the haptic touch sensor reads data from the arm or skin, converts that data into stimulus pulses, transfers those pulses as an electrical stimulus to the subcortical and cortical regions of the brain, integrates that information within the primary somatosensory cortex and the motor cortex, and leads to the conscious and subconscious selection of emotional and behavioural responses [21], [22].

Anomalies occurring throughout any of these stages may result in atypical sensory information processing in autistic people [23]. Most of the research on tactile dysfunction has primarily focused on the observations and responses of caregivers, while neglecting or overlooking performance-based evaluations such as behavioral response analysis, statistical analysis (tactile sensory pattern), and comparative-based machine learning analysis [32], [33]. These methods can be used to investigate tactile abnormalities in autistic people. The aim of this study is to investigate and identify the most appropriate method for analysing tactile sensory sensitivity in autistic people. This will be achieved by comparing three different experimental methods: behavioural response analysis, statistical analysis of tactile sensory patterns, and comparative analysis using machine learning. Additionally, the study aims to identify the most effective machine learning model for detecting tactile sensory sensitivity in autistic people.

The Short Sensory Profile 2 (SSP2) and the Adolescent/Adult Sensory Profile (AASP) are two different methods under the aspect of behavioral response analysis that use questionnaires to measure the sensory system response for both children and adults in their day-to-day activities [34]. This indicates that this questionnaire is used to measure the impact and contribution of the sensory aspects of this group of people in their everyday activities. Moreover, it is used to identify and explain these variances in tactile sensitivity. Furthermore, the Tactile Sensory Patterns (TSP) method, under the aspect of statistical analysis, employs 9-axis IMU sensors and EMG sensors from a haptic device to investigate vibration sensitivity in order to identify the presence of touch sensors in a person while interacting with either physical or virtual objects. Meanwhile, comparative-based machine learning analyses are trained using data on tactile sensory sensitivity. This study is interested in achieving three main objectives. Firstly, it seeks to determine and demonstrate the difference in sensory integration among autistic people who have sensory brain development disorder by utilizing SSP2 and AASP profiles. This assessment will be conducted both before and after exposure to haptic technology. Secondly, the study is intended to investigate whether there is evidence of tactile sensory perception in the same group of people using performance metrics and haptic technology. Lastly, the study intends to employ machine learning models to accurately predict and classify the tactile sensitivity of autistic people.

II. LITERATURE REVIEW

Multiple studies have employed different methodologies to ascertain the tactile sensory sensitivity of autistic people. The primary objective of employing different methods on autistic people is to identify and address tactile sensory impairments, with the aim of enhancing tactile sensory experiences through the use of haptic technology, ultimately leading to an improved quality of life. This study aims to provide an extensive overview of the perception of autism, haptic technology, and the present methodology that is based on tactile sensitivity:

1) PERCEPTION OF TACTILE SENSORY PROCESSING IN AUTISTIC PEOPLE

Autistic people frequently exhibit tactile sensitivity, which may be classified as either hypersensitivity or hyposensitivity when it comes to their response to touch stimuli [35]. This sensitivity can significantly affect their everyday activities and social interactions [36]. A study has indicated that anomalies in the somatosensory cortex may be responsible for the aberrant processing of tactile sensations found in autistic people [37]. Furthermore, based on a clinical investigation, there is a primary focus on the prevention of gentle contact with the head and body, which may arise from wearing specific garments [38]. In the field of psychological tactile studies, researchers investigate the thresholds and sensitivity of touch perception by using vibrotactile feedback as a modality [39]. It was observed that adults with autism have lower sensitivity to high-frequency vibrations and are more sensitive to the Pacinian corpuscle receptor, which is found in the skin [40]. Furthermore, it is crucial to highlight that the way in which tactile hypersensitivity manifests itself in autistic people varies from their responses to vibrotactile and thermal stimuli. Unlike adults with autism, children with autism do not show a noticeable variation in their ability to sense vibrations through touch. However, there is a significant correlation between their behavioral tactile sensitivity phenotype and their emotional or social reactions. Furthermore, another research investigation has shown evidence that the use of median nerve stimulation, which is frequently noticed in the right hemisphere's response, leads to increased peaks of low-level somatosensory evoked potential in children with autism [41]. Moreover, a study showed that the use of magnetoencephalography (MEG) in individuals diagnosed with high-functioning autism spectrum disorder (ASD) indicated an altered cortical representation of the face and hands [42]. Further, it is crucial for electrophysiological and imaging approaches in this field to include behavioral response measures. It is important to do this in order to prevent the true differences between groups from being overwhelmed by the variances within each group, which can be attributed to the varied characteristics identified among autistic people. In addition, many scholars have not given as much attention to current technologies, such as haptic technology, compared to the extensive focus on visual and auditory sensitivities [43], [44]. However, studies have indicated the use of haptic technology as an intervention tool for autistic people [45], [46]. The reason behind this is that haptic devices have the ability to deliver tailored tactile stimulation. Autistic people can derive advantages from enhancing their tactile sensory response and processing [47]. Considering that autistic people often have a heightened sensitivity to touch, it is crucial to conduct a thorough evaluation or assessment in this domain.

2) HAPTIC TECHNOLOGY AND ITS PROGRESSION WITH TACTILE SENSITIVITY

Haptic technology is rapidly expanding in numerous fields. Haptic devices are frequently incorporated into a wide variety of interaction products that are presently accessible on the market. Haptic technologies commonly include various devices such as joysticks, Phantom Premium, T-Pads, and CyberGrasp-based systems. Haptic devices primarily generate vibrations to provide a tactile reaction when interacting with different surfaces of an object [48]. Furthermore, multiple studies have shown that using vibration as a tactile method with autistic people is more effective in promoting social interaction compared to using verbal cues or interpersonal engagement [49], [50], [51].Haptic technology provides numerous advantages that make it highly appropriate for the evaluation of sensory processing. Understanding the connection between haptic technology and autistic people in terms of their sensory responsiveness is of utmost importance. However, there is a lack of study undertaken on the tactile sensory pattern, which impairs the ability to completely understand the complexities of its relationship [19], [52]. Prominent researchers's papers, such as those by Söchting and Garzotto, have made efforts to close this gap [53], [54]. Söchting employed the Grading of Force (GoF) test to examine the precision of haptic feedback in autistic people and found a statistically insignificant decrease in haptic perception [53]. However, Garzotto discovered a significant improvement in sensory sensitivity by utilizing haptic feedback [54]. The use of the MAT Board as a haptic interface has resulted in significant improvements in sensitivity. In addition, a study conducted by Cibrian has provided evidence of a significant impact on sensory therapy for autistic people using the Bendable Sound haptic device [55]. Moreover, Zapata-Fonseca et al. have shown that the effectiveness of haptic technology can differ based on the type of interaction in a virtual environment [26]. Their study focused on examining the correlation between different ''ObjectType'' categories in haptic stimulation and the influence of these categories on the sensory patterns of autistic people. Furthermore, they noticed a substantial decrease in sensory interaction while moving from one haptic condition to another. Overall, the findings argue that haptic technology has made significant progress in studying the patterns and precision of sensory processing in autistic people. Hence, the ongoing advancement of haptic technology and its beneficial effects on haptic feedback in autistic people, particularly in the context of investigating tactile sensory processing, emphasizes the need for a deeper understanding of the methods employed in this domain. The use of appropriate methodology as a framework can enhance the efficacy of employing haptic technology to examine and identify the tactile sensory experiences of autistic people.

