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ORIGINAL RESEARCH ARTICLE

Using a handwriting app leads to improvement in manual dexterity in kindergarten children

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This study aimed to determine the effectiveness of using electronic handwriting applications (apps) in addition to a traditional method of teaching handwriting on kindergarten children's manual dexterity (MD) and handwriting skills. Testing was done with 125 children in two groups: control (n = 67) and experimental (n = 58). Both groups used worksheets, but the experimental group also used an app with a stylus for their practice time. A 2 (group) × 2 (time) analysis indicated a significant interaction for MD ($p < 0.03$), with a significant improvement in the experimental group. Significant differences emerged for legibility, showing that both groups improved at handwriting over time. Study results demonstrated that using apps in the kindergarten classroom can enhance handwriting as well as a traditional handwriting teaching method. Apps also have the advantage of improving MD, which is a building block for several fine motor skills.

Keywords: manual dexterity; handwriting; iPad; app; kindergarten; school-age children

Introduction

Manual dexterity (MD) is associated with fine motor tasks that involve manual manipulation. It is defined as the ability to use the hands in a coordinated way to grasp and manipulate objects, and to perform precise movements that have significant impact on academic skills (e.g. handwriting) and daily functional activities such as dressing and self-care with utensils (Fuelscher *et al.* 2018). Good MD is essential for school-aged children, and problems with this ability can negatively affect children's academic success and self-esteem (Feder and Majnemer 2007). A common consequence of MD problems is difficulties in handwriting, a problem that exists in 10%–30% of school-aged children (McGlashan *et al.* 2017). Handwriting is a motor skill regularly used in academic, personal and professional communication. According to Vinter and Chartrel (2010), handwriting can be conceptualised as a perceptual–motor skill,

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in which the perceptual component pertains to seeing the letter shape and the motor component pertains to the movement producing the letter trajectory. In school, 42% of the time is spent on paper-and-pencil tasks, with the time increasing throughout the grades (Dinehart 2015; Marr *et al*. 2003). Children who have difficulties in mastering handwriting tend to demonstrate lower academic performance and lower self-esteem, sometimes requiring intervention to aid in improving their academic success (Richards 2009).

As previously mentioned, proficient handwriting is one of the scholastic skills that children need to acquire to meet the common demands in classroom work (Volman, van Schendel, and Jongmans 2006). Traditionally, children practise handwriting through the use of worksheets, taught in the classroom first through letter recognition, where the letter shape is connected to a sound (perceptual and linguistic knowledge), followed by tracing and copying letter shapes (motor skills), which employ cognitive skills such as motor planning and motor execution (Overvelde and Hulstijn 2011). In recent years, technological resources for reading and writing have led to changes in some schools' methods. For example, several schools have introduced tablets as a supplement to existing written class work (Marquardt *et al*. 2016). The use of technology seems to be a feasible solution to facilitate learning of handwriting skills and engage children in the process of practicing. Within technology, the development of applications (apps) specifically for handwriting can be applied to a variety of potential educational situations. However, little is known about the outcomes associated with using these apps, especially in the context of specialised fine motor skill such as handwriting.

Despite the increasing use of new technologies in classrooms, Quesenberry, Mustian, and Clark-Bischke (2016) asserted that many classrooms underutilised their technology resources due to scepticism about the benefits and developmental appropriateness for young children. In this vein, we evaluated the effectiveness of using one technology-based app in addition to a traditional method of teaching handwriting to children starting kindergarten. The aim of the present study was to compare the effectiveness of an app-based method of learning handwriting when added to the traditional method versus the use of the traditional method only on both MD and handwriting skills of kindergartners. We predicted that replacing a portion of traditional methods of teaching handwriting with the use of an app would be more effective in developing either one or both variables than traditional methods only. Potential benefits of this and other similar studies include the development of improved pedagogy for teachers and parents, an evaluation of the efficacy of specific apps, as well as findings that could be of use in the future development of educational apps.

