Case Study on Fine Motor Skills of Special Children when Using Light and Sound Tool

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***Abstract*—Autism and D syndrome children are example of children that have motor skills disabilities as their hand do not seem to coordinate properly, in addition to observably low muscle tone. Therefore, an early intervention program is needed to improve their find motor skills. This paper proposes an integrated approach for the enhancement of children's fine motor skills and functional performance that are fundamental in daily activities. This can be achieved by inventing a tool that's designed with the implementation of sound and light for children use in fine motor activity. Henceforth, to specify the muscular performance and amplitudes of muscular activation generated during fine motor activity, surface electromyography (EMG) technique was used. The analysis was performed on two healthy children and two special needs children, each with Autism and Down syndrome, ages ranging from four to six years old. EMG activity of hand muscles, specifically flexor muscle was recorded while human subjects grasped a ball and transferred it to the tool. The results as analysed through computer software such as LabVIEW and MATLAB demonstrated that there are differences in muscular performance and amplitude of surface EMG signals between the involved children. Furthermore, a correlation between engagement and learning was found among the children during the fine motor activity using the designed tool.**

***Index Terms*—Average Rectified (AVR); EMG Signal; Fine Motor Skills; Linear Envelope.**

I. INTRODUCTION

The development of fine motor skills among the children is an important foundation to help them throughout their routines and experiences of performing activities such as threading beads, holding small objects, writing and playing with play dough. However, there are some children who have difficulty with fine motor skills as their hand do not seem to coordinate properly in addition to observably low muscle tone. Children with Autism and Down syndrome are example of children that have the motor skills disabilities facing problems which includes limited concentration, impulsive behavior and sluggishness in finishing assigned tasks [1].

This case study presents a design of an intervention of fine motor tool that can attract children to willingly repeat the fine motor activities, thus, helping them to enhance their fine motor skills and ultimately increase their muscle strength. In addition, surface Electromyography (EMG) amplitudes were recorded as the secondary aim of this paper is to study the differences of a flexor muscle activity between the two types of children: healthy children and children with motor skills disabilities, during fine motor activities. Thusly, LabVIEW and the hardware from National Instrument as well as the electrodes were employed to capture EMG signals. MATLAB was then used to analyze the obtained data and compare the results.

II. LITERATURE REVIEW

A. Fine Motor Activity

The acquisition of fine motor skills refers to manipulation of the hands and fingers in developing basic movement and skills like picking up objects and transferring objects from one hand to another [2]. In order to develop and enhance the skills, the studies conducted in [3], the children were given some objects, such as paper, scissors and glue and subsequently asked to manipulate said objects based on their creativity and imagination.

Besides, the children were also given some additional directed activities such as finger painting, finding small objects in resistive materials like play clay and using magnetic wands to pick up small metal objects. The intervention activities were designed to expose to the children in small object manipulation in addition to actual sensory experiences to improve tool use, increase grasp strength and individual functional abilities [4]. However, it should be mentioned that the activities at this stage have yet to involve any music element. Nevertheless, as stated in the scientific study, art and music therapy play a great part in the development of efficient learning process and emotional self-regulation [5].

Music therapy can also be effective for children as it obviously provides positive effects in the improvement of communication skills, maturity and the emotional development [5,6]. The scientific study demonstrated that music and art elements can be associated with various educational activities as they aid in speeding up skills development by method of grabbing the children's attention to perform the activities repeatedly thus training their muscles. In addition, it can help to develop other skills like self-help, communication and cognitive skills where the children would be able to self-feed, play with peers and reason in problem solving [2].

B. EMG Measurement of Hand Muscles

EMG is a technique to record and analyse myoelectric signals which are formed by physiological variations of muscle fiber membranes. EMG signal is produced due to electrical activity of skeletal muscle cells caused by neuromuscular activity during contraction and relaxation [7]. The neural control of this muscular contraction process is called a Motor Unit, the smallest functional unit that innervates the cell and muscle fibers, generating a motor unit action potential (MUAP) when activated [8].

EMG signals are widely used in the medical community to aid in rehabilitation and diagnosis of health care. In this experiment, EMG signals were recorded from the movement of children's hand during fine motor activities. The term of fine motor involves the use of the small muscles in the fingers, arm and hand to work together to perform precise and refined movements such as manipulating, controlling, and using tools and materials [9].