3) THE VARIOUS METHODS USED FOR EVALUATING TACTILE SENSITIVITY

The use of a short sensory profile (SSP) and an adolescent or adult sensory profile (AASP) in sensory analysis for individuals of various age groups, including children and adults, has primarily relied on self-reported measures and interviews with parents or caregivers [56]. The SSP and AASP can be valuable tools in the behavioral response analysis method in terms of evaluating the tactile and sensory experiences of autistic people [57]. The SSP and AASP, being the most extensively employed standard psychological assessment methodologies in this discipline, are predominantly centered on this method of acquiring sensory information [58]. Hence, this type of methodology entails numerous subjective assessments. In addition, the use of Likert-type scales posed a constraint on the comprehensive evaluation of individual sensitivity, as the limited number of response options restricted the range of possible evaluations [59]. Furthermore, it is important to emphasize that this type of method prioritizes the overall sensory encounters rather than the distinct sensory encounters of everyone, thereby neglecting the potential variations among individuals [60]. These constraints prompt us to emphasize the necessity for alternative approaches to assess an individual's sensory system in a manner that is more objective, precise, and tailored to each specific case. This research discovered multiple approaches employed to study tactile sensitivity in autistic people, including behavioral response analysis, statistical analysis, and machine learning.

a: THE RELATIONSHIP BETWEEN BEHAVIOURAL RESPONSE ANALYSIS AND TACTILE SENSITIVITY

Behavioral response analysis is a commonly employed method in studies related to autistic people to examine their tactile response when interacting with an object [61]. Parent-report measures and direct behavioral observation are frequently employed as evaluations to comprehend the tactile sensitivities and differences of autistic people, as well as to ascertain the correlation between tactile sensitivity and functional impairment [52]. This method prioritized and emphasized the examination or investigation of people's experiences and observable behaviors while evaluating or studying tactile sensitivity.

b: THE RELATIONSHIP BETWEEN STATISTICAL ANALYSIS AND TACTILE SENSITIVITY

The author employed Quantitative Sensory Testing (QST) as a method of statistical analysis to measure sensory detection levels, ascertain the unique tactile sensory profile, and evaluate the responses of autistic people to tactile stimuli [40], [62]. The outcome of the QST can be analyzed with statistical methods to understand the tactile sensitivity of autistic people. The QST offers a standardized metric that is beneficial to performing investigations into tactile sensitivity, and the statistical analysis will assist in interpreting the metric and obtaining significant information to fulfill the study objectives.

c: THE RELATIONSHIP BETWEEN MACHINE LEARNING ANALYSIS AND TACTILE SENSITIVITY

Recent research has increasingly emphasized the application of machine learning to studying the behavioral response patterns of autistic people. This study utilized machine learning methods to analyze and effectively predict social interactions involving autistic people [63], [64]. However, very limited studies do explore tactile sensory sensitivity in autistic people [65]. Hence, there is a need for a specialized investigation to specifically address this matter by examining the potential utilization of machine learning by autistic people to comprehend their tactile sensitivities.

Overall, while there have been advancements in haptic technology and the widespread use of methodologies like machine learning, there is still a gap in evaluating the efficacy of machine learning methods through haptic technology, specifically for evaluating tactile sensitivity in autistic people. Thus, there is a necessity for a study to determine how different methodologies, particularly machine learning, might contribute to evaluating the tactile sensory processing in autistic individuals through haptic feedback.

III. MATERIALS AND METHODS

The following sections explain the types of instruments, procedures, and data analysis used to conduct the testing. This method can be split into three types: using a sensory profile to analyse behavioural responses; using vibration detection to analyse tactile sensory patterns; and using a vibration detection signal to perform comparative analysis. Furthermore, before taking part in the study, all subjects provided written informed consent.

Method of analyzing behavioral response (Short Sensory Profile 2 – SSP2 and Adolescent / Adult Sensory Profile – AASP): A two-way mixed ANOVA analysis method was used to study the behavioural responses of autistic people (participants) between the use of a haptic device (experimental group) and without a haptic device (comparison group) during interaction in a virtual environment. This experiment was conducted based on the modified Short Sensory Profile 2 (SSP2) for the children's group (ages ranged between 9 and 10 years) and the

Adolescent/Adult Sensory Profile (AASP) for the adolescent or adult group (ages $>$ 11) to study sensory sensitivity. The SSP2 and AASP each contain 86 and 60 (item) self-reported questionnaires, respectively, with access to sensory processing across various sensory modalities (such as touch, visual, auditory, movement, and taste/smell), but this study only focused on the touch (haptic feedback) aspect. Each participant will take approximately 15 minutes to complete with support by caregivers or teachers to evaluate the participant's behavioural response. Participants are requested to specify the frequency of responses to tactile sensory during the interaction with the haptic device on a five-point scale (1 = almost never, 2 = occasionally, 3 = half the time, 4 = frequently, 5 = almost always).

Method of analyzing tactile sensory pattern (statistical analysis): In general, the haptic device includes or integrates 9-axis IMU sensors and EMG sensors to quantify vibration as haptic feedback during contact with a three-dimensional environment. The vibration signal observed on the MYO armband haptic device toward the experimental group is the consequence of autistic people's muscles contracting and their arms interacting or moving when handling a virtual object. As a result, the purpose of this study was to analyse the usage of 9-axis IMU sensors signal and EMG sensors by reflecting vibration information as vibration sensitivity to determine the presence of tactile sensory in autistic people. This study focused on detecting vibration correlations between experimental group users and critical data metrics. The procedure and parameters used to study the tactile sensory pattern in autistic people are described and defined in the following section.

Method of comparative analysis (machine learning models): This approach has seven distinct stages, namely data collection, data preprocessing, feature extraction, machine learning model selection, training the model, evaluation, and implementation. Initially, the collection of tactile sensory data will be conducted using electromyography (EMG) tactile sensors that are incorporated into the Myo Armband haptic device. The sampling rate for this data will be set at 200 Hz. EMG sensors are capable of measuring the sensitivity of people's skin and facilitating the identification of various stimuli, including texture, hardness, and temperature variations, during interactions with three-dimensional objects. The data was divided into 40-pixel windows with a 20% overlap. The collected data will be properly encoded into various sensor outputs. Simultaneously, during the data processing phase, the collected sensor data will undergo pre-processing to improve data quality and standardize it. The application of noise reduction techniques can be employed to eliminate extraneous signals that are captured during the data collection process. Additionally, regular processes can be implemented to standardize the output of tactile sensors. Furthermore, separation protocols can be utilized to separate the continuous tactile sensory data stream into distinct touch-based measures. This work aims to discover and extract the pertinent characteristics of vibration signals from the irrelevant pre-processed tactile sensory data through the feature extraction procedure. This approach enhances the accuracy and efficiency of the analysis by using tactile sensory input. The practice will be conducted using two distinct approaches, namely frequency-domain and time-domain. The frequency domain will be employed to illustrate the distribution of vibrations from the tactile sensor across a spectrum of frequencies during the interaction with autistic people. Meanwhile, the time-domain analysis will be utilized to illustrate the temporal evolution of the detected tactile sensor. Subsequently, these attributes will serve as inputs for the subsequent machine learning models. Moreover, the objective of this study was to employ four distinct machine learning models to determine the most appropriate model for this study. The models are employed to handle vibration signal information and derive hierarchical features from tactile sensory data. The inclusion of multiple layers in the models was intended to facilitate the extraction of sensory features from tactile touch input. The subsequent enumeration comprises the machine learning models used in this study:

1) SIMPLE NEURAL NETWORK (SINGEL-LAYER PERCEPTION)

The development of this model involved the utilization of 21 input neurons, with the activation function employed being Sigmoid. In addition, the Stochastic algorithm was used as the training algorithm, with a learning rate of 0.01 for a total of 7 epochs.

2) DEEP NEURAL NETWORK (DNN)

The model was constructed using three layers: an input layer consisting of ten neurons, a hidden layer including twenty neurons, and an output layer consisting of two neurons. The activation function used is Softmax. The training algorithm applied was Scaled, with a learning rate of 0.001, and it was used for 7 epochs.

3) SUPPORT VECTOR MACHINES (SVMS)

This model was used in conjunction with the Radial Basis Function (RBF) as the kernel function. The data was subjected to analysis using a confusion matrix.

4) RECURRENT NEURAL NETWORKS (RNNS)

This model consists of two layers, each containing 50 units. A Scaled Conjugate Gradient training algorithm was used with a learning rate of 0.001 for a total of seven epochs.

