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ORIGINAL ARTICLE

Usability of Otulis Application and Handwriting Performance among Four to Six Years Old Children in Malaysia

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ABSTRAK

Kesukaran dalam tulisan tangan ialah perkara biasa dalam masyarakat teknologi masa kini, walaupun ia merupakan satu keperluan dalam pendidikan. Kebiasaanya, ahli terapi cara kerja menggunakan penilaian tulisan tangan untuk mengenal pasti kesukaran tersebut. Walau bagaimanapun, tiada instrumen penilaian tulisan tangan untuk kanak-kanak berumur 4 hingga 6 tahun yang tersedia dalam Bahasa Malaysia. Oleh itu, OTulis merupakan penilaian tulisan tangan dalam Bahasa Malaysia yang baru dibangunkan dan ditukar menjadi aplikasi bagi menjadikannya lebih mudah diakses. Kajian ini bertujuan untuk menilai kebolehgunaan aplikasi OTulis serta menilai prestasi tulisan tangan dalam kalangan kanak-kanak berumur 4 hingga 6 tahun di Malaysia. Kajian ini dibahagikan kepada dua fasa. Fasa pertama melibatkan temu bual separa berstruktur dan soal selidik kebolehgunaan. Lima responden telah dipilih menggunakan kaedah persampelan bertujuan dan data dianalisis melalui analisis deskriptif dan kandungan. Dalam fasa kedua, kanak-kanak direkrut melalui persampelan mudah dan prestasi tulisan tangan mereka dinilai. Data yang diperoleh dianalisis secara deskriptif. Penemuan menunjukkan bahawa aplikasi OTulis mempunyai kebolehgunaan yang baik. Penemuan ini mendedahkan bahawa kebanyakan kanak-kanak berumur 4 hingga 6 tahun telah mencapai genggaman pensel yang matang serta dapat menyalin dengan tepat masing-masing 13 huruf besar dan 11 huruf kecil, 24 huruf besar dan 25 huruf kecil, serta 24 dan 25, masing-masing. Aplikasi OTulis mempunyai kebolehgunaan yang baik dan sesuai digunakan oleh ahli terapi cara kerja, guru prasekolah dan ibu bapa. Secara keseluruhannya, penemuan menunjukkan bahawa prestasi tulisan tangan kanak-kanak bertambah baik dengan peningkatan umur.

Kata kunci: *Kanak-kanak prasekolah; penilaian tulisan tangan; perkembangan tulisan tangan; prestasi tulisan tangan; terapi pekerjaan*

ABSTRACT

Handwriting difficulties are common in today's technological society, although it is a requirement for schooling. Commonly, occupational therapists use handwriting assessments to identify handwriting difficulties. However, no handwriting assessment for 4 to 6-year-old children is available in Bahasa Malaysia. Thus, OTulis is a newly developed Bahasa Malaysia handwriting assessment and it has been converted into an application to make it more accessible. This study aimed to evaluate the usability of the OTulis application and assess the handwriting performance of 4 to 6-year-old children in Malaysia. The study was divided into two phases. Phase one involved semi-structured interviews and a usability questionnaire. Five respondents were selected using the purposive sampling method and data were analysed through descriptive and content analysis. In phase two, the children were recruited through

convenient sampling and their handwriting performances were assessed. Data obtained were analysed descriptively. The findings show that the OTulis application has good usability. The findings reveal that most 4 to 6-year-old children have achieved a mature pencil grip and can accurately copy 13 uppercase and 11 lowercase letters, 24 uppercase and 25 lowercase letters, and 24 and 25, respectively. OTulis application has good usability and is applicable to use by occupational therapists, preschool teachers, and parents. Overall, the findings show that children's handwriting performance improves with age.
Keywords: Handwriting assessment; handwriting development; handwriting performance; occupational therapy; preschool children

INTRODUCTION

Handwriting is a vital skill for school-aged children, serving as a primary means of communication in note-taking, completing assignments and examinations. Despite advances in digital technology, handwriting remains fundamental in education. Teachers overwhelmingly emphasise its importance, with a survey reporting that 99.3% of school teachers consider handwriting crucial (Marquardt et al. 2016). Neuroscience findings also highlight handwriting's cognitive benefits: activation of the anterior cingulate cortex and Broca's area is more significant during writing than typing, strengthening reading and letter recognition skills beyond sensorimotor activity alone (James & Engelhardt 2012). Handwriting has also been associated with improvements in visual-spatial processing and fluency (James 2010; Mayer et al. 2020).

Nevertheless, handwriting difficulties are widespread. Globally, as many as 38.5% of primary school children experience challenges with handwriting fluency and legibility (Marquardt et al. 2016). Common issues include letter inversion, spacing, pressure control and orientation (Kushnir et al. 2013). Such errors are particularly evident in younger children aged three to seven years, with mirror writing frequently observed (Fischer 2011; Portex et al. 2018). Factors such as the "right writing rule" and preceding letter influence exacerbate these difficulties, leading to errors in letters like b/d or p/q (Fischer 2011). Beyond developmental errors, persistent handwriting difficulties are classified as dysgraphia, a specific learning disorder associated with deficits in visuomotor integration and visual memory (Chung et al. 2020; Vlachos & Karapetsas 2003). Children with dysgraphia typically produce handwriting that is less legible, slower and less consistent compared to their peers (Prunty & Barnett 2017).