The muscles that produced the movement of hands and fingers are divided into two groups: extrinsic and intrinsic muscles. Extrinsic muscles are large and provide strength as they originate in the forearm while intrinsic muscles are small and give precise coordination for fingers as they originate primarily in the hand [10]. Presently, many researches are being carried out to measure EMG of the movement of hands but with different aims and tasks.

Muscles measurement also varies depending on the tasks as each of the muscles has their own function. For example, flexor digitorum superficialis (FDS) flexes the phalanges and hands and abductor pollicis brevis (APB) abducts thumb and moves anteriorly [11]. Most researches have shown that more than two types of muscles were used to be detected in EMG signal.

Similar to the previously conducted studies, surface electromyography (sEMG) data of forearm muscles were measured via an eight channel wireless electrodes and placed on three finger flexor and two extensor muscles of each participant's dominant hand [12]. As the study also examines the involvement of adjacent and non-adjacent fingers in a sequence during keyboard playing task, the different types of muscles with different function were measured.

The placement of electrodes on particular muscles is important as to acquire more information about their movements. In this study, it was focused more on children, especially special children who are easily distracted leading to refusal in carrying out the directed action. Therefore, the muscle to be measured in this study was limited to only one type of muscle, which is the Flexor Digitorum Superficialis (FDS). FDS was chosen as a dominant muscle as it flexes the proximal interphalangeal joints and contributes to wrist flexion [13]. EMG was therefore recorded at that specific muscle during the children's fine motor tasks.

III. METHODOLOGY

This research consists of three main parts, namely; (i) the process of designing a suitable tool for children, (ii) EMG data acquisition and lastly, (iii) the tool evaluation, indicating its suitability.

A. Fine Motor Training System

As this project aims to suggest a fine motor technique which could increase the children's attention level during their learning as well as to train their fine muscles, a support system was designed with the specific function of aiding in the improvement of children's fine motor skills especially for special children such as Down syndrome and Autism children. Figure 1 shows the prototype of the Fine Motor Training system.

Figure 1: Prototype of fine motor training system

Fine motor support system focused on in-hand manipulation as a small ball was utilised as the training object that will be grasped and manipulated by the children. A relatively small object was used because the attention of children to the object increase with their desire to grasp it and this could then train their fine muscles to be stronger [14]. Besides, the light and music element were applied to this fine motor tool as it can attract the children to perform the fine motor activities repeatedly whilst retaining its appeal.

The fine motor tool function is initiated when the children inserted a small ball into one of the holes, whereby the light will turned on along with the music. Here, different music were assigned to each hole. The small ball was detected by ultrasonic sensor acting as a distance sensor that provides measurement distance ranging from 2 cm to 400 cm. Analog LED RGB strip and buzzer are used to turn on the light and produce sound, respectively. The Arduino Uno board is used as the controller and the three aforementioned components are connected to this board.

B. EMG Measurement

1) Subjects

A total of four healthy children of approximate age group, four to six-year-old with two of them normal and the other two were children with Autism and Down syndrome, respectively participated in this study.

2) Procedures

The surface EMG (sEMG) data of the forearm muscle was acquired using an isolation amplifier, ISO-Z and BMA-400 Bioamplifier. BMA-400 was used due to the low signal level generated by a human, thus, necessitating for a device that can amplify the signal to a certain measurable voltage. A pair of differential Ag/AgCl surface electrodes was placed on the Flexor Digitorum Superficialis (FDS) and the reference electrode was attached on the wrist. The electrode placement and the experimental setup are presented in Figure 2.

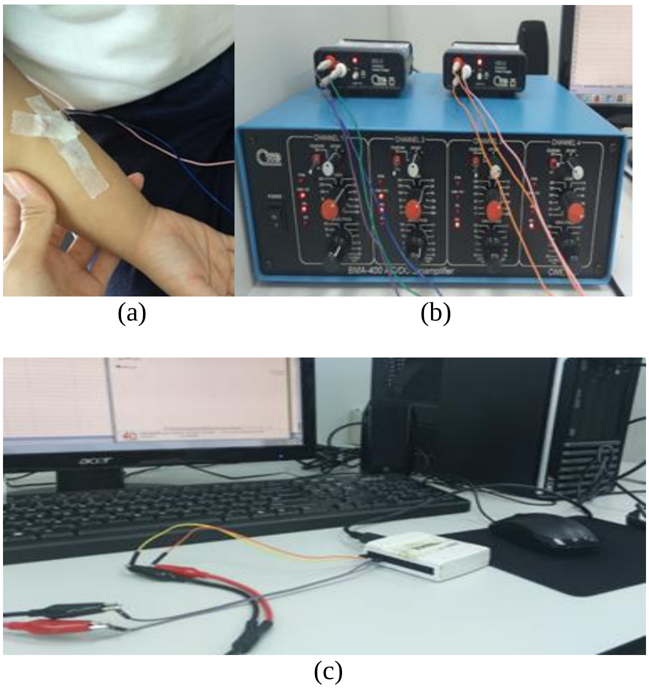


Figure 2: (a) Electrode placement on the subject (b) BMA-400 Bio-amplifier and ISO-Z amplifier (c) National Instrument USB-6009 connected to computer and the input from bio-amplifier

