Research Article

Impact of Hand Therapeutic Exercises Using Touch Devices on Handwriting Performance: Case Studies in School Children

Smitha John[1] & Renumol V. G.[2]
[1]School of Engineering, Cochin University of Science and Technology
Kochi, Kerala
Email- smithajohnkunnel@gmail.com
[2]School of Engineering, Cochin University of Science and Technology
Kochi, Kerala

Abstract

Handwriting is one of the complex tasks in school years and it is very important for academic excellence. However, various learning disorders can interfere with the learning of basic skills such as reading and writing. The primary objective of this study was to explore whether the digital learning environment reshapes the characteristics of handwriting performance in children with handwriting difficulties. Hence, we have conducted two case studies on two school children studying in 5th and 6th grade. These students were selected for the study based on poor handwriting performance as reported by their class teachers. As part of the study, they have participated in a training session using the 'Dexteria' software. This software comprises two fine motor activities and a letter tracing activity. The principle behind this study is that improving fine motor skills may improve handwriting skills. After the training programme, the experimenter has introduced some fine motor activities using crayons and colour pencils to observe the influence of the touch-based training in their drawing and colouring. They were also asked to write some text to compare the pre- and post-training handwriting samples. It was observed that their fine motor control in drawing skills and handwriting was improved. These case studies were conducted as part of ongoing research work to develop an application for children with handwriting difficulties.

Keywords: Fine motor skills, iPad with Dexteria application, handwriting difficulty, handwriting performance

Introduction

Handwriting is considered an important developmental ability and an essential ingredient for the academic success of a child (Feder, K. P., & Majnemer, A., 2007). It is used in many situations such as notes preparation, examinations, class worksheets, homework, etc. This skill consumes considerable time in a regular classroom routine (Ziviani, J., & Elkins, J., 1986). Acquisition and performance of handwriting skill are related to the perceptual-motor abilities in children (Laszlo, J. I., & Bairstow, P. J., 1984). Illegible handwriting, poor motor control and speed stroke are the core handwriting problems experienced by dysgraphic children (Chang, S. H., & Yu, N. Y., 2013). Handwriting legibility is related to the reading ability of a child, and it is derived from the connection theory of reading and writing (Rose 2004).

Legible handwriting is an important skill and deserves great attention by teaching professionals and health practitioners (Feder, K. P., & Majnemer, A. (2007). In the early school years, paper and pencil was a common practice used by children. However,

the popularity of smart devices, such as tablet computers, kindle, laptops, etc. introduced a new way to young children's learning experience in the interactive environment (Crescenzi, L., et al., 2014; Neumann, M. M., & Neumann, D. L., 2017). Thus, education becomes smart which fosters their academic performance (Neumann, M. M., & Neumann, D. L., 2017).

The objective of this study was to explore whether the touch-based digital environment reshapes handwriting performance in school children. We have introduced an iPad application named Dexteria for developing fine motor skills in school children with handwriting difficulties. Dexteria has three activities, two direct hand-therapeutic fine motor exercises (tapping and pinching) and a letter tracing activity (upper- and lower-case alphabets). The participants were asked to perform these activities under the observation of the experimenter. This paper describes 2 case studies where 2 schoolchildren underwent Dexteria based training to reinforce their fine motor skills to reshape their handwriting performance.
The paper is organized as follows: Section 2 describes the related literature, Section 3 explains the methodology, Section 4 describes the results followed by a discussion and Section 5 concludes the study.

Related works

Handwriting is one of the interesting and complex tasks in human communication (Rosenblum, S., et al., 2013). A good handwriting sample can be related to different abilities of a person and the theory of handwriting (Hollerbach J.M., 1981). Grissmer, D., et al., (2010) have identified that fine motor skills and hand-eye coordination have influence on handwriting skills. These skills are age-based developments, which interact with physical, mental, and cognitive developments in children (Accardo, A. P., et al., 2013: Feder, K. P., & Majnemer, A., 2007). Fine motor development is one of the important aspects of every child to complete their daily activities and it is improved through different practices (Ungerleider, L. G et al., 2002). McHale, K., & Cermak, S. A. (1992), noted that most of the children in elementary schools spent 30-60 percent of the whole day completing fine motor activities, such as writing and other manipulating tasks.