In Malaysia, evidence shows that handwriting difficulties remain a concern, although systematic prevalence data are limited. Research indicates that many primary school students continue to struggle with basic handwriting skills (Abdul Rasid et al. 2012; Yahya & Suzanawaty 2014). A survey of preschool and kindergarten teachers in Klang Valley revealed that nearly 70% of children had not mastered the basic 3Rs, with handwriting issues such as writing off the line, inconsistent letter size and prolonged task completion commonly reported (Hamid 2021; Wahab & Yassin 2022). To address early literacy challenges, the Ministry of Education Malaysia (MOE) introduced the Literacy and Numeracy Screening (LINUS) program in 2009 (Ministry of Education Malaysia 2013). However, despite these initiatives, there is still a lack of validated, standardised tools in Bahasa Malaysia specifically targeting handwriting performance among children aged four to six.

Occupational therapists recognise handwriting as a critical skill for academic success, often using assessments to identify difficulties and plan interventions (Hammerschmidt & Sudsawad, 2004; Asaba et al. 2017). Internationally, tools such as the Print Tool, Shore Handwriting Screening, and Minnesota Handwriting Assessment are widely used, but these instruments are not culturally or linguistically adapted for Malaysian children. To fill this gap, the OTulis assessment

has been developed as the first validated and reliable handwriting tool in Bahasa Malaysia for children aged four to six (Achmy et al. 2023). More recently, OTulis has been digitised into an application, improving accessibility and usability for practitioners, educators and parents.

Given the growing need for culturally relevant tools to assess and support children's handwriting development in Malaysia, this study aimed to evaluate the usability of the OTulis application and assessed handwriting performance among preschool-aged children. Findings from this research provided evidence for early identification and targeted intervention, addressing gaps in current assessment practices and contributing to improved educational outcomes.

MATERIALS AND METHODS

Ethical approval was granted by the Research Ethics Committee of Universiti Kebangsaan Malaysia (UKM PPI/111/8/JEP-2021-474) and Educational Policy Planning and Research Division, Ministry of Education, Malaysia [KPM.600-3/2/3-eras(14330)]. The present study utilised a mixed-method research design, which comprised two phases. Phase one aimed to evaluate the usability of the OTulis application. Meanwhile, phase two aimed to assess handwriting performance among children 4 to 6-years old in Malaysia.

Phase 1

According to Maramba et al. (2019), usability referred to the degree to which a product may be utilised by users to attain specific objectives with efficacy, efficiency and satisfaction. The study design used in this phase combined qualitative and quantitative, which involved a usability questionnaire and semi-structured interview among the target users (occupational therapists, preschool teachers and parents). The combination of qualitative and quantitative methods provided a deeper understanding of the target user's perspective and engagement (Weichbroth 2019). This phase was conducted at a private preschool in Malaysia with the owner's permission.

In this phase, respondents assessed children's handwriting performance using the OTulis application. After the assessment session, respondents completed 18 items of the Malay-mHealth Application Usability Questionnaire (M-MAUQ). The m-Health Application Usability Questionnaire (MAUQ) is a usability questionnaire that was originally in English and developed and validated by Zhou et al. (2017). Meanwhile, M-MAUQ is the Malay version of MAUQ translated and validated by Mustafa et al. (2021). M-MAUQ consists of three domains: (i) ease of use (five items); (ii) interface and satisfaction (seven items); and (iii) usefulness (six items). According to Mustafa et al. (2021), the content and face validity indexes exceeded 0.79, indicating that the items in the M-MAUQ are relevant in measuring the clarity and comprehensibility of the target users.

After the respondents completed the M-MAUQ, a semi-structured interview was carried out. The semi-structured interview was conducted to obtain respondents' feedback regarding the usability of OTulis application. The interviews began with broad, introductory questions to establish rapport and ease participants into the discussion, before gradually transitioning into more focused and in-depth questions based on participants' responses. The structure of the interview guide incorporated four main types of questions: grand tour, core questions, planned follow-up questions and unplanned follow-up questions, as outlined by DeJonckheere and Vaughn (2019). In addition to this structure, the interviews also considered key usability factors to better understand how participants interacted with the application being evaluated. Attention was given to attributes such as efficiency, user satisfaction, learnability and low error rates, which reflected essential components of effective usability design. These elements were consistent with the framework proposed by Zhou et al. (2017), who highlighted efficiency, satisfaction, learnability, memorability and low error rates as fundamental usability

characteristics. Efficiency referred to the product that allowed the user to achieve their goals. Satisfaction referred to the user giving positive feedback, learnability referred to the product that was easy to learn, memorability referred to the procedure of using the product that was easy to remember even if the user had not used it for a long time and the low error rate referred to the rate of errors occurring during use (Zhou et al. 2017). Since the present study was a cross-sectional study design and was not conducted over a long period of time, the memorability attribute was not measured. Table 1 showed the example of interview guide.