During the training of the model, a supervised learning approach was used, wherein the sensory pattern in the tactile data was effectively associated with the early determination of labels and outputs. Random data division techniques were utilized to enhance the training dataset. The evaluation metrics used to assess the success of each machine learning model were determined based on the specific characteristics of the task, including test performance, sensitivity, and accuracy. Cross-entropy is employed as a means of validating performance and ensuring the reliability of the results. The

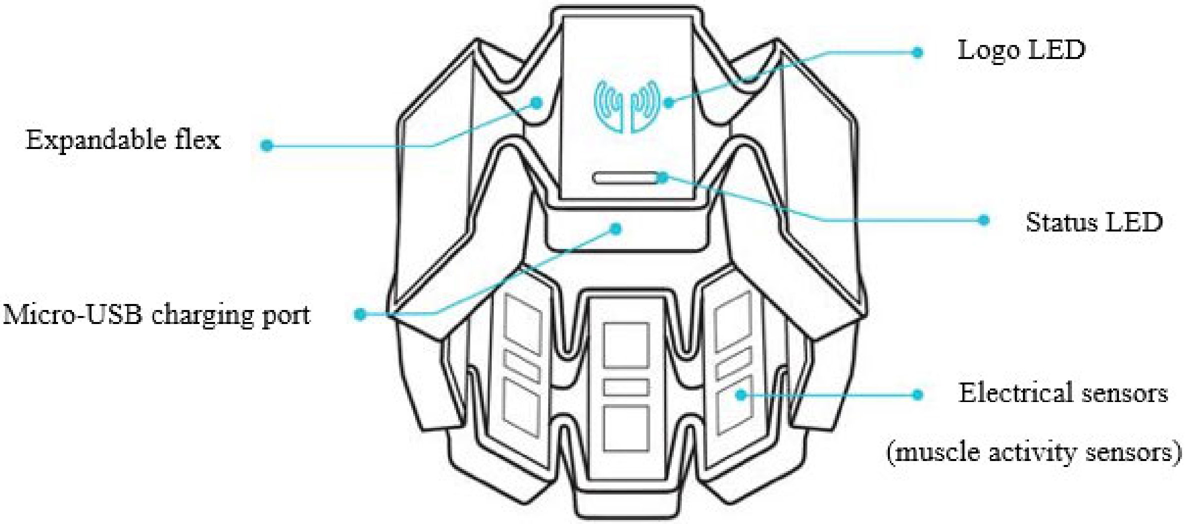

FIGURE 1. The MYO Armband gesture (haptic device) movement orientation.

present study uses a particular comparison methodology utilizing the MATLAB programming language, incorporating neural network tools to facilitate machine learning operations for data manipulation and visualization purposes.

A. PARTICIPANTS

This study included six participants (children: 1 female, 1 male, mean age 9.50, SD =.503; adolescents or adults: 4 males, mean age 21.00, SD = 3.401) for both methods of research: analysing behavioural response; and analysing tactile sensory pattern. All participants confirmed that they have an autism spectrum disorder (ASD) diagnosis and computer experience, but none of them had previously used haptic devices.

B. MATERIAL AND DESIGNS

This experiment used the MYO Armband as a haptic wearable device to simulate haptic interactions (as shown in Fig. 1) and it used a MATLAB-based MYO Armband patten analysis application to understand autistic people's sensory performance. Furthermore, this experiment used a standard windowbased LCD screen computer with an Intel Core(TM) i5-3570 CPU @3.40GHz.

C. OBJECT FORCE PUSHING INTERACTION TASK

This study proposed an object force pushing interaction task to evaluate the performance of haptic (tactile) sensitivity among autistic people. This task was conducted in two different aspects to detect the vibrations through the accelerometer signal: Right-to-left force direction; and Top-to-bottom force direction (as shown in Fig. 2 and Fig. 3). The user should use the virtual finger to push the 3D ball towards the floor and wall until a collision occurs in between. This task was implemented in both the comparison and experimental groups.

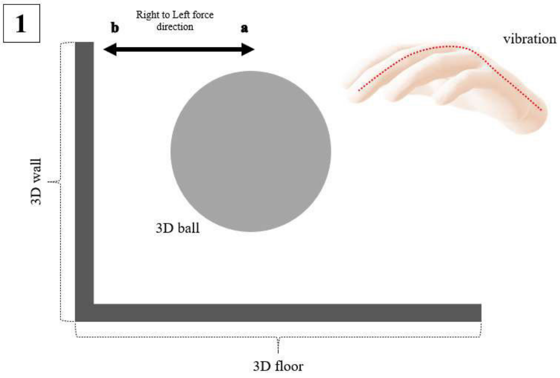

FIGURE 2. Right-to-left force direction aspect.

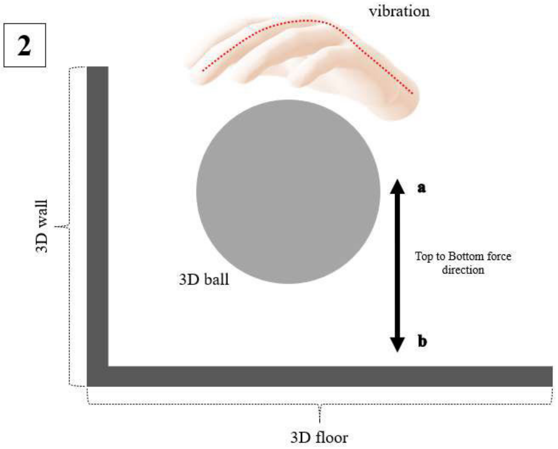

FIGURE 3. Top-to-bottom force direction aspect.

D. DATA MEASUREMENT AND ANALYSIS

In order to examine the effectiveness of the haptic device in terms of detection of sensory sensitivity level towards autistic people, the following measures are used:

1) DATA MEASUREMENT FOR BEHAVIORAL RESPONSE

The Paired Samples T-Test method is used to examine if there aren't any differences in the types of sensory profiles between experimental and comparison groups of autistic people. The mean, standard deviation, and p-value were used to determine the significance levels in this analysis.

2) DATA MEASUREMENT FOR TACTILE SENSORY PATTERN

The experimental data will be measured and interpreted based on the following types of measurements:

a: ACCELERATION (G)

This parameter is used to determine the rate of change of velocity of a virtual object. This is measured based on the net force acting upon the virtual object and inversely upon the mass of the virtual object. The acceleration value is measured based on the following equation (1):

$$acceleration(g) = \frac{F(resultant/netforce)}{m(mass)}. \tag{1}$$

b: ELECTROMYOGRAPHY SENSOR (MV)

This parameter data was captured based on eight electromyography (EMG) sensors from the haptic device, which are used to measure the muscle activity in millivolts (mV). The following equation shows how the average mean absolute deviation (MAD) was computed for the EMGs sensors (2):

$$MADofelectromyographysensor(mV) = \frac{\sum |mV - \overline{(mV)}|}{n}. \tag{2}$$

c: ACCELEROMETER SENSITIVITY (MV/G)

This parameter is used to measure the dynamic acceleration of a haptic device as a voltage. This means this accelerometer is used to monitor autistic people sensitivity levels. During muscle activities, the accelerometer signals produce real-time sensitivity to autistic people. The accelerometer sensitivity value is measured based on the following equation (3):

$$accelerometerSensitivity(mV/g) = \frac{mV(millivolts)}{g(acceleration)}. \tag{3}$$

d: FREQUENCY (F)

This parameter is required to determine the sensitivity of the accessing muscle. It is necessary to obtain the following equation to measure the frequency of the wave, which is 200Hz and completes once every second (4):

$$frequency(f) = \frac{1}{T(timetakentocompleteonecycle)}. \tag{4}$$

Overall, the frequency response towards accelerometer sensitivity will show participants' muscle sensitivity during the usable frequency range. The accelerometer sensitivity (mV/g) will be subjected to statistical analysis using two metrics: the mean and the standard deviation (SD).

3) DATA MEASUREMENT FOR COMPARATIVE ANALYSIS

The hyperparameters that were adapted are as follows:

a: SIMPLE NEURAL NETWORK (SINGLE-LAYER PERCEPTRON)

The learning rate and number of epochs.

b: DEEP NEURAL NETWORK (DNN)

The parameters to consider include the number of layers, the number of neurons per layer, the learning rate, the number of epochs, and the regularization parameters.

c: SUPPORT VECTOR MACHINES (SVMS)

The type of kernel used, a regularization parameter (C), and a kernel coefficient (γ).

d: RECURRENT NEURAL NETWORKS (RNNS)

The number of Long Short-Term Memory (LSTM) units, the learning rate, the number of epochs, and the sequence length.