Research has found that the integration of fine motor activities with picture cards in the classroom has an impact on school skills, such as pencil grip and motor development (Ohl, A. M., et al., 2013). West, J., & Haskins, E. (1995), introduced training on fine motor skill development using crayons and pencils in kindergarten to accomplish kids' academic and pre-academic tasks. In school years, the achievement of every child is determined by their academic performance, behaviours, multi-curricular activities, and their school readiness (Pianta, R. C., et al., 2007) and these are measured in terms of handwriting, literacy, and math abilities.

Research studies have proved that the use of e-learning tools, Learning Management Systems (LMS), web-based technologies and other ICT-related tools provide a great opportunity to improve the quality of the learning process. Murray-Smith, R., et al., (2002), have investigated the use of personal digital assistants (PDA) in teaching and shown that it enabled the full participation of individuals with special needs. Adam, T., & Tatnall, A. (2008), have identified that the use of Information and communication technology (ICT) environments provide learning resources and improve the lives of people with learning difficulties. Kumar, K. R. A., et al., (2011) have discussed various techniques to facilitate human-computer interaction. Becker, H. J.

(1986), has identified that systematic use of a computer could support individualized learning and attention. Another study showed that assistive technology with tactile experience could support the handwriting ability of preschool children (Neumann, M. M., & Neumann, D. L., 2017). The unique benefits of touch screen portability and easy navigation allow young children for independent practice and learning with multimedia effects (Mize, M. K., et al., 2018). Martín, E., et al., (2019) showed that touch devices let a direct interaction between students and devices. It also enables students to focus on the content presented and learn how to use these devices easily.

From the literature study, it is obvious that technology-enhanced learning has an impact on young children's learning experience and quality. Motivated by these studies, the authors have conducted case studies on two children who have handwriting difficulty, checking the impact of hand therapeutic exercises using touch-based devices on their handwriting performance.

Methodology

The main objective of this study was to explore whether the touch-based digital environment with hand therapeutic exercises reshapes handwriting performance in school children. We have used case study as the methodology and selected two students having poor handwriting. It was a pre-test post-test-based experiment. The same set of tasks was given in the pre-test and post-test. The idea was to check the influence of a fine-motor skill development application on these students' handwriting performance. There are physical factors such as hand-eye coordination, pen-grip, hand and wrist flexibility, etc. that play a role in the development of handwriting skills and research has proved that fine motor skill influences handwriting. Moreover, the handwriting theory (Hollerbach, J. M., 1981) views handwriting production as a constrained modulation of an underlying oscillatory process where vertical and horizontal oscillations are responsible for letter formation.

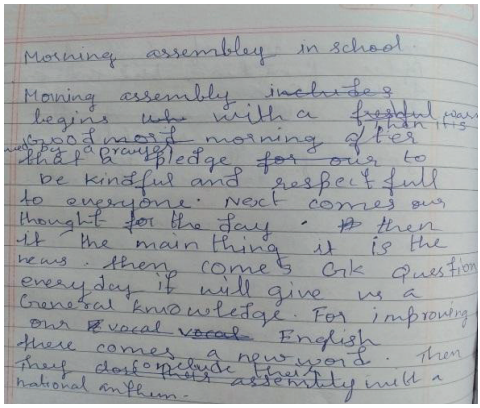
1). Participants

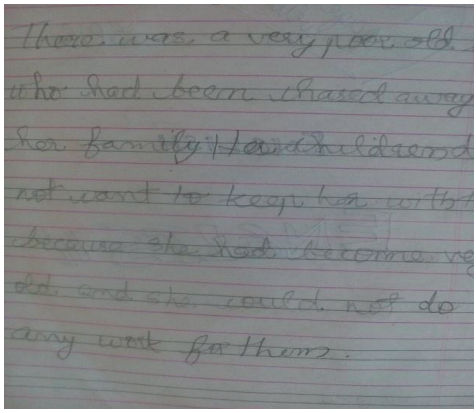
The participants were two female school children studying in 5th and 6th grade in different schools in Kochi, Kerala. We call them participant-1 and participant-2 respectively to identify them. These students were selected for the study based on a report from their class teachers, about their poor handwriting performance. According to their academic performance, they were strong in mathematics and good at reading. They had issues in comprehension and writing. The students participated in the experiment after getting written consent from their parents. The participants were given a pencil, a pen, a ruled notebook and a four-line notebook to record their handwriting performance on pre-test and post-test. They were free to choose among these items.

2). Procedure

To evaluate the participants' current handwriting performance, a pre-test was conducted using paper and pen/pencil. Participant-1 was asked to copy regular class works from a textbook in a rule book and participant-2 was asked to copy an English passage from a storybook in a four-line notebook. The experimenter collected these pre-test samples (see Figure 1) and measured various parameters on handwriting performance. The handwriting rubric used for this study was retrieved from www.YourTherapySource.com/rubricshandwriting.

