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Dot-Connecting Practice Improves Graphomotor Skills in Kindergarteners with Difficulties: Benefits of Varied Practice

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Highlights

What are the main findings?

- Both constant and varied dot-to-dot tracing practice significantly improved visual–motor