The evaluation of each model's performance involved the utilization of three metrics: test performance, sensitivity, and accuracy.

IV. RESULTS

This section presents the findings from three experimental methods (Behavioral Response Analysis, Tactile Sensory Pattern-Statistical Analysis, and Comparative Analysis-Machine Learning) using different sets of metrics or measurements to determine the presence of haptic feedback (vibration) as a sense of touch among autistic people during interaction with virtual objects.

A. OUTCOME OF THE BEHAVIORAL RESPONSE ANALYSIS METHOD (SHORT SENSORY PROFILE 2 – SSP2 AND ADOLESCENT / ADULT SENSORY PROFILE – AASP)

The Paired Samples T-Test was used in this study to determine whether there was a significant difference in the overall outcome of the modified SSP2 and AASP sensory profiles between the experimental group (with haptic technology experience) and the comparison group (without haptic technology experience) of autistic people. The sensory profile quadrant is treated as a dependent variable, while the experimental and comparison groups are treated as independent variables. Overall, the general tactile sensitivity based on different age groups (SSP2: 3 to 10 years; AASP > 11 years) shows that there is a significant difference ($p < 0.001$). The AASP slightly shows less reading (mean and SD) in terms of low registration, sensory sensitivity, and sensation avoiding, compared to SSP2 due to age gaps, which are more stable in terms of sensation seeking (refer to Table 1).

Following the significant of overall sensory processing profile outcome through the Paired Samples T-Test, the same test analysis method was conducted to compare the sensory profile quadrant scores of autistic people with and without

TABLE 1. Sensory processing quadrant scores for the SSP2 and AASP in autistic people (age factor).

Factor in types of sensory profile	Sensory processing (SSP2)		Sensory processing (AASP)	
	Mean	SD	Mean	SD
General Tactile Sensitivity				
Low registration	55.83	3.53	46.67	9.53
Sensation seeking	15.00	7.07	20.83	9.57
Sensory sensitivity	62.50	17.68	40.63	8.07
Sensation avoiding	82.50	10.60	41.25	12.58

TABLE 2. Sensory sensitivity quadrant scores for the experimental and comparison groups in autistic people.

Factor in types of sensory profile	Experimental group		Comparison group		Group differences	
	Mean	SD	Mean	SD	t	p
Sensory processing (SSP2) - VR Communication Device	35.00	8.84	56.87	10.60	17.50	0.036
Low registration	23.75	8.84	78.75	5.30	22.00	0.029
Sensation seeking	80.00	7.07	17.50	10.60	-25.00	0.025
Sensory sensitivity	21.25	5.30	68.75	8.83	19.00	0.033
Sensation avoiding	15.00	14.14	62.50	17.68	19.00	0.033
Sensory processing (AASP) - VR Communication Device	34.53	3.83	48.17	8.94	2.60	0.080
Low registration	17.50	6.12	61.88	10.68	6.25	0.008
Sensation seeking	83.75	6.29	19.58	6.71	-29.10	0.001
Sensory sensitivity	19.38	3.75	55.00	6.12	8.14	0.004
Sensation avoiding	17.50	8.66	56.25	23.93	3.39	0.043

haptic experience. The results of this study indicate that there are significant group differences in all the factors (low registration, sensation seeking, sensory sensitivity, sensation avoiding), where the experimental group shows higher scores compared to the comparison group on the sensory sensitivity for both types of sensory profile, respectively (SSP2 and AASP), and this can be seen in Table 2. In order to further understand sensory sensitivity through haptic feedback as the use of touch to interact with autistic people, the correlation analysis was conducted to examine the strength of the relationship between sensory sensitivity and age. The two-tailed significant level ($p < 0.01$) was used to avoid the issue of type 1 errors due to the fact that this study used a minimum number of within-group correlations. Pearson correlations demonstrated significant among sensory sensitivity in the experimental group ($r = 0.010$ to 0.020, $p > 0.05$) and when compared to the comparison group ($r = 0.111$ to 0.112, $p > 0.05$ in the comparison group), and this indicates that sensory sensitivity is present in autistic people during the interaction with haptic technology, while unusual sensory sensitivity is found in autistic people before the haptic technology experience. Furthermore, the SSP2 shows that significant correlations were observed between sensory sensitivity and autistic people traits in the experimental and comparison groups ($p > 0.05$), but not in the AASP for the experimental and comparison groups ($p > 0.05$). This shows autistic people traits do not influence the sensory sensitivity of AASP compared to SSP2 during the interaction with haptic technology.

B. OUTCOME OF THE TACTILE SENSORY PATTERN ANALYSIS METHOD (STATISTICAL ANALYSIS)

As a haptics device and an interaction platform, the MYO armband was used in this study. The virtual environment served as the test environment. The accelerometer is most typically measured with the use of a haptic device that vibrates. This means that the accelerometer is a sensor that is capable of measuring the dynamic acceleration of a haptic device (such as the MYO Armband) as a voltage output signal [24]. This sensor is comprised of a 9-axis IMU sensor (3)-axes accelerometer, 3-axes gyroscope, and 3-axes magnetometer), and this study only extracted the 3-axes accelerometer and eight dry surface EMG sensors in order to provide real-time sensory data to pattern analysis software (MATLAB) for further investigation of sensory detection. An intelligent machine method was used to analyse data from a 3-axis accelerometer as well as EMG data. To investigate tactile sensory patterns, the IMU data and EMG sensors use two domain features: Accelerometer Sensitivity (mV/g) and Frequency (Hz). The haptic vibrations on the surface of the IMU and EMG sensors in the MYO Armband were used to determine the threshold of sensory sensitivity for the MYO Armband. Fig. 4 presents a sample of the detection of real-time acceleration signals via haptic devices during the interaction and manipulation activity in the virtual environment by participant number three. Meanwhile, Fig. 5 displays the real-time signal from eight EMG sensors, which is captured by the electrical impulses generated by the forearm muscles during interaction and manipulation activities in a virtual environment.

Table 3 shows the average sensitivity results for acceleration (g) and EMG sensors (mV) when the vibration frequency is 200 Hz, and these average sensitivity values are estimated based on nine trials for each of the participants. The individual standard deviation falls between 0.0 mV/g and 0.1 mV/g. Fig. 6 shows the overall haptic sensitivities detected among all the participants during the interaction with the haptic device at different trial sessions. The high level of sensitivity observed in trial number 9 was attributable to the fact that the majority of participants were seeking

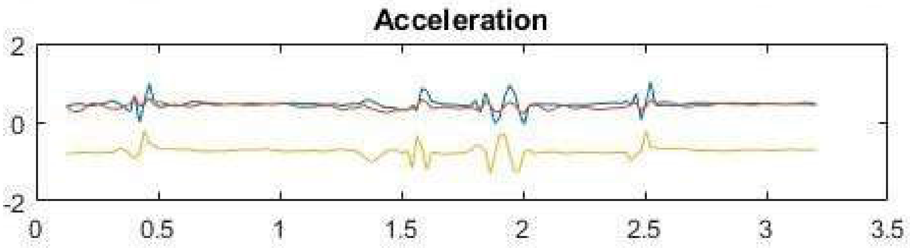

FIGURE 4. The detection of acceleration signals via haptic device for participant number three during the testing.

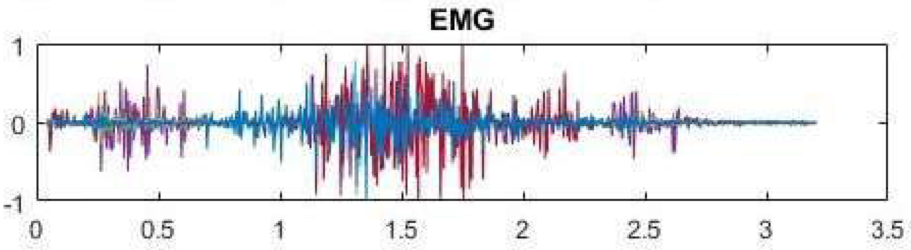

FIGURE 5. The detection of EMG signals via haptic device for participant number three during the testing.