The interview sessions were recorded with the respondents' agreement for transcription purposes. The interview sessions were held for about 15-20 minutes for each respondent. Respondent validation was carried out at the end of each interview session to strengthen the trustworthiness of the data gained from respondents (Birt et al. 2016). The usability testing involved five respondents. The respondents were recruited using purposive sampling as this phase aimed to assess usability among the target users of the application. Virzi (1992) stated that four or five respondents were sufficient to identify 80% of the usability problems. The respondents were selected based on inclusion and exclusion criteria. The inclusion criteria for this phase were occupational therapists or teachers who worked with children ages 4 to 6 years and parents who had children ages 4 to 6 years and can communicate in Bahasa Malaysia. Meanwhile, the exclusion criteria were occupational therapists or teachers working with special needs children and parents with special needs children.

Finally, the respondents' demographic data and the data from M-MAUQ were analysed descriptively to obtain the mean and standard deviation. The M-MAUQ was determined by the mean score of all items. The higher the means, the better the app's usability. Whereas the mean lower than four indicates poor usability (Mustafa et al. 2021). Meanwhile, semi-structured interviews were analysed using content analysis. Content analysis involved three steps, namely preparation, organising and reporting (Elo et al. 2008). The first step began with the recording of interviews were transcribed into verbatim. The researcher thoroughly reviewed the transcript several times to comprehend and master the entire transcript. The second step was the organising process, which entailed the organising process encompassing the identification of data codes, the segmentation of data into distinct categories and the formulation of a comprehensive description for each category. The data were categorised based on four usability attributes: learnability, efficiency, error rate and satisfaction (Zhou et al. 2017). Next, the last step was reporting. The researcher summarised the data provided by respondents and a report was produced.

TABLE 1: Example of interview guide

Grand tour	Core	Planned Follow-Up
Can you tell me your experience when using the application?	Efficiency Do you think you can use the application to conduct the assessment efficiently?	Were there any steps that felt unnecessarily time-consuming?
	Satisfaction How satisfied were you with the overall experience of using the application?	What aspects of the application did you enjoy the most?
	Learnability How easy was it for you to learn how to use the application?	Did you need any guidance or training before using the application?
	Low error rates Did you encounter any errors or difficulties while using the application?	Were you able to continue using the application after the issue occurred

Phase 2

In this phase, researchers assessed handwriting performances among children aged 4 to 6 using the OTulis application. This phase was conducted at government and private preschools in Malaysia. OTulis application contained two sections. Sections A and B required different methods to conduct, which section A required children to complete the task in the application. Meanwhile, section B needed to be completed using pencil and paper. Table 2 presented the components included in the OTulis application. Section A comprised four tasks: pencil grip, posture, visual memory and letter recognition. For the pencil grip and posture tasks, researchers observed how the children held the pencil and their body posture during the assessment. In the visual memory task, children were shown a sequence of shapes for five seconds and were required to recall the sequence. For the letter recognition task, children identified the letter dictated by the application by pointing to the correct one on the screen. Section B also included four tasks: fine motor control, fine motor precision, shape copying and sentence copying. In the fine motor control task, children were instructed to draw a line between two parallel lines without crossing the boundaries. For the fine motor precision task, they were asked to color eight circles of varying sizes without coloring outside the lines. Lastly, children were required to copy shapes and sentences as displayed on a given sheet.

TABLE 2: Content of OTulis application

Section	Task
Section A	Pencil grip
	Posture
	Visual memory
	Letter recognition
Section B	Fine motor control
	Fine motor precision
	Copying shape
	Copying sentence

The sampling method used was convenience sampling as this method allows for obtaining a large number of samples quickly. The children were chosen based on inclusion and exclusion criteria. The inclusion criteria for phase two were children ages 4 to 6 who can communicate in Bahasa Malaysia. Meanwhile, the special needs children were excluded from the study. The sample size for Phase 2 of the study was calculated using Krejcie and Morgan's (1970) formula for determining the appropriate sample size for a given population, which recommended a sample size of 384 for populations of 100,000 or more. Therefore, our final sample size of 384 participants was appropriate for the intended analysis and ensured reliable results.

Next, descriptive analysis was performed to analyse the data. The descriptive analysis used for demographic data was the frequency. Besides, pencil grip and posture were also analysed using frequency as they involved categorical data. Meanwhile, visual memory, fine motor control, fine motor precision, letter recognition, copying shapes and copying sentences were analysed using means, standard deviations and Z-scores because they involved continuous data. Effect sizes (Cohen's d) were also calculated to determine the magnitude of differences between age groups (Cohen 1988). Effect sizes were interpreted based on Cohen (1988), with 0.2 indicating a small effect, 0.5 a medium effect and 0.8 a large effect.