Method

Participants

One hundred and twenty-five (76 boys and 49 girls) kindergarten students in the same school participated in this study. The gender split reflected the composition of the cohort. The school was located in a middle-class area in a large urban city in North Texas, and had nine kindergarten classes. The experimental group (EG) included 58 students randomly selected from four kindergarten classes, and the control group (CG) included 67 students from the rest of the classes. Age of the participants ranged

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between 4.5 and 5 years. The study began in August and concluded in December, lasting 12 weeks overall. All procedures were approved by the Institutional Review Board at the University of Texas at Arlington.

Procedures

All children were tested for both MD and handwriting skills before and after the semester-long fall teaching period, with the pre- and post-test being 12 weeks apart. Because the school could not separate the students within the same class, which is the norm in educational research, children were assigned to the CG and EG dependent upon which class they were in. Children placed in the CG learned and practised handwriting using only traditional pen-and-paper methods as determined by the school curriculum. The traditional handwriting curriculum of the school involved a session of 45 min a day, every day of the week, which required students to practise writing letters, words, sentences, paragraphs and stories using a pencil and paper. One teacher instructed students from the front of the classroom on how to hold a pencil, form letters and eventually how to compose sentences. Students then practised the skills on a sheet of paper. Although students practised the skills of correctly holding a pencil, applying the correct pressure on the pencil and paper and forming letters, the teacher moved around the room observing and providing correction and instruction when necessary. The EG was allotted the same amount of time for writing instruction, but unlike the CG, they used traditional methods for 80% of their practice and replaced 20% (1 day of the week) with a stylus-based handwriting app downloaded onto an iPad. The EG participated in the same handwriting exercises as the CG 4 days a week. On the fifth day, the EG students collected their iPad and stylus from the charging station (one for each student), while the CG completed the traditional handwriting lesson for the day.

The app used by the EG was ‘Letter School’. The app was downloaded on each student’s school tablet. Once logged on the app, the child would use a ‘stylus’ (similar to a pencil) to press the letter on the screen and practise the ‘letter of the day’. Firstly, students would watch an illustrated representation of how the letter was formed. Then, they were prompted to form the letter on the screen using beginning and ending points, using the stylus. If the app detected misdirection of the stylus, the students would be directed to begin again until no misdirection was detected by the app. Once this step was complete, a movement-based illustrated representation would reinforce the steps to forming the letter. For the final step, students would use the stylus to draw a chalk representation of the letter on the screen. The beginning and ending points were only visible prior to the stylus starting of the letter. Once the student began to write, the points disappeared and would only reappear if misdirection of the letter on the screen was detected. The student would then be given unlimited chances to write the letter until it was completed correctly. Once the child felt confident with the letter and had completed all three steps in the app, they were allowed to review previously learned letters. The D’Nealian font was previously selected in settings for the app. It has been stated that the D’ Nealian is a handwriting system that minimises formational differences between manuscript and cursive; letters are slightly oval and slanted with ending strokes (Shaw 2011). This style of handwriting was the preferred style of writing at the school because they believe that it helps students move easily from manuscript to cursive writing in the upper elementary grades. Students were supervised during their practice time on the app by their classroom teacher.

Children were individually tested for MD and handwriting in a quiet room before the practice started (in August, during the first 2 weeks of school, and in December, during the last 2 weeks of school before the winter break). Each individual testing session lasted about 30 min, depending on each child.

Instruments

Handwriting app. The stylus-based handwriting app used in this study is called 'Letter School', an alphabet tracing app for toddlers and preschoolers. The app was developed by the Letter School Enabling Learning, and is compatible with the iPhone, iPad and iPod touch (available for downloading at the Apple App Store). The app allows the child to select any letter that they wish to practise. When a letter is selected, the letter shape is presented on the screen, followed by the sound of the letter and an audio presentation of a word beginning with that letter. For example, if the child selects the letter E, the app says 'E is for elephant', while a picture of an elephant is briefly superimposed upon the letter shape. Although highly engaging due to the nature of the graphic presentation, the informational content presented via letter shape, sound and word is relatively similar to the instruction in a traditional classroom. However, the remaining elements of the app, which involve observing writing, tracing and then writing from memory with cues when needed, go beyond traditional classroom capabilities.