TABLE 3. Tactile sensory pattern scores for the experimental groups at vibration frequency 200Hz.

Participants	Acceleration (g)			EMG sensor (mV)			Average Sensitivity (mV/g)			
	g	Mean	SD	mV	Mean	SD	mV/g	Mean	SD	%
1	16.565	1.8406	0.3691	0.0078	0.0009	0.0242	0.0066	0.0007	0.0124	4.5
2	17.690	1.9655	0.0108	0.0733	0.0081	0.0210	0.0376	0.0042	0.0107	25.7
3	17.409	1.9344	0.0142	0.0349	0.0039	0.0294	0.0179	0.0020	0.0152	12.2
4	17.439	1.9377	0.0139	0.0781	0.0087	0.0247	0.0399	0.0044	0.0128	27.3
5	16.709	1.8565	0.2853	0.0097	0.0011	0.0051	0.0022	0.0002	0.0033	1.5
6	17.571	1.9523	0.0228	0.0829	0.0092	0.0119	0.0423	0.0047	0.0061	28.9

TABLE 4. Tactile sensory pattern scores for two different force directions in autistic people at vibration frequency 200Hz.

Participants	Top to Bottom Force Direction (Push to the floor)			Right to Left Force Direction (Push to the wall)		
	mV(g)	Mean	SD	mV(g)	Mean	SD
1	0.0132	0.0015	0.0248	0.00947	0.0011	0.0291
2	0.0752	0.0084	0.0215	0.0511	0.0069	0.0308
3	0.0357	0.0040	0.0303	0.0280	0.0032	0.0446
4	0.0799	0.0089	0.0256	0.0547	0.0072	0.0379
5	0.0045	0.0005	0.0065	0.0027	0.0002	0.0072
6	0.0846	0.0094	0.0121	0.0691	0.0078	0.0174

sensitivity during their interaction with virtual objects. This study separated the captured accelerometer sensitivity data into individual reports in order to conduct a more in-depth investigation. Please refer to Fig. 7, which depicts the overall findings of the accelerometer sensitivity testing for participant number three during the course of the session. It has been discovered that when the frequency is 130Hz, participants present with resonance frequency towards the accelerometer sensitivity. This demonstrates that there is a high level of touch sensitivity towards autistic people when they engage with virtual objects in a virtual environment.

As shown in Table 4, the results of this study revealed significant differences in haptic (touch) sensation between the two different force direction groups (Top to Bottom and Right to Left) during the interactions with the virtual environment via a haptic device. The individual standard deviation falls between 0.0 mV/g and 0.1 mV/g, which is within the acceptable range.

C. OUTCOME OF THE COMPARATIVE ANALYSIS METHOD: MACHINE LEARNING MODELS

This section provides an overview of the outcomes obtained from four distinct machine learning models. The purpose of this section is to determine the optimal machine learning model for detecting tactile sensory sensitivity in autistic people. Table 5 presents a comprehensive comparison of the overall findings for all the machine learning models utilized in this study. The classification results can be compared using four possibilities: False Positive (FP), False Negative (FN), True Positive (TP), and True Negative (TN). False Positive (FP) refers to the detection of sensory sensitivity when it does not in fact exist. False Negative (FN) refers to the detection of

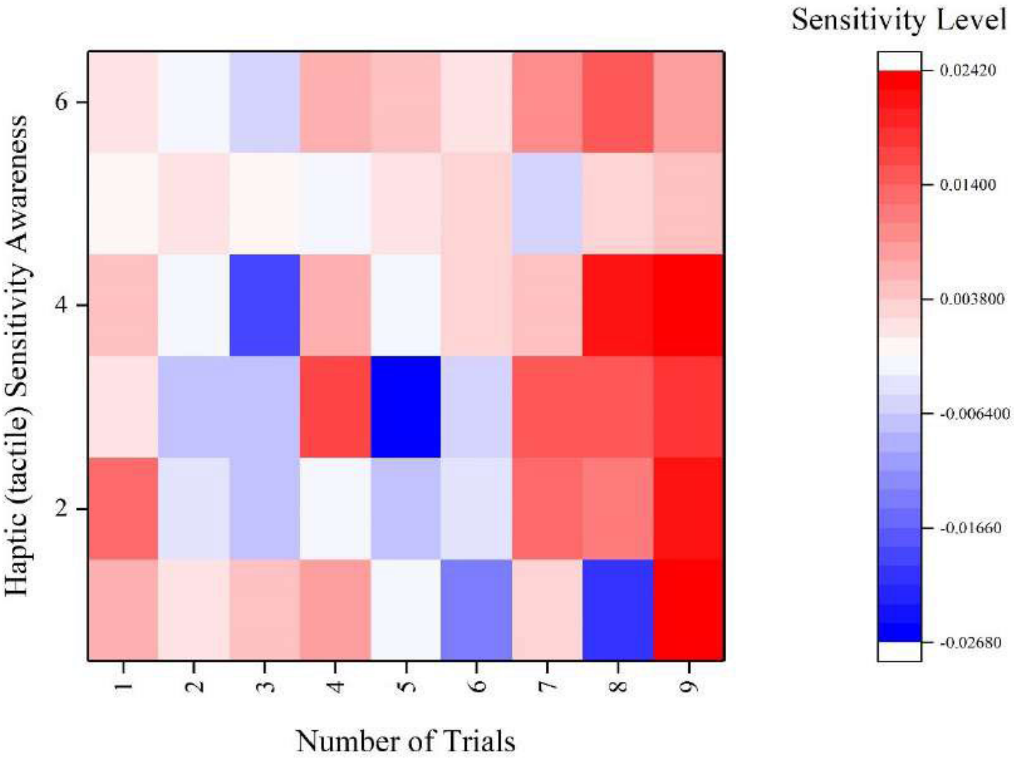

FIGURE 6. The detection of acceleration signals via haptic device for participant number three during the testing.

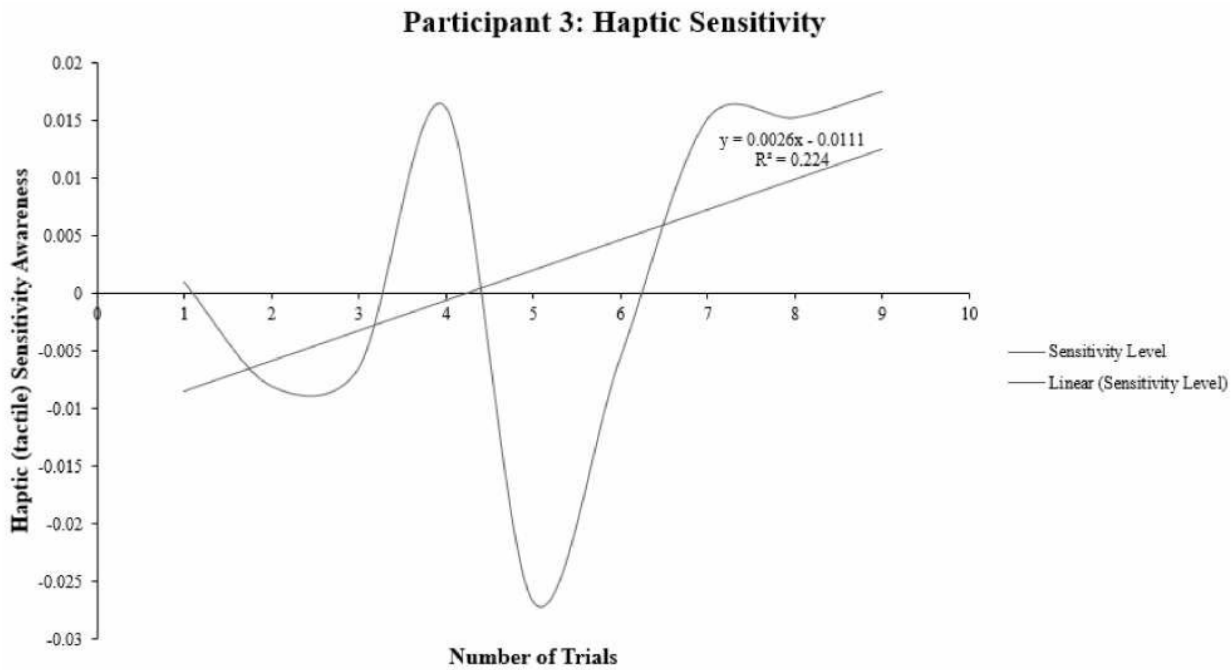

FIGURE 7. The detection of EMG signals via haptic device for participant number three during the testing.

sensory sensitivity when it in fact exists. True Positive (TP) refers to the detection of sensory sensitivity when it in fact exists. True Negative (TN) refers to the absence of sensory sensitivity detection. The findings obtained from the tactile sensory pattern can be analyzed and compared using a matrix table with 2 * 2 contingencies. This matrix table allows for the determination of sensory sensitivity. The findings and comparisons based on the models are as follows:

TABLE 5. The outcomes of the sensory experiments conducted on four distinct machine learning models.