Based on Andrade (2021), Z-scores allowed scores in different units to be interpreted. The total scores for visual memory, fine motor control, fine motor precision, letter recognition, copying shapes and copying sentences were converted into Z-scores. A normality test was performed because the Z-score assumed the data had a normal distribution (Devore 2017). If the data were normally distributed, the Z-score was interpreted based on the empirical formula that 68% of the observed data was within one standard deviation of the mean, 95% was within two standard deviations and 99.7% was within three standard deviations (Haynes 2018). However, normality testing revealed a non-

normal data distribution; therefore, the Z-scores were interpreted according to the percentage of students who scored above or below the mean. According to Andrade (2021), a positive Z-score indicated a score higher than the mean (above average), while a negative Z-score indicated a score less than the mean (below average). The Z-score was calculated using the formula below:

$$Z = \frac{x - \mu}{\sigma}$$

Whereas,

μ = mean
σ = standard deviation

RESULTS

Phase 1

A total of five respondents were included in phase one of the study. Table 3 presented the demographic characteristics of the respondents. Table 4 presented the mean score of the usability questionnaire (M-MAUQ). The mean score for all respondents was in the range of 4.5 to 6.3, and the overall mean was 5.5. Next, Table 5 presented categories and relevant excerpts of semi-structured interviews.

TABLE 3: Demographic characteristics of respondents in Phase 1

Variables	n (%)
Profession	
Preschool teacher	3 (60%)
Occupational therapist	1 (20%)
Parent	1 (20%)
Gender	
Male	-
Female	5 (100%)
Education level	
Diploma	2 (40%)
Bachelor's Degree	3 (60%)

n: Number of respondents

TABLE 4: The mean score of the usability questionnaire (M-MAUQ)

Respondents	Mean
Occupational therapist 1	6.3
Preschool teacher 1	6.0
Preschool teacher 2	5.2
Preschool teacher 3	4.5
Parent 1	5.7
Overall average	5.5

Phase 2

In Phase 2, 114 of 4 years old, 134 of 5 years old and 136 of 6 years old children were involved. Table 6 showed the demographic characteristics of the children involved. All the 4-year-old children were from private preschools. Meanwhile, 5-year-old and 6-year-old children were from government and private preschools. The 4-year-old children comprised 59 boys and 55 girls, 5-year-old children comprised 66 boys and 68 girls and 6-year-old children comprised 65 boys and 71 girls. Most children were observed using their right hand as their dominant hand. Next, Table 7 showed the frequency of the pencil grip observed during the assessment. The most frequently observed pencil grip was the dynamic quadruped, followed by the lateral tripod. Table 8 showed the posture observed during the assessment. Most children used appropriate desks for their height and sat with knees and hips at 90 degrees. Besides, throughout the assessment, most children were observed not leaning against the chair and with their feet not flat on the floor.

Table 9 showed the means, standard deviations, and Z score for letter recognition, fine motor control, fine motor precision, copying shapes and copying sentences. Four-year-old children showed the best performance for the shape-copying task with the highest mean score of 73.91. The highest positive Z-score was also observed for the shape-copying task, indicating that 58% of 4-year-olds scored above average. Next, 5-year-old children also showed the best performance for the shape-copying task, with

TABLE 5: Categories and relevant excerpts of a semi-structured interview

Categories	Respondent (%)	Relevant excerpts
1) Learnability		
- Requires a long time	40%	"I take more time to understand how to use this application, I think I need training before using the application "I need more time to understand the scoring procedure and to key in the scores."
- Require a short time	60%	"I can understand how to use this application easily. For me, if you read the manual carefully, you will understand well." "Very easy because the instructions are all complete, and the scoring box has been provided." "This application is not complicated, so it is easy to understand."
2) Efficiency		
- Efficient	40%	"I can conduct the assessment efficiently using this application." "No problems because the manual is complete."
- Inefficient	60%	"Inefficient because for me it's a bit confusing since this assessment involves two mediums, paper and application. It is easier if this assessment is in an application only." "I need much time to key the scores into the scoring box. Furthermore, I cannot proceed to the next task until I finish keying all the scores
3) Error		
- Make error	40%	"I made a mistake in scoring for the fine motor presicion task." "I made a mistake in scoring for the sentence copying task. It's a bit confusing to enter a score for each letter."
- No error	60%	-
4) Satisfaction		
- Satisfied	100%	"I feel satisfied after completing the application as I become clearer about which component my students having problems." "I feel very satisfied even though it's a bit complicated." "OTulis is a good assessment and easy to use."
- Dissatisfied	-	-

TABLE 6: Demographic characteristics of respondents in Phase 2

Variables	n (%) 4 years old	n (%) 5 years old	n (%) 6 years old
Gender			
Male	59 (52)	66 (49)	65 (48%)
Female	55 (48)	68 (51)	71 (52%)
School			
Private	114 (100)	77 (57)	32 (24%)
Government	-	57 (43)	104 (76%)
Dominant hand			
Right	101 (89)	122 (91)	125 (92)
Left	13 (11)	12 (9)	11 (8)

n: Number of respondent

TABLE 7: Frequency of pencil grip observed during the assessment

Types of pencil grip	n (%)		
	4 years old	5 years old	6 years old
Radial cross palmar	-	-	-
Palmar supinate	8 (7)	-	-
Digital pronate	-	-	-
Brush	2 (2)	-	-
Extended finger	3 (3)	1 (1)	-
Cross thumb	2 (3)	4 (3)	3 (2)
Lateral quadrupod	11 (10)	18 (13)	13 (10)
Dynamic quadrupod	42 (37)	59 (44)	57 (42)
Lateral tripod	34 (30)	38 (28)	37 (27)
Dynamic tripod	10 (9)	11 (8)	24 (18)
Others	2 (2)	3 (2)	2 (1)