To achieve the lower electrical impedance and reduce the skin resistance, the alcohol prep pads were used before the experimentation start to rub as well as clear the skin and let the electrode paste soaked into the skin for several minutes. By doing this, it is possible to decrease the skin resistance from 200 kΩ to 5 kΩ [11]. Each subject was instructed to sit calmly and carry out the task of inserting a ball into one of the holes of the fine motor tool. The task was made running for 1 minutes and each subject was allowed to pause for approximately 5 seconds to prevent forearms fatigue.

3) Data Acquisition

In this experiment, a National Instruments USB-6009 data acquisition and LabVIEW were used to collect the EMG data. MATLAB was afterward employed to analyse the EMG signals that were sampled at 1000 Hz, which is double the maximum frequency of 500 Hz to prevent signal aliasing as well as adhere to the Nyquist formula. The signals were bandpass filtered using a Butterworth Band Pass Filter with low and high cut-off at 20 Hz and 500 Hz, respectively. Figure 3 illustrates the experiment configuration used in this research.

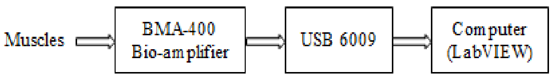


Figure 3: The diagram of experiment configuration

4) Data Analysis

The EMG data acquired using LabVIEW was saved as technical data management (.tdms) file and converted to an excel file for data processing using MATLAB. The EMG signal waveforms were displayed in MATLAB where it showed and identified the activation segment of the flexor movement. Time and frequency analysis was performed on the activation segments to analyze the signals.

The Raw EMG signal is in a complex form which is difficult to comprehend hence requiring further analysis. Fourier transform was performed on the activation segments of the signals to analyze the spectrum. Then, EMG signal is full wave rectified and passed through a low pass filter with a frequency of 5 Hz to smoothen the peaks and obtain a linear envelope of EMG signal as shown in Figure 4. Meanwhile, Figure 5 shows an image of EMG signal as well as its corresponding power spectral density (PSD).

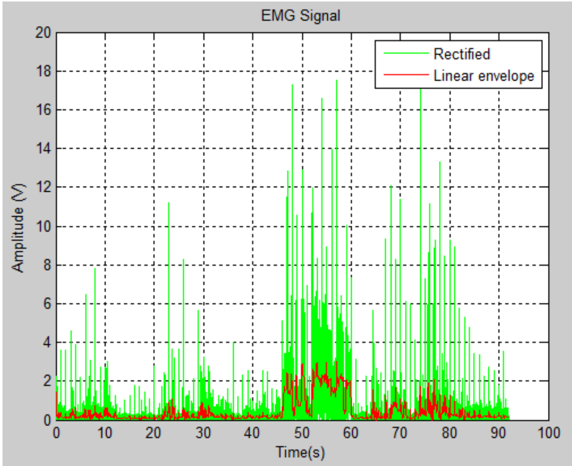


Figure 4: An envelope detection of EMG signal of one of the subject (special needs children *a*)

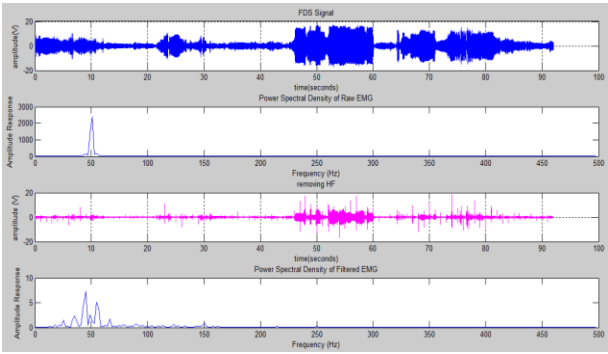
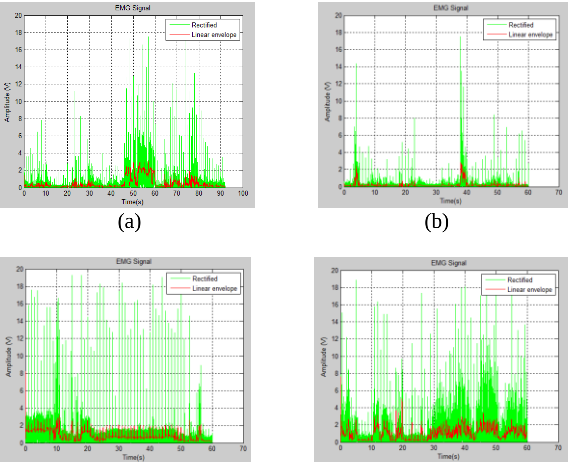