Movement Assessment Battery for Children, 2nd edition (MABC-2; Henderson, Sugden, and Barnett 2007). This tool is a well-documented, individually administered, standardised test that provides an assessment for children with motor impairment. The MABC-2 is designed for children, ranging in age from 3 to 16 years. The test contains eight subtests across three domains: manual dexterity, aiming and catching, and balance. In this study, we used only the MD subtest to assess levels of MD proficiency. This test consisted of three sections: posting coins, threading beads and a trail drawing. The posting coins section required a test taker to insert 12 coins into a box with a small slit on the top, completed by using first the preferred and then the non-preferred hand. The fastest time was recorded on the score sheet for trials on each hand. The threading beads section asked the test taker to use their preferred hand and thread 12 beads on a string. The fastest time was documented on the score sheet. The drawing a trail section demanded the test taker to complete two trials by drawing a trail leading a bicycle rider to their home. The pen marks were only allowed to show forward movement, anything to the contrary resulted a deduction in the score recorded on the score sheet. Total standard and percentile score are provided. The instrument's measures of reliability are at 0.75 for test–retest and 0.70 for inter-rater reliability.

Evaluation Tool of Children's Handwriting (ETCH; Amundson 1995). The ETCH is a criterion-referenced standardised tool developed to assess children's handwriting speed and legibility, with seven specific tasks similar to those required in the classroom. The assessment is divided into manuscript and cursive, and is given on the basis of use in the classroom. Here, we only administered the manuscript version due to the age of the children. The seven tasks are as follows: writing the alphabet from memory using lower- and uppercase letters, writing numerals from memory, copying words and sentences from near and far distances, writing a dictation of non-words and numbers, and composition of a sentence. Here, only the first three subtests for manuscript handwriting were administered; these subtests included writing uppercase letters, lowercase letters and numbers from memory. Word, letter and numeral

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legibility are scored according to specific criteria, allowing a legibility percentage to be calculated. The percentage of legibility for each task is averaged together for total legibility percentage of word, letter and numeral. The ETCH manual describes the test as being appropriate for testing children from grades 1 to 6. The test was chosen for use in the present study of kindergartners following the example of Hall and Case-Smith (2007), who also used the first three subtests on younger children. This was done to limit the areas of writing to numbers and printed letters, and to avoid cursive given that no equivalent test for kindergartners currently exists. The inter-rater reliability is acceptable (0.84) between experienced raters. Pearson coefficients for test–retest reliability range between 0.63 and 0.77.

Data analysis

MD and handwriting were the dependent variables. Handwriting was evaluated through the word, letter and number legibility (WL, LL and NL) of the ETCH. We conducted a 2 (group: EG/CG) × 2 (time: pre-/post-test) mixed model analysis for each one of the dependent variables to compare the results of the groups and the results of the pre- and post-test. Statistical significance was set at 0.05. All analyses were conducted using SPSS Version 24.0 (SPSS Inc., Chicago, IL).

Results

Manual dexterity

Figure 1 shows the results of the 2 × 2 mixed model analysis for MD. Results indicated no significant differences between the groups, $F(1,123) = 1.93$, $p > 0.05$ and time of testing, $F(1,123) = 1.67$, $p > 0.05$. However, a significant interaction was detected, $F(1,123) = 4.81$, $p < 0.05$, with results indicating that only the EG improved from the pre- to the post-test.

Handwriting skills

The results for handwriting are divided in WL, LL and NL. Figure 2 shows the results of the 2 × 2 mixed model analysis for WL. Results indicated no significant differences

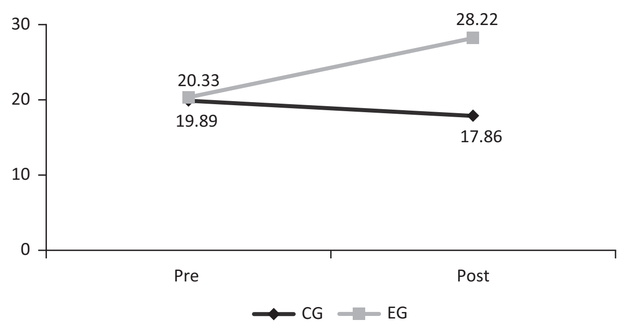

Figure 1. Differences in pre- and post-test means for manual dexterity.