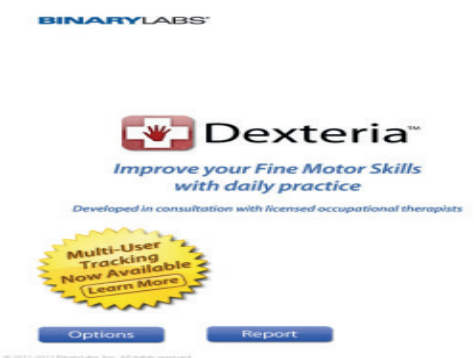
Figure-1: Pre-test samples from participant1 and participant 2





After the pre-test, then as part of the training process, they were introduced to the fine motor skill development app Dexteria (see Figure 2) run in iOS. It comprises three activities, such as 'Tap it', 'Pinch it', and 'Letter tracing' (both upper and lower case). The first two activities are touch-based hand therapeutic exercises to warm up the hand and the third activity was for letter formation. Each participant was allotted 30 minutes of training on a tablet computer for the hand therapeutic exercises and 10 minutes for the letter tracing activity (see Figure 3). Thus, one participant got a total of 40 minutes of training in a day. The training period was in 8 weeks and each participant received an average of 24 hours of training on the 'Dexteria' app to strengthen their hand muscles and handwriting readiness.

Figure-2: Screenshot of Dexteria application with 3 activities -Tap it, Pinch it and Write it



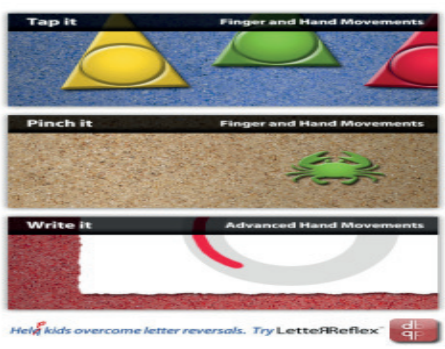


Figure-3: Participants interacting with 'Dexteria' application using tablet computer

Each day after the training session, the experimenter asked them to copy a passage from the given storybook to observe their daily progress. It was then graded using the rubric (see Table 1) and charted to see the progress throughout the training period. It was observed that their fine motor control in the handwriting process was improving. The entire experiment was conducted individually in a university laboratory and the experimenter observed the participants during the training process. The rubric has various parameters on handwriting performance, such as the letter formation, size of letters, the spacing of letters, placement, and neatness for copying tasks. For each participant, the experimenter measured their handwriting performance in pre-test and post-test in terms of letter formation, placement, spacing of letters, neatness, and letter sizing using the Likert scale from '1' to '5', where '1' indicates distorted letter and '5' indicates perfectly written letter. During the training process, the parents of the participants were allowed informally to observe their performance.

Table-1: Handwriting rubrics used for performance evaluation

Parameters of Handwriting	5	4	3	2	1	Final Score
Letter Formation	All the letters are formed correctly	Most of the letters are formed correctly (more than 75%)	Some of the letters are formed correctly (50-75%)	Few of the letters are formed correctly (25-50%)	Less than 25% of the letters are formed correctly	

Placement	All letters are oriented correctly on the lines	Most of the writing samples are oriented correctly on the lines (more than 75%)	Some of the writing samples are oriented correctly on the lines (50-75%)	Little of the writing samples are oriented correctly on the lines (25-50%)	Less than 25% of the writing samples are oriented correctly on the lines	
Letter Sizing	All letters are sized correctly	Most of the letters are sized correctly (more than 75%)	Some of the letters are sized correctly (50-75%)	Few of the letters are sized correctly (25-50%)	Less than 25% of the letters are sized correctly	
Spacing of Letters	All letters are spaced correctly	Most of the letters are spaced correctly (more than 75%)	Some of the letters are spaced correctly (50-75%)	Few of the letters are spaced correctly (25-50%)	Less than 25% of the letters are spaced correctly	
Neatness	Writing assignments are always neat without erasures, torn paper or cross-outs	Most (>75%) of the writing assignment is neat without erasures, torn paper or cross-outs	Some (50-75%) of the writing assignment is neat without erasures, torn paper or cross-outs	Little (25-50%) of the writing assignment is neat without erasures, torn paper or cross-outs	Less than 25% of writing assignment is neat without erasures, torn paper or cross-outs	