Figure 5: EMG signal and EMG power spectral density

The enveloped EMG can help in computing the amplitude and performance of the children's muscles. As shown in Figure 6, there is the envelope detection of four subjects in 1 minute which (a) and (b) are the envelope detections of children with motor disabilities while (c) and (d) are the envelopes for normal children. The enveloped signals clearly reveal the difference performance of their movement during fine motor activity and from these, the mean signals can be drawn as shown in Table I.



(a) (b) (c) (d)

Figure 6: An envelope detection of EMG signal of four subjects

Table 1
Mean value of enveloped signals in 1 minute

Subject	*a*	*b*	*C*	*d*
Mean (V)	0.4491974	0.2091264	0.8658798	1.0355888

Other than that, EMG data recorded from FDS has been split into three different periods which is when the muscles were in an active period. The plots in Figure 7 represent three phases of an activity lasting 1 minute; in particular the 10 seconds in early, middle and the last parts of the activity were represented. Next, Table 2 represents the mean value for each enveloped signal.

Table 2
Mean value of enveloped signal in every 10 seconds

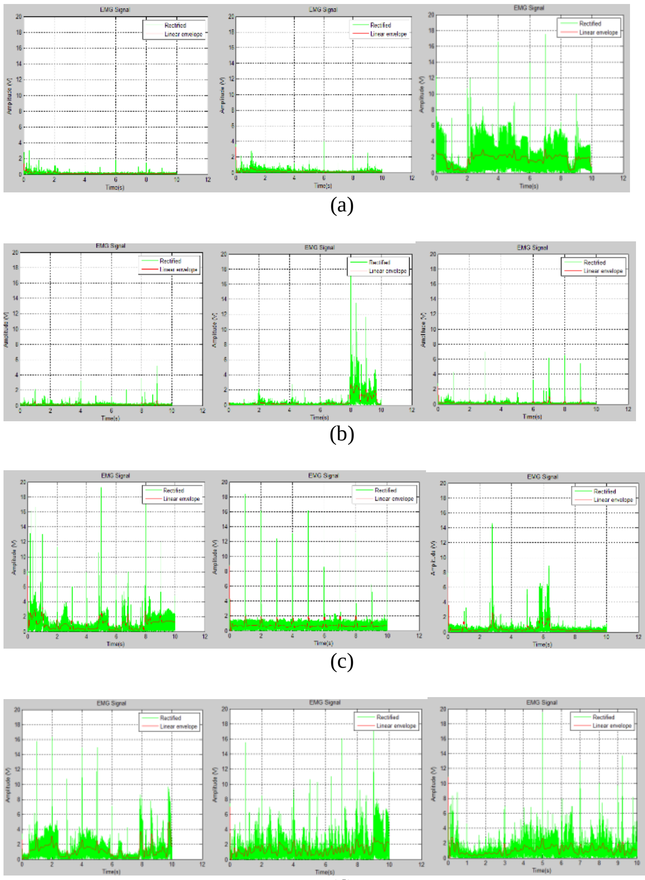
Subject	Special		Normal	
	a	*b*	*c*	*d*
Early	0.1351625	0.1388998	0.972593	1.1605977
Middle	0.1855984	0.4005187	0.7539467	1.331652
Last	1.7283034	0.1538822	0.4437051	1.1070652

C. Fine Motor System Evaluation

To meet the study goals, the project was started with designing a tool that can help the children to develop and enhance underlying fine motor foundations for more skilled hand use and improved control of hand and fingers movements. Thus, to determine the acceptability of fine motor tool that had been invented, an observation was done on children as they used and played with the tool. The response and reaction of children on using the tool that was implemented with music and light element, as well as the time taken are recorded as shown in Table 3.