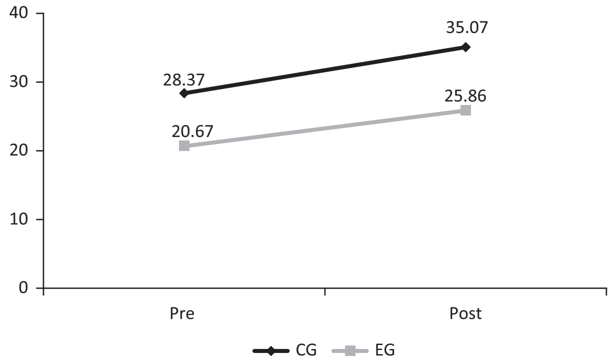

Figure 2. Differences in pre- and post-test means for word legibility.

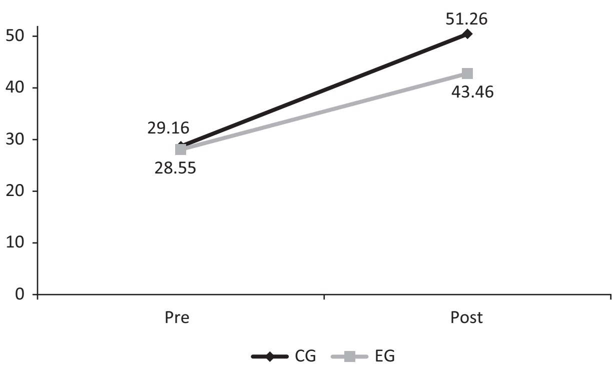

Figure 3. Differences in pre- and post-test means for letter legibility.

between the groups, $F(1,123) = 2.93$, $p > 0.05$ and time of testing, $F(1,123) = 1.67$, $p > 0.05$. No significant interaction was detected, $F(1,123) = 0.28$, $p > 0.05$.

Figure 3 shows the results for LL. Results indicated no significant differences between the groups, $F(1,123) = 1.26$, $p > 0.05$. However, a significant difference was observed for time of testing, $F(1,123) = 87.84$, $p < 0.01$. The interaction was not significant, $F(1,123) = 3.30$, $p > 0.05$.

Figure 4 shows the results for NL. Results indicated no significant differences between the groups, $F(1,123) = 1.02$, $p > 0.05$. However, a significant difference was observed for time of testing, $F(1,123) = 42.12$, $p < 0.01$. The interaction was not significant, $F(1,123) = 2.42$, $p > 0.05$.

Discussion

The purpose of this study was to evaluate the effectiveness of using an app in addition to a traditional method of teaching handwriting to children starting kindergarten. To achieve this goal, we compared the effectiveness of an app-based method of learning handwriting added to the traditional method to a traditional method only on both MD and handwriting legibility of kindergartners. We predicted that replacing 20%

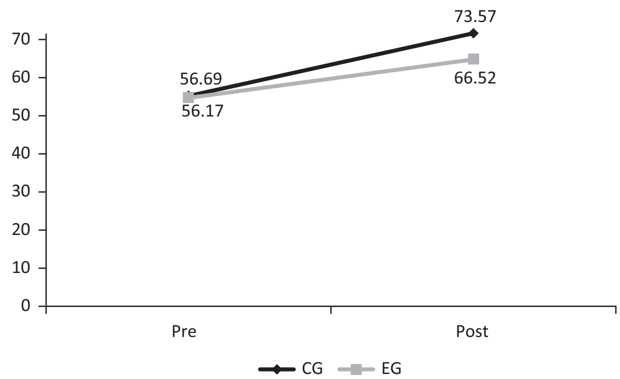

Figure 4. Differences in pre- and post-test means for number legibility.

of the time spent on pen-and-paper methods with the use of an app would result in marked improvement of either one or both variables than would traditional methods alone. Overall, our results met these expectations with only the EG showing significant improvement in MD, while both groups improved handwriting skills with regard to both LL and NL equally. Here, we discuss these findings.