n: Number of respondent

TABLE 8: Postures observed during the assessment

Posture	4 years old, n (%)		5 years old, n (%)		6 years old, n (%)	
	Yes	No	Yes	No	Yes	No
Desk at elbow height	68 (60)	46 (40)	95 (71)	39 (29)	116 (85)	20 (15)
Knee at 90°	65 (57)	49 (43)	92 (69)	42 (31)	108 (79)	28 (21)
Feet flat on the floor	35 (31)	79 (69)	45 (34)	89 (66)	58 (43)	78 (57)
Body leaning straight against the chair	33 (29)	81 (71)	57 (43)	76 (57)	53 (39)	83 (61)
Hip at 90°	61 (54)	53 (46)	93 (69)	41 (31)	109 (80)	27 (20)

n: Number of respondent

TABLE 9: Mean, standard deviation, and Z-scores for letter recognition, fine motor control, fine motor precision, copying shape and copying sentences

	Tasks	Mean (Standard deviation)	Z-scores	
			Z-score (-)	Z-score (+)
4 years old	Letter recognition	62.82 (27.35)	49%	51%
	Fine motor control	44.15 (16.69)	59%	41 %
	Fine motor precision	60.86 (31.86)	45%	55%
	Copying shape	73.91 (20.21)	42%	58%
	Copying sentence (uppercase letter)	48.95 (37.83)	46%	54%
	Copying sentence (lowercase letter)	41.24 (37.60)	53%	47%
	Copying sentence (spacing)	8.47 (19.71)	80%	20%
	Copying sentence (size)	41.37 (41.36)	52%	48%
	Copying sentence (writing on the line)	29.10 (37.75)	59%	41%
5 years old	Visual memory	47.48 (37.17)	56%	44%
	Letter recognition	74.47 (22.35)	46%	54%
	Fine motor control	51.67 (15.50)	56%	44%
	Fine motor precision	85.28 (19.72)	32%	68%
	Copying shapes	91.34 (9.95)	54%	46%
	Copying sentence (uppercase letter)	93.05 (11.35)	35%	65%
	Copying sentence (lowercase letter)	90.58 (12.53)	34%	66%
	Copying sentence (spacing)	27.65 (36.51)	63%	37%

Continued...

...continuing

	Tasks	Mean (Standard deviation)	Z-scores	
			Z-score (-)	Z-score (+)
	Copying sentence (size)	82.32 (28.73)	27%	73%
	Copying sentence (writing on the line)	67.19 (36.86)	47%	53%
6 years old	Visual memory	54.37 (39.15)	49%	51%
	Letter recognition	84.56 (16.86)	43%	57%
	Fine motor control	60.85 (16.39)	46%	54%
	Fine motor precision	90.40 (13.04)	46%	54%
	Copying shapes	95.44 (7.78)	32%	68 %
	Copying sentence (uppercase letter)	96.08 (5.21)	49%	51 %
	Copying sentence (lowercase letter)	95.10 (5.70)	37%	63%
	Copying sentence (spacing)	48.17 (40.25)	54%	46%
	Copying sentence (size)	94.94 (13.71)	16%	84%
	Copying sentence (writing on the line)	72.65 (32.43)	48%	52%

the highest mean score of 91.34. Meanwhile, the highest positive Z-scores were discovered for copying sentences (size), suggesting that 73% of 5-year-old children performed above average for copying sentences (size). On the other hand, 6-year-old children performed best at copying sentences (uppercase letters), with a mean value of 95.44. The highest positive Z-scores were observed for the copying sentence (size), indicating that 84% of 6-year-olds performed above average on the copying sentences (size).

Table 10 presented effect sizes (Cohen's d) for OTulis task performance comparing 4,5 and 6 years old. Cohen's d values indicated very large effect sizes for sentence copying tasks between ages 4 and 6, particularly for uppercase letters (d = 1.75), lowercase letters (d = 2.00) and size (d = 1.74). These findings indicate marked improvement in fine motor coordination and handwriting execution with age. Similarly, tasks such as copying shapes (d = 1.41) and fine motor precision (d = 1.21) exhibited large to very large effects, suggesting rapid development in visual-motor integration during the preschool years. In contrast, visual memory demonstrated only a small effect size between 5- and 6-year-olds (d = 0.18), implying more gradual development or potential ceiling effects in this area. Overall,

TABLE 10: Effect sizes for each otulis task by age group

	Cohen's d (4 years old vs and 5 years old)	Cohen's d (4 years old vs and 6 years old)	Cohen's d (5 years old vs and 6 years old)
Visual memory	-	-	0.18
Letter recognition	0.47	0.96	0.51
Fine motor control	0.47	1.00	0.58
Fine motor precision	0.92	1.21	0.31
Copying shapes	1.09	1.41	0.46
Copying sentence (uppercase letter)	1.58	1.75	0.34
Copying sentence (lowercase letter)	1.76	2.00	0.46
Copying sentence (spacing)	0.65	1.25	0.53
Copying sentence (size)	1.15	1.74	0.56
Copying sentence (writing on the line)	1.02	1.24	0.16

most tasks measured in OTulis showed the greatest gains between ages 4 and 5, with smaller incremental improvements between 5 and 6 years.