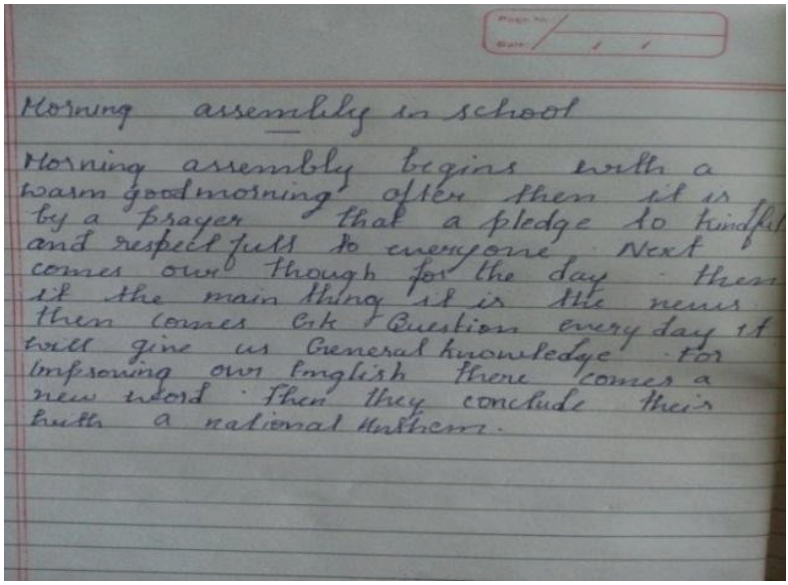
Results and discussion

Over this course of case study research, it was observed that their fine motor control in drawing and handwriting was improved. This was visible through the pictures as well as their handwriting performance. The degree of handwriting performance of each

student on their written expression was uniquely different. The results of the case study, along with the findings of both the participants are given below:

Participant-1: Throughout the study, we have focused on handwriting performance and fine motor skill development. During the first week of training, it was observed that participant-1 had expressed a lack of interest in the training process. But after one week of training, the participant has gained confidence in handwriting and the overall performance of the participant was improved by eight weeks of training. This was visible through their handwriting performance and pictures. We have assessed the handwriting performance based on five attributes, such as letter formation, placement, spacing of letters, neatness, and letter sizing. The initial performance of the child was an average of 2.42 for these five attributes. In the second week, the participant scored 3.39, while in the third week scored 4.24 and in the last week, the participant scored 4.6. The increase of score from the first week to the last week was 2.18 points on the 5-point 'Likert' scale. This result shows that iPad-based training for fine motor skill development was effective for improving the handwriting performance of participant-1. The handwriting sample after 8 weeks of training is given in Figure 4.

Figure-4: Post-test sample from participant-1

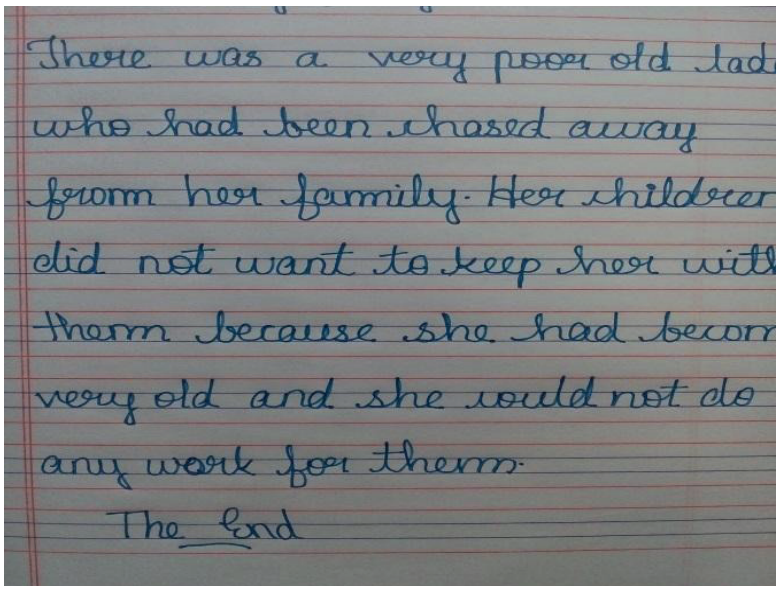

Morning assembly in school

Morning assembly begins with a warm good morning after then it is by a prayer that a pledge to kindful and respect full to everyone. Next comes our thought for the day. then it the main thing it is the news then comes Gk Question every day it will give us General knowledge for improving our English there comes a new word. then they conclude their with a national Anthem.