Table 3
A Comparison of using between conventional way and fine motor system in fine motor activity

Subject	Conventional	Fine Motor System
a	3 minutes 45 seconds	±10 minutes
b	55 seconds	±5 minutes



(a) (b) (c) (d)

Figure 7: An envelope detection of EMG signal of three phases of an activity lasting one minute

There were two children with motor delays in which subject *a* is a child with Down syndrome while subject *b* is an Autistic child. Based on Table 3, conventional type represents the typical activities in Sekolah Kerencatan Akal Johor Bahru where in the fine motor class, children do activities such as playing with playdough, tearing manila cards, drawing and matching an interlocking puzzle. However, this study narrows sown this aspect to the time taken by the children in tearing manila cards and compare it to the time spent playing with the fine motor system with music and light element already implemented.

Apart from that, an observation of using the fine motor system was also carried out on children over the target age to identify their acceptability.

IV. RESULTS AND DISCUSSION

A. EMG Measurement

From the power spectral density of filtered EMG obtained, it was seen that most of the frequencies are within the 20 Hz to 100 Hz range and the PSD of raw EMG clearly shows the signal has power line interference of 50 Hz. The high power peak at 50 Hz determines the contamination of noise in the signal recording, typically due to increased electrical ground noise [2]. Thus, a notch filter at 50 Hz was used to remove and clean the noise from the raw signal. However, the use of a notch filter also suppresses a lot of signal, thus causing the loss of useful information within the EMG signals. Therefore, this clearly shows that a notch filter would not be recommended for EMG data analysis.

Linear envelope computation of the EMG signal is a step required by numerous applications involving the analysis of amplitude in muscular activation [15]. From the enveloped signals, they provide a visual feedback on the activation of muscles. Based on Figure 7, the signals clearly show a difference between them as subject *a* has a higher amplitude at the last 10 seconds of the activity while subject *c* has a higher amplitude at the beginning of exercise. However, the other two subjects have results that are comparatively similar. To attain greater understanding about the comparison of the signal amplitudes, visual graph of the results was plotted as shown in Figure 8.

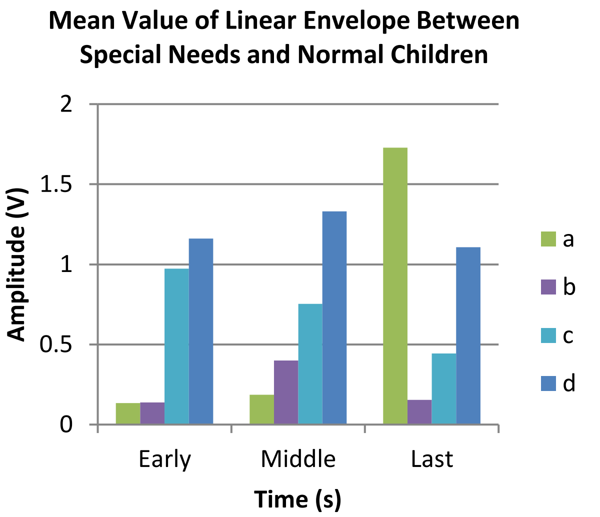


Figure 8: Linear envelope between special needs and normal children

B. Fine Motor System Evaluation

As this study investigates the acceptability of fine motor training kit on children, an observation had been made between normal and special needs children. From Table 3, it presents that children had more focus on using fine motor system compared to the conventional method and it also demonstrates that special needs children were more engaged with the activities involving music and light. Apart from music and light, the fine motor training kit was built with different colors such as blue, green, yellow, red and white which are the basic colors that children should know.

Based on the observation, most of the children have a good response and reaction during the fine motor activity using an intervention system which has been implemented with a new element. Some of them sang and dance along with the music and some of them just kept quiet yet focus on carrying out the activity remained. Nevertheless, special needs children above 12 years old exerted different responses towards the intervention system. Although they do not seem to be interested in the music and light stimuli, they were still doing well in the core activity that is grasping and inserting a ball into a hole of the tool.

V. CONCLUSION

This paper presents a design of an intervention of fine motor tool and implementation of music and light elements to investigate the relationship between children and the fine motor activity involving music and light. Moreover, it also discusses the issues related to fine motor muscles movement on FDS and EMG. The fine motor system is able to successfully attract children to willingly repeat the fine motor activities, thus, it can help them to enhance their fine motor skills and increase the strength of muscles. Furthermore, surface EMG amplitudes were successfully recorded and the performance was evaluated based on the linear envelope approach.

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