Model	Test Performance	Accuracy	Sensitivity	Example Prediction		Sensory Status
				Actual Label	Predicted Label	
Simple Neural Network	1.1962	NaN	0	1	0.50722	Poor Sensory Detection
Deep Neural Network (DNN)	0.22857	1	0.9	0	1	High Sensory Detection
Support Vector Machines (SVMs)	-	1	0.3	2	2	Moderate Sensory Detection
Recurrent Neural Networks (RNNs)	0.16315	0.9	1	1	1	High Sensory Detection

1) SIMPLE NEURAL NETWORK (SINGLE-LAYER PERCEPTRON)

The findings of this experiment utilising a Simple Neural Network model indicate that the model's performance in enhancing tactile sensory sensitivity among autistic people is suboptimal. The lack of sensitivity and zero accuracy in this model indicate its failure to effectively analyze and extract significant patterns from the data. The sensitivity value in this study measures the ratio of accurately detected positive values to touch sensitivity in autistic people by the model. Therefore, the presence of NaN indicates that the sensitivity cannot be determined or computed as a result of the lack of true positive instances in the data analysis. Furthermore, the model's accuracy of zero (0) signifies that it did not accurately predict tactile sensory sensitivity among autistic people, resulting in a 0% success rate.

2) DEEP NEURAL NETWORK (DNN)

In contrast to the Simple Neural Network, the Deep Neural Network (DNN) model demonstrates superior performance, yielding favorable outcomes in terms of tactile sensory sensitivity among autistic people. The findings of the sensitivity and accuracy analyses indicate that this model has the capability to examine significant sensory patterns derived from test data. Result 1 of the sensitivity test demonstrates a positive value, indicating that the model accurately detected touch sensitivity. Furthermore, the model's accuracy rate of 90% demonstrates its ability to accurately predict tactile sensory sensitivity in autistic people. This suggests that the model has successfully classified or detected tactile sensory sensitivity in this population. Nevertheless, the model's prediction of tactile sensory sensitivity does not align with the previously reported high results in terms of both sensitivity and accuracy metrics. This is due to the model's inaccurate prediction, wherein the actual label is zero, indicating normal tactile sensory sensitivity, but the predicted label is 1, indicating excessive tactile sensory sensitivity.

3) SUPPORT VECTOR MACHINES (SVMS)

According to the results of the SVM model, it is not exhibiting satisfactory performance in terms of tactile sensory sensitivity for autistic people. This can be attributed to the lower level of accuracy provided by the measure, which indicated an overall correct prediction rate of 30%. Nevertheless, the sensitivity measure continues to exhibit a true positive (TP) in 10 cases, suggesting that individuals with autism who possess specific degrees of touch sensitivity, denoted as class 1, are capable of accurately detecting and predicting sensory information (refer to Fig. 8). While the sensitivity measure demonstrates a favorable outcome for class 1, it may exhibit subpar performance for other classes, as evidenced by the overall lower accuracy detection level. Furthermore, while the actual and predicted labels correspond to accurate predictions with varying levels of touch sensitivity for a specific prediction measure, it is important to note that these labels do not accurately represent the overall performance of the model, as indicated by the lower reported accuracy.

4) RECURRENT NEURAL NETWORKS (RNNS)

This RNN model demonstrates a high level of efficacy in enhancing tactile sensory sensitivity in the context of autistic people. This is due to the fact that both the sensitivity and accuracy metrics demonstrate that this model has examined significant tactile sensory patterns with actual positive values obtained from the test. Additionally, it is capable of accurately identifying and classifying tactile sensory sensitivity with a 90% correct prediction rate. Nevertheless, upon comparing the DNN model, it was observed that both the actual and predicted labels were labeled as 1, indicating a correct prediction. This aligns with the high accuracy and sensitivity measures produced by the model, indicating its effectiveness.

5) A COMPARISON OF THE DNN AND RNN MODELS

Moreover, it is necessary to do a comparative analysis in order to comprehensively understand and identify the relative performance of the two models, namely DNN and RNN, in terms of accuracy and sensitivity. The Receiver Operating Characteristic (ROC) is employed to depict a probability curve, while the area of the Area Under the Curve (AUC) signifies the degree of separability. The findings indicated that both modules underwent evaluation across many aspects and were subsequently compared. Both the DNN model and the RNN model exhibited superior sensitivity, accuracy, and AUC compared to the model with data dimension reduction. The DNN model demonstrated a moderate level of sensitivity, as shown by a value of 0.670. This suggests that autistic people experience a moderate impairment in tactile sensory processing while engaging with haptic interfaces (refer to Fig. 9). Fig. 10 displays the ROC of the RNN prediction model for autistic people during their interaction with haptic interfaces. The curves are located near the upper left corner, and the AUC is reported to be greater than 0.89. This indicates that the models have a strong predictive ability for detecting sensory sensitivity. Moreover, this conclusion is substantiated by the superior validation performance seen in

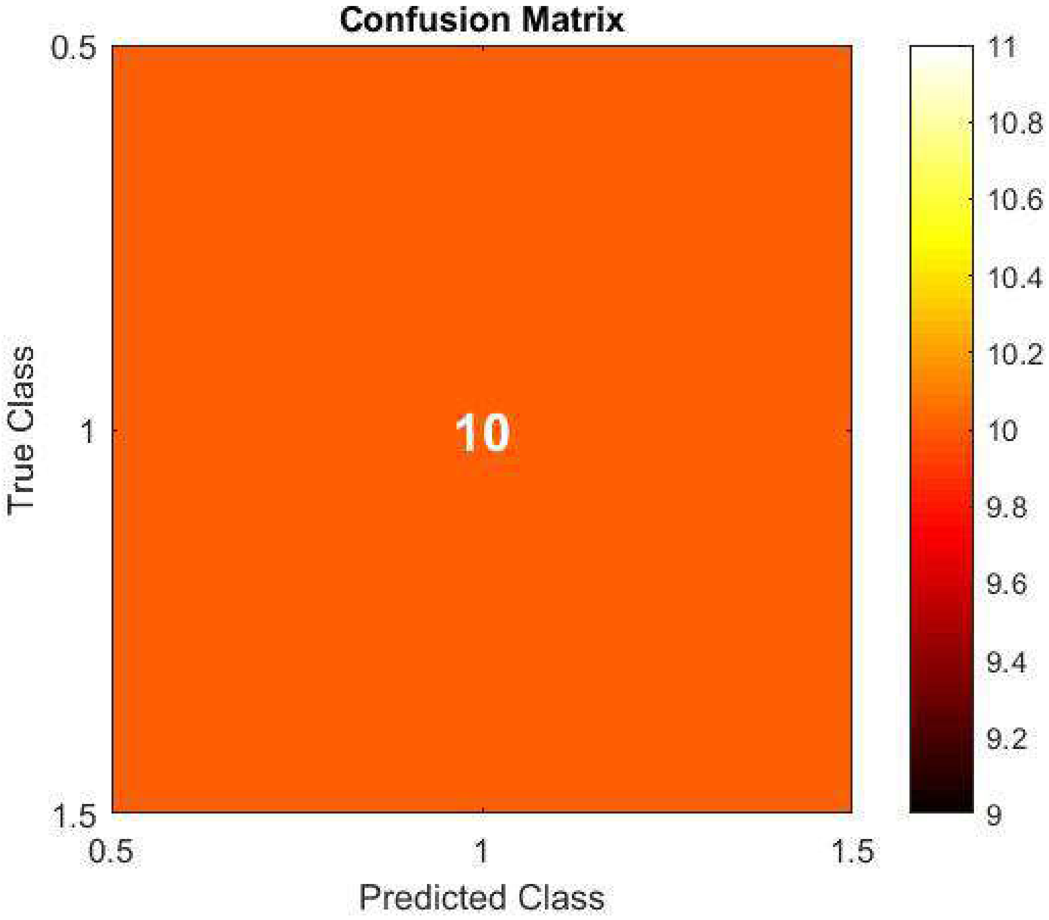

FIGURE 8. The Confusion Matrix of SVM model.