DISCUSSION

Phase 1

Phase 1 of the present study evaluated the usability of the OTulis application and assessed handwriting performance among 4- to 6-year-old children in Malaysia. OTulis demonstrated good usability among occupational therapists, preschool teachers and parents, as indicated by an overall M-MAUQ mean of 5.5. In addition, 60% of participants required minimal time to learn the application and reported no usage errors, and all respondents expressed satisfaction with OTulis. These findings suggest OTulis is user-friendly and suitable for use in the Malaysian context.

Despite positive usability outcomes, several issues were identified through the semi-structured interviews. More than half of the participants reported challenges in administering the OTulis application, which may be attributed to initial unfamiliarity with the tool, as it was introduced for the first time during the session. Respondents received only a brief explanation of the study and were not provided with prior training or demonstrations, as OTulis was designed to be utilised by all parties without requiring qualifications or training. Thus, inefficiency and some errors are expected feedback from the first-time users. In addition, respondents also remarked that the OTulis handwriting assessment should be developed fully as an application. The current hybrid model, which involves both the application and printed materials, was reported to cause confusion among users. However, the development of OTulis assessment solely within the application will not accurately reflect actual handwriting performance, particularly for tasks requiring writing instruments, such as fine motor control, fine motor precision, copying shapes and copying sentences. Thus, OTulis remains a combination of application and paper.

Phase 2

Phase 2 of the study assessed handwriting performance in Malaysian children aged 4 to 6 years, revealing a progressive improvement in skills with increasing age. The findings align with previous research that found handwriting improves with age (Accardo et al. 2013; Germano & Capellini 2019).

(i) Pencil grip

The findings reveal that 85% of 4-year-olds, 94% of 5-year-olds and 96% of 6-year-olds demonstrate mature pencil grips, indicating that most 4- to 6-year-olds in Malaysia have achieved a mature pencil grip. Schneck and Henderson (1990) reported that 95% of 320 children aged 6.5 to 7 years were observed using a mature pencil grip. A mature pencil grip is characterised by a grip stabilised by the thumb, index finger, middle finger, ring finger, slightly extended wrist and supinated arm (Case-Smith & O'Brien 2015 According to Dennis and Swinth (2001), mature grips include the dynamic tripod, lateral tripod, dynamic quadrupod and lateral quadrupod patterns. As children age, improvements in fine motor skills enhance their ability to adopt mature grips. The development of fine motor coordination and strength enables children to perform more complex tasks, including handwriting (Henderson & Pehodki 2006). Additionally, sensory development contributes to the application of appropriate pressure during pencil use (Henderson & Pehodki 2006).

(ii) Posture

According to the Frame of Reference for the development of handwriting skills, good posture is required to produce legible handwriting (Kramer & Hinojosa 2010). The frame of reference outlines the key characteristics of optimal sitting posture, including feet placed flat on the floor, knees and hips flexed at 90 degrees, elbows bent, and wrists

slightly extended (Kramer & Hinojosa 2010). The findings revealed that while more than half of the 4- to 6-year-old children were observed sitting with their knees and hips at a 90-degree angle, a significant portion of them were also noted to have their feet not flat on the floor and not leaning against the chair. Instead, many children were observed hunching forward or slumping backwards during the assessment. Proper posture, such as supporting the back by leaning against the chair, is essential for maintaining an upright position, which in turn minimises mechanical load on the intervertebral discs and other spinal structures. While posture is widely recognised as a critical factor influencing handwriting quality, the observed misalignments-feet not flat and not leaning against the chair-could reflect developmental limitations, as children's motor coordination and postural control are still in the process of maturing. Moreover, environmental factors, such as mismatched desk and chair sizes, may also contribute to improper posture, a finding that aligns with previous research (Saarni et al. 2007). Therefore, to enhance posture during handwriting tasks, it may be necessary to consider adjustments such as ergonomically designed furniture or instructional interventions, as suggested by existing study.

Based on Floyd and Roberts (1958), table height is related to the elbow height, whereas the ideal table height influences the elbow and wrist position. The ideal table height, which corresponds to the height of the elbow when seated, allows for proper elbow flexion on the table surface and slight wrist extension, promoting ergonomic positioning during tasks (Floyd & Roberts 1958). In the current study, 60% of 4-year-old children, 71% of 5-year-old children and 85% of 6-year-old children were observed using desks at elbow height, which is considered appropriate for their height. In contrast, a study conducted in Finland among 12 and 14-year-old children showed that, on average, school desks and chairs did not match the students' anthropometric measurements (Saarni et al. 2007). Overall, the findings suggest a progressive improvement in posture with age, with 5-year-olds demonstrating better postural alignment than 4-year-olds and 6-year-olds better than 5-year-old. This is consistent with the observations of Schärli et al. (2012), who reported that postural stability improves as children mature. Emphasising correct posture is critical, especially considering that children spend a greater proportion of time sitting during school hours compared to non-school hours (Abbott et al. 2013).