The first point to be made is that the EG which replaced 20% of traditional writing instruction with an electronic app and stylus fared no worse in any skill measured. Further studies should test the dose–response relationship of an app-based handwriting training to verify whether it is possible to increase the use of technology and still get efficient handwriting results. Whether MD would increase by a greater degree and whether EG and CG would differ at LL, NL or WL at higher levels of app use, in this case 'Letter School' would be of interest. Considering Arndt's (2016) comment that there is no sufficient evidence to conclude that paper and pencil should be replaced by digital devices may be a reason to at least partially replace some pen-and-paper handwriting instruction with digital devices, considering that digital media has become an important part of our everyday life, and is likely to be increasingly present in education due to the degree of motivation and engagement with technology possessed by today's digital native students.

The most interesting finding pertains to a significant improvement in MD in the EG, not found in the CG. MD is the ability to use manual coordination to grasp and hold objects in fine motor tasks, and is significantly associated with handwriting skills. In other words, MD is an ability that underlies performance in handwriting, and can be a significant predictor of average or high handwriting skills. The results of this study allow us to infer that manipulating the iPad and the stylus increased students' MD, even when it was only used for 20% of their handwriting training time. Although this result is novel in the educational setting, it is supported in rehabilitation settings as Coutinho *et al*. (2017) found that using iPads along with traditional therapy can improve visuomotor integration skills in preschool children being treated for a specific weakness in this skill by occupational therapists.

This leads to the question of what it was about this particular app that supported MD more than traditional methods alone. Firstly, the physical tools being used were different. There is the possibility that the use of a stylus on a screen allowed the children to have a grip, hand position or degree of friction between the stylus and screen that allowed for the development of greater dexterity. Another possibility, one that we estimate as more likely, is the ability of the app to provide immediate feedback to the students. Although a teacher would typically only be able to comment on particular parts of letters after they were complete, the app was able to provide feedback while an individual line was still being drawn. The immediacy of this feedback and the need to correct the drawing of each line to proceed to the next step likely allowed children the rare opportunity to make 'microcorrections'. The feedback provided by the app regarding line positioning is very different from receiving feedback from a teacher after having completed several letters or perhaps an entire worksheet.

Another aspect that may have influenced the children's participation is the motivation and engagement that the use of the technology may have brought to handwriting practice. Although we did not formally assess these variables, it is highly possible that an interest in using technology influenced the children's interaction with the tablet and potentially motivated them to practise more, with and without the tablet. Pegrum, Oakley, and Faulkner (2013) indicated that iPads are a familiar feature in classrooms around the world, regarded as a promising tool for supporting teaching and learning, and definitely motivating and engaging for students. Bryant *et al*. (2015) have found that student engagement is higher when instruction is delivered by use of electronic apps. Certainly, future studies need to address engagement and other similar variables in the context of handwriting learning.

Although the present study addressed significant questions, the findings should be interpreted in light of its limitations. We used a convenience sample in the same school, and were unable to randomise children to each condition. We were also not able to control children's experiences with tablets and apps, and their use outside of school. Future studies should address these limitations as well as continue to study the effectiveness of adding technology and apps into the classroom with direct outcome measures, such as the ones used here. Another limitation was the use of ETCH – the test is originally validated for children starting grade 1 – however, the first three subtests of ETCH, the same used in the current study, have been used with 5-year-olds (Hall and Case-Smith 2007). In addition, the expansion of the types of apps and the dose–response effectiveness can be a significant step towards incorporating technology in the classroom. Despite the limitations, the findings of this study are an important step towards understanding the effectiveness of using apps in the classroom to improve MD and handwriting.

These results also have implications, especially in regards to academic achievement. Dinehart and Manfra (2013) stated that preschool students' performance on writing and object manipulation tasks can have significant effects on 2nd grade reading and math achievement. One possibility that might partially account for this motor and cognitive causal link is that most activities that build or display cognitive skills also involve the use of fine motor skills, and earlier motor skill development could have a significant impact on later cognitive development (Grissmer *et al*. 2010). That is another reason why the improvement of MD and other forms of fine motor abilities must be studied and enhanced in school settings.

In conclusion, the results of this study demonstrate that using apps in the classroom can enhance handwriting as well as a traditional handwriting teaching method, and has also the advantage of improving MD, which is a building block for several fine motor skills. We suggest that teachers and schools should explore the use of handwriting apps and incorporate these activities in the classroom environment.

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