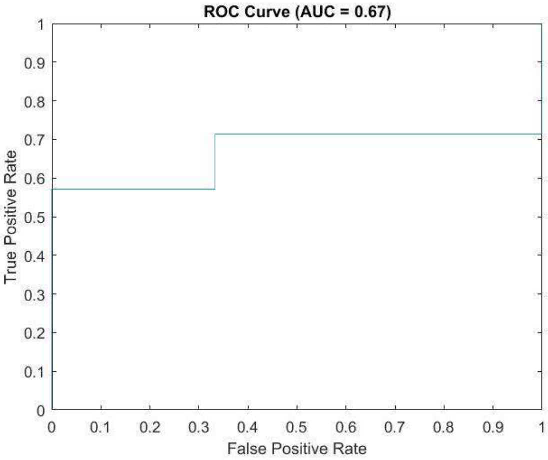

FIGURE 9. The ROC Curve of DNN model.

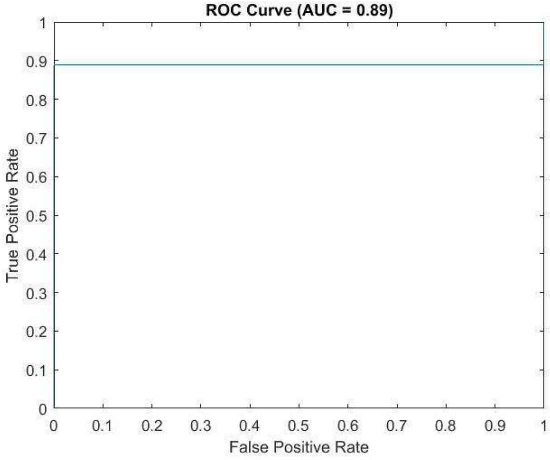

FIGURE 10. The ROC Curve of RNN model.

RNNs. Specifically, the value of 0.362 indicates the minimal error during the training process of the sensory dataset. Notably, the best validation performance was achieved after the first epoch of training, as depicted in Fig. 11. This phenomenon can likely be attributed to the model's exceptional speed in detecting significant sensory patterns among the data collected from the first porch. Hence, after comparing the DNN and RNN models, it can be concluded that the RNN model is marginally superior in analyzing tactile sensory sensitivity among autistic people. This is due to the fact that, when evaluating these models in terms of test performance and example prediction, RNNs exhibit greater confidence in their performance compared to DNNs. The test performance indicates a reduced amount of

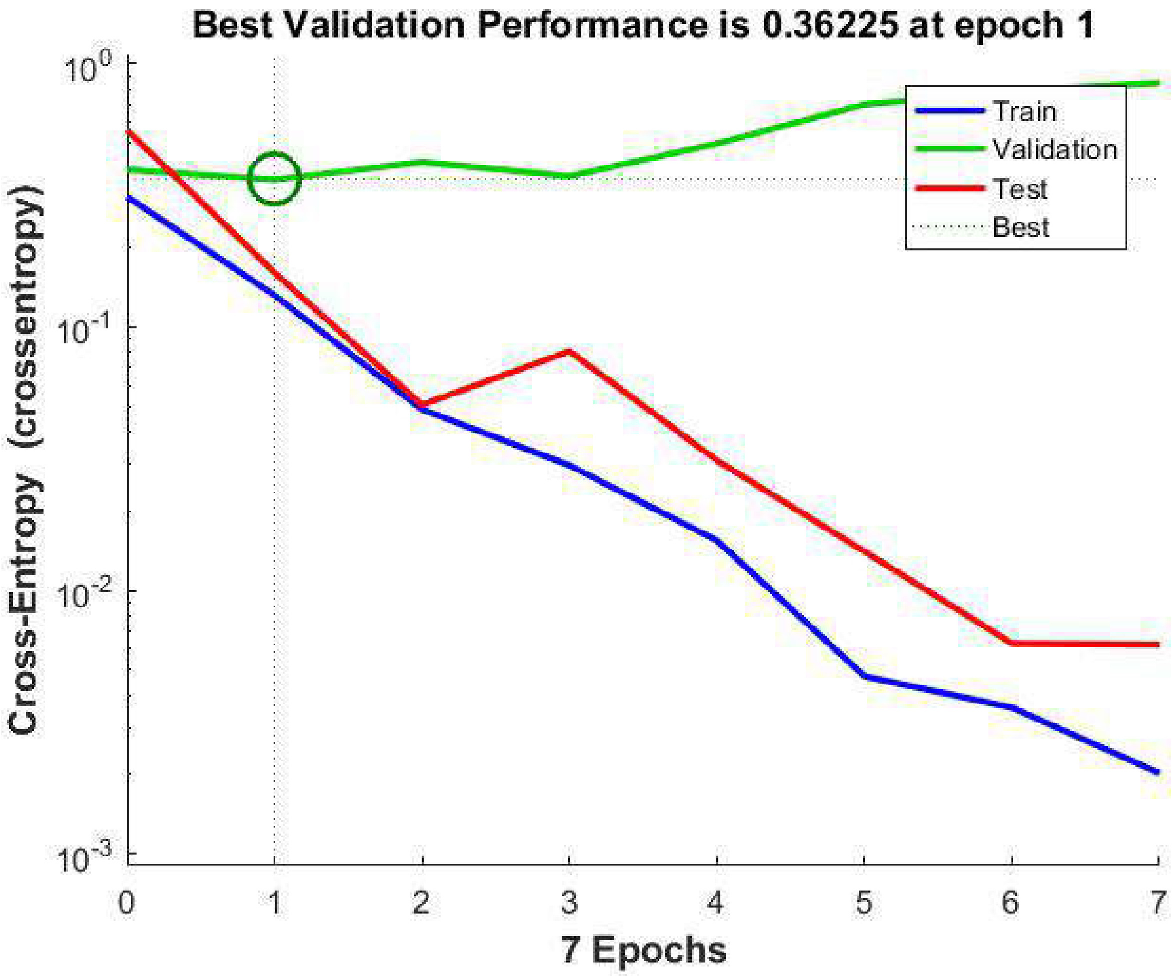

FIGURE 11. The best validation performance of RNN model.

error in the predictions, and the actual and predicted labels for the example prediction value are correct. Furthermore, to substantiate this assertion, the ROC indicated a substantial predictive impact for the RNN model, together with the best validation performance. As a DNN model, this RNN model has exceptional proficiency in detecting tactile sensory sensitivity in autistic people. This is due to the fact that both the sensitivity and accuracy metrics indicate that the model has examined significant tactile sensory patterns, yielding actual positive results in the test. Additionally, the model has the ability to effectively detect and classify tactile sensory sensitivity, with a prediction accuracy of 90%. However, while comparing the DNN model, it was observed that the RNN model made correct predictions. Both the actual and predicted labels were assigned a value of 1, which was consistent with the high accuracy and sensitivity metrics provided in this model.