(iii) Visual-motor integration

Visual-motor integration (VMI) skills were measured using the copying shapes task. The significant differences in mean shape-copying scores between 4- and 5-year-olds (d = 1.09) and between 4- and 6-year-olds (d = 1.41) reflect large effect sizes. In contrast, the more moderate effect size between 5- and 6-year-olds (d = 0.46) suggests that the rate of improvement slows after age 5, pointing to a critical period of rapid development between ages 4 and 5. The findings are similar to a previous study that reported a significant increase between 4- and 5-year-old children (Fang et al. 2017). However, Fang et al. (2017) found inconsistent findings for 5 to 6-year-old children. The study used the Beery-Buktenica Visual-Motor Integration assessment to assess VMI skills in 4- to 6-year-old children. The assessment also uses shape-copying activities to assess VMI skills. The discrepancy between the findings for 5- and 6-year-olds across the two studies may be attributed to differences in scoring methods, given that distinct assessment tools were utilised.

(iv) Visual memory

Next, visual memory was assessed only among 5- and 6-year-old children, in accordance with the OTulis manual guidelines. The results indicated that 6-year-olds outperformed 5-year-olds; however, the effect size was small (d = 0.18), suggesting minimal developmental change in visual memory across this one-year span. This finding may imply that visual memory either

stabilises earlier in development or that it is less sensitive to age-related changes within this age range. Previous research has revealed that children's visual memory capacity increases with age (Riggs et al. 2006; Simmering 2012; Vlachos & Karapetsas 2003). One possible explanation for the discrepancy may lie in the role of selective attention during assessment. Plebanek and Sloutsky (2017) reported that younger children tend to process more irrelevant information due to difficulties in filtering distractions, which may interfere with effective memory encoding and retrieval. Therefore, although older children typically demonstrate better visual memory, the minimal difference observed in this study may reflect the influence of attentional variability, task demands or measurement limitations.

(v) Letter recognition

Letter recognition is defined as the ability to recognise letter shapes and is a sub-skill of letter knowledge vital in children's handwriting (Puranik et al. 2011a; Puranik et al. 2011b; Puranik et al. 2013). In the present study, 4-year-old children correctly recognised an average of three to four letters out of the six assessed. Five-year-olds recognised approximately four letters correctly, while 6-year-olds recognised five letters on average. These developmental differences were supported by small to large effect sizes: a moderate effect between 4- and 5-year-olds (d = 0.47), a large effect between 4- and 6-year-olds (d = 0.96) and a moderate effect between 5- and 6-year-olds (d = 0.51). This indicates a steady and meaningful improvement in letter recognition skills from ages 4 to 6. Based on Fisher (2011), difficulty remembering the shape of letters is more likely to be observed for left-facing letters due to the influence of the right writing rule. However, the findings contradict the study from Fisher (2011), children in the current study most frequently confused the letters "b" and "p," both of which share highly similar visual structures. This suggests that perceptual similarity plays a more significant role in early letter recognition errors. If the right writing rule were the primary factor, errors would be expected more frequently with left-facing letters.

(vi) Fine motor skills

The two sub-components of fine motor skills assessed in OTulis are fine motor control and fine motor precision. Both tasks showed improvements in fine motor skills with increasing age. For fine motor precision, large effect sizes were observed between 4- and 5-year-olds (d = 0.92) and between 4- and 6-year-olds (d = 1.21), indicating substantial developmental gains. The effect size between 5- and 6-year-olds was small (d = 0.31), suggesting slower improvement during this later period. Similarly, fine motor control demonstrated moderate to large effect sizes, with d = 0.47 between 4- and 5-year-olds, d = 1.00 between 4- and 6-year-olds, and d = 0.58 between 5- and 6-year-olds, reflecting steady and meaningful progress across these ages.

Similar results were reported in Memisevic and Hadzic (2013), who reported significant improvements in fine motor skills using the Lafayette Pegboard Test, particularly among younger children (2.8-4.5 years) compared to older children (4.6-6.5 years). Thus, the study concludes that there is a period of accelerated development of fine motor skills and that this period is an optimal time to implement interventions to prevent fine motor delays (Memisevic & Hadzic 2013). Johan et al. (2017) also reported significant age-related improvements, showing rapid fine motor skill development in preschool and early elementary grades compared to later grades, supporting the idea that fine motor skills develop most rapidly during early childhood and early schooling.

(vii) Copying sentences

In the copying sentences task, significant differences observed in the mean scores between 4-year-old children and their 5- and 6-year-old counterparts, while performance between 5- and 6-year-olds was relatively similar. Four-year-old children generally were unable to copy

all uppercase and lowercase letters, whereas most 5- and 6-year-old children demonstrated the ability to copy nearly all letters accurately. On average, 4-year-old children can accurately copy 13 uppercase and 11 lowercase letters, 5-year-old children can copy 24 uppercase and lowercase letters and 6-year-old children can correctly copy 25 uppercase and lowercase letters. These developmental differences were supported by very large effect sizes for both uppercase and lowercase letters: for uppercase letters, d = 1.58 between 4- and 5-year-old and d = 1.75 between 4- and 6-year-old, indicating substantial improvement. The effect size between 5- and 6-year-old was small (d = 0.34), suggesting minimal change during this later period. For lowercase letters, even larger effects were found, with d = 1.76 between 4- and 5-year-old, d = 2.00 between 4- and 6-year-old, and a small effect (d = 0.46) between 5- and 6-year-old. These results highlight rapid development in letter copying skills from ages 4 to 5, with slower gains between ages 5 and 6.