Participant-2: In this case, the participant had started school years with nominal writing skills, but after third grade, the handwriting skills became sluggish and meagre. Hence, the participant had displayed a lot of hindrance with respect to handwriting development. Also, the pressure applied to the tripod by the participant varied from pencil to pen. This would make a discontinuity in the fluid movement of handwriting. Hence, the experimenter suggested to this participant to maintain a uniform tripod grip. During the fine motor activities on the iPad, we were trying to strengthen the participant's hand muscles to control the tripod and improve the letter formation. After the pre-test, we evaluated the initial performance on

handwriting and got an average score of 2.46 for the 5 handwriting parameters as mentioned in the rubrics in Table 1. The participant has scored an average score of 2.96 in the second week, during the third week the participant has scored an average score of 3.56 and in the last week, the participant has scored 4.32. The progress of this participant from the beginning to the last week was 1.86 points on the 5-point Likert scale. Hence, we can say that the fine motor activities on a touch device were effective for participant-2 also. The sample of improved handwriting is shown in Figure 5.

Figure-5: Post-test sample from participant-2



After the training program, the experimenter introduced some fine motor activities using crayons and colour pencils to observe the influence of touch-based training in drawing and colouring. The pictures drawn (see Figure 6) by them showed visible improvement in their fine motor skills.

Figure-6: Participants' fine motor activities on paper using crayons and colour pencils

In addition to these evaluations, we have conducted a feedback session for the parents to give their valuable feedback/ suggestions on the training process. They mentioned that the technology-based training enabled a better tactile experience for the children, and they were more attentive and motivated during this training than a conventional training method. They Stated that the Dexteria application did not provide any feedback when the participant's haptic movement went wrong. Moreover, the 'Pinch it' activity was tougher for the children, especially at higher levels of the activity where the number of the crabs and the speed of the crabs were high.

Legible handwriting is one of the most important tools for students in their academic excellence (Feder, K. P., & Majnemer, A., 2007). The results of this study indicate that fine motor control has an impact on handwriting performance and drawing skills. Personalized writing style becomes the product of many factors, such as model system, artistic ability, muscular control, nature of employment, frequency of writing and exposures to the writing of others, and it is developed throughout the childhood to adolescent years (Desai, B., & Kalyan, J. L., 2013). In the context of the digital age, computer mediated communication (CMC) can have a positive effect on students and interpersonal interaction. Therefore, today's teachers prefer the implementation of these technologies into their classrooms (Everett, D. R., & Ahern, T. C., 1994). Digital writing supports the students to promote their critical thinking and enrich learning across different writing experiences. Hence, technology is an effective vehicle to help all pupils to develop their skills individually (Chicu, S. et al., 2014).

These case studies were conducted as part of ongoing research work to develop an educational game for children with handwriting difficulties. The major drawback associated with the Dexteria application is that it does not provide any visual or oral feedback when the participant's haptic movement goes in a wrong manner. Moreover, this app is proprietary, hence may not be affordable to children from lower socio-economic backgrounds. But our idea is to develop an android app that would be simple and affordable. It may be complementary to the traditional teaching-learning system used for students with learning difficulties. This case study has given an idea about the pros and cons of the existing tools, which may help us to design a better technology-based tool for handwriting. India's educational vision is to provide basic education for every child through mainstream schools. Sooner these schools will be fully equipped with active learning environments to support the students with learning disorders also. In this context, we plan to introduce some technology-based tools for students with writing disorders to support their academic achievements. They also need individual attention during their learning process, which can be achieved through personalization of the proposed software.

Conclusion and future work

Handwriting is one of the complex tasks in school years, so it is very important to the students who have writing difficulties. This study examined the impact of training on the Dexteria app in handwriting performance. It was obvious that there was an improvement in the handwriting performance of the participants after the training. So, we can conclude that the fine motor development activities using Dexteria have an impact on handwriting performance and drawing skills.

Motivated from the case study results, we are planning to develop simple software to help students having handwriting difficulties. We have studied

the prerequisites for new software and the use of touch-technologies can play an important role in setting an active learning environment for students with handwriting issues. To collect further requirements for the software, we have visited various special schools in Kerala and interacted with the teachers, therapists, and students with dysgraphia. We hope that the use of touch-technology based training interfaces can play an important role in setting an active learning environment for students with writing difficulties.

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