V. DISCUSSION

A. BEHAVIOURAL RESPONSE: SENSITIVITY

The objective of this study is to explore sensory processing (SP) in terms of tactile sensitivity among autistic people before and after experiencing haptic interfaces. The sensory profile questionnaire was completed by caregivers for children, compared to adults or adolescents, which gave the impact of the high or low level of tactile sensory detection. Based on the modified SSP2 and AASP questionnaire structures, the sensory quadrant scores were reported in four different factors as: low regression, sensation seeking, sensory sensitivity, and sensory avoidance for autistic people. In general, sensory profile studies show that SSP2 reported slightly higher sensitivities compared to AASP for adolescents or adults, and this may be due to the age factor, where children tend to become physically reactive, which can cause them to attempt to remove themselves from the environment [25]. Meanwhile, for the comparison between the experimental group (with haptic device) and the comparison group (without haptic device) for the SSP2, the results show that autistic people in the comparison group had high levels of tactile sensory experience when compared to the experimental group who had experience with haptic interface in terms of low regression, sensory sensitivity, and sensory avoidance. The high levels of sensory may affect their learning ability, especially in terms of their spatial awareness, such as feeling and recognising the size and shape of objects [26]. Due to oversensitivity, they try to avoid engaging with communication devices [27]. This shows that an existing haptic interface can become a good sensory therapy to improve their ability to engage with their surroundings. Meanwhile, the AASP profile was reported to be slightly lower in adults or adolescents compared to children, which was likely due to age differences as well as other factors such as environment and tendency [28]. There has been positive significant reported in adult or adolescent autistic people in the experimental group who had experience with haptic technology compared to the comparison group, especially in terms of sensation seeking. As a grown adult or adolescent, they are able to sense their touch in a healthier way compared to children, but there is a possibility that they were not well mastered when it came to organising the sense in terms of feeling during the interaction with an object, and this has been proven from the result of the comparison group [26]. However, after being exposed to haptic technology, they progressively learn to organise the senses within their understanding and are able to show good improvement by focusing on touch sensations. This is proven by the quadrant scores for all the factors, especially sensation seeking, which show more than 20% differences. As a result, the ability to organise sensations via haptic feedback (vibration) by a child or adult allows them to control their interaction and response, and as an outcome, they will probably be more engaged with their surroundings, whether in a virtual or real environment.

B. A COMPREHENSIVE ANALYSIS OF TACTILE SENSORY PATTERNS

As presented in the result of the experiment, autistic people were able to receive ordinary tactile sensory sensitivity. Mostly, autistic people have different levels of tactile sensory sensitivity information, either oversensitive or undersensitive, and the response and expression of their sensitivity awareness will be different [29]. This can be supported based on the results of participants at the beginning of four testing sessions, where almost all of the participants reported being undersensitive to tactile sensory information when they were seeking sensory experience by looking for virtual objects to touch and feel (as shown in Fig. 6). Similar to being oversensitive to tactile sensory information, where the participants 2 and 4 faced oversensitivity at the second testing session, this was due to the fact that these autistic people try to avoid tactile sensory experiences in virtual environments. Meanwhile, different force directions methods have different levels of seeking tactile sensory information by autistic people during interaction with virtual objects via haptic devices. This finding can be supported based on the results from the two different force directions (pushing the virtual ball to the floor and to the wall). The detection of accelerometer sensitivity among autistic people during the pushing of the virtual ball towards the floor task shows slightly higher sensitivity compared to pushing the virtual ball towards the wall task for most of the autistic people participants (as shown in Table 4), and this might be due to seeking different directions of the virtual object's position and momentum when the time handling with wearable haptic device. Furthermore, there are studies [30], [31] that report that there is a possibility where these experimental evaluation results can be impacted due to being overly anxious or stressed during the interaction with a virtual object in a virtual environment via a haptic device. From the outcome of both experimental studies, it can be concluded that the interaction with haptic devices in a virtual environment enables the creation of positive tactile sensory therapy among autistic people.

C. COMPARATIVE ANALYSIS OF MACHINE LEARNING MODELS

This study explores and evaluates the efficacy of four distinct machine learning models, namely Simple Neural Network (Single-Layer Perceptron), Deep Neural Network (DNN), Support Vector Machines (SVMs), and Recurrent Neural Networks (RNNs), for the purpose of analysing touch sensitivity in autistic people. The findings indicate the identification of a proficient model that can effectively aid in an analysis of the intricacies inherent in sensory sensitivity data. The Simple Neural Network model exhibited suboptimal performance, characterized by low accuracy and indeterminate sensitivity. This limitation arises from the inadequacy of this model for handling complicated data, mostly due to its linear integrity and limited ability to discover nonlinear patterns [32], [33]. Consequently, this study necessitated the use of a more advanced model to study tactile sensory sensitivity in autistic people, due to its lower performance outcome. Similarly to the Simple Neural Network, the SVM model exhibited suboptimal performance in terms of accuracy. However, it demonstrated significant sensitivity for class 1. This implies that, in contrast to a Simple Neural Network, this model exhibits efficacy in capturing specific tactile sensory patterns among autistic people, despite potential challenges in performing more comprehensive classification tasks [66]. However, we can enhance this model by incorporating various kernel functions or addressing the issue of class imbalance in the sensory data. Both the DNN and RNN models demonstrated strong performance in terms of sensitivity and accuracy. The achievement of these models can enhance their capacity to effectively handle and analyze data related to tactile sensory sensitivity. The DNN possesses the capability to analyze the hierarchical structure of sensory data, thereby facilitating the identification of the intricate and non-linear associations that underlie tactile sensory sensitivity in autistic people [67], [68]. RNNs have the capability to effectively model sequential data, making them particularly suitable for the analysis of tactile sensory sensitivity, which often exhibits spatial dependency [69], [70]. The inconsistency of the DNN model's tactile sensory sensitivity is compromised by the inaccurate prediction at the label level, which deviates from the expected indication of normal tactile sensory sensitivity. Consequently, after analyzing the outcomes of all four machine learning models, it is concluded that the RNN model is the most efficient model for assessing tactile sensory sensitivity in autistic people.

D. COMPARISON OF THREE EXPERIMENTAL METHODS

This study aims to determine the most appropriate way for analyzing tactile sensory sensitivity in individuals with autism by comparing three distinct experimental methods: behavioral analysis, statistical analysis, and comparative analysis utilizing recurrent neural networks (RNNs). Every methodology offers a distinct comprehension and viewpoint on the sensitivity of tactile sensory perception in autistic people. Behavioral response analysis is used to directly observe and comprehend the reactions of individuals with autism to haptic devices. The study yielded a high mean and moderated standard deviation, indicating a lack of consistency in the responses. Furthermore, this type of analysis is likely incapable of addressing the intricate complexity of sensory sensitivity in autistic people. In the context of understanding the sensory sensitivity of autistic people, statistical analysis can prove to be a valuable instrument. This approach specifically targets the identification of direct tactile sensory patterns that may not be readily apparent through behavioral analysis. The research reveals a sensory sensitivity pattern among autistic people, as indicated by the reported mean and standard deviation. However, it is likely that this pattern is not consistent and has a limited influence in terms of its significance. RNNs are used for comparative analysis to classify and forecast tactile sensory sensitivity in autistic people utilizing haptic devices. The reported results (sensitivity of 1 and an accuracy of 90%) indicate that this method's model is highly effective in accurately identifying true positive cases and predicting correctly, specifically those describing high sensory sensitivity among autistic people. Therefore, it can be proven that the computational method's model is capable of effectively handling intricate tactile sensory sensitivity data and patterns in autistic people. By comparing these three methods, it can be concluded that employing different sorts of methods to comprehend and analyze tactile sensory sensitivity in autistic people will yield greater benefits and prove to be a more efficient approach. However, considering the objective of this study, which is to identify and accurately predict tactile sensory sensitivity in autistic people, the most suitable method for analysis would be comparative analysis using recurrent neural networks (RNNs). This decision was made based on the high sensitivity and accuracy observed in the analysis of complex sensory data.

VI. FUTURE WORK AND CONCLUSION

Through a comprehensive examination and comparison of three distinct methods, this experiment effectively demonstrates the efficacy of the comparative analysis method, specifically Recurrent Neural Networks (RNNs), in classifying tactile sensory sensitivity levels among autistic people. This classification is based on the analysis of 8's EMG signals generated by the MYO Armband haptic device. The findings demonstrate computational significance, yet there is room for enhancement in relation to data imbalance and the employed modeling techniques. Therefore, this study aimed to investigate other techniques, such as convolutional neural networks (CNNs), in order to use their capacity to effectively process complex visual patterns.

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