The findings of this study are consistent with those of Case-Smith and O'Brien (2015), who stated that 4-5-year-old children can copy some letters and may write their names, while 5-6-year-old children can copy most letters and write their names. However, it should be noted that name writing was not assessed in the present study. The findings of this study contradict those of Molfese et al. (2006), who reported that, on average, 4-year-old children can write or copy only one to three letters and can write some or all of the letters in their names. Other than that, the finding revealed that the mean score for uppercase letters is higher than the lowercase letters for all three age categories, indicating that children 4 to 6 years old have better performance in the formation of uppercase letters than lowercase letters. This may be influenced by the exposure period, whereas children are often introduced to uppercase before lowercase letters (Bolton et al. 2021).

Integrated Perspectives on Handwriting Development in Malaysian Preschoolers

This study highlights developmental patterns in handwriting among Malaysian preschoolers, with implications typical learners. Younger children, particularly at age four, showed weaker fine motor control, difficulties in spacing and line placement, and immature grasps and posture. Such weaknesses mirror handwriting difficulties commonly observed in developmental coordination disorder and related conditions, suggesting that OTulis may serve as an effective tool for early identification and targeted support (Barnett et al. 2020). The findings also emphasise the critical importance of implementing appropriate accommodation, particularly in instances of low assessment scores. In line with occupational therapy principles, the provision of adjustable desks, adaptive writing tools and optimised assessment platforms can facilitate equitable access while enhancing the validity of assessment outcomes (Fajariani et al. 2025).

Beyond individual needs, cultural and international comparisons enrich the interpretation of the data. Malaysian children develop handwriting within a multilingual, multiscript context (Bahasa Malaysia, English, Mandarin and Tamil), which shapes the timing and style of acquisition and explains some variability across recognition and copying tasks. By age six, children performed at levels comparable to international milestones, but four-year-olds lagged in sentence spacing and alignment, suggesting contextual rather than developmental delays (Hall 2022). These results emphasise the necessity of culturally grounded benchmarks while reinforcing evidence that handwriting practice itself supports literacy beyond digital input (Ibaibarriaga et al. 2025). Together, these findings affirm the validity of OTulis as a developmental assessment tool and highlight directions for inclusive, culturally sensitive handwriting education in Malaysia.

Despite the strengths of this study, several limitations must be considered. The sample was limited to typical children from a few selected states in Malaysia, and cultural diversity was not explicitly accounted for, meaning the findings cannot be generalised to represent the handwriting performance of all Malaysian children aged 4 to 6 years. Consequently, normative data could not be established. However, the findings still offer valuable insights for clinical use, as OTulis remains an effective tool for within-child progress monitoring. Clinicians and educators can compare an individual child's performance to the mean scores of their age group (provided in Tables 9-10), allowing for meaningful tracking of handwriting development over time and helping to identify areas that may require intervention. This approach enables practitioners to assess each child's unique handwriting progression, ensuring personalised support even in the absence of broad normative data. To address the limitations, future research should involve a more diverse and representative sample, incorporating children from all states and cultural backgrounds to reflect Malaysia's multi-ethnic population. Furthermore, while this study applied only descriptive analyses, it is essential for future research to incorporate inferential statistical analyses and normative data collection. This will help ensure that the findings are truly representative of Malaysian children aged 4 to 6 years, enabling the establishment of developmental benchmarks for handwriting performance. Such efforts will enhance the generalisability of OTulis as a reliable handwriting assessment tool for children across Malaysia.

CONCLUSION

In conclusion, the OTulis application has good usability and is applicable to use by occupational therapists, preschool teachers and parents. The findings of this study indicate a clear developmental progression in handwriting performance among children aged 4 to 6 years. Besides, the present study also discovered the types of pencil grips and postures observed among children. In addition, children's performance in fine motor, visual memory, VMI, and letter recognition were identified. The study also identified the number of letters children can write based on age. Finally, the handwriting performance data obtained in this study can serve as a preliminary guideline for occupational therapists, preschool teachers and parents in supporting the handwriting development of children aged 4 to 6 years.

The present study is the first handwriting assessment in Bahasa Malaysia that has been developed as an application. The development of application-based assessment aligns with the nation's accelerated technological advancements and the increasing integration of digital tools in education and healthcare. Next, this study employs a holistic approach, targeting occupational therapists, teachers, and parents as the primary users of the developed application. Their involvement is critical in supporting and reinforcing children's handwriting development within clinical, educational, and home settings. The findings of this study indicate a clear developmental progression in handwriting performance among children aged 4 to 6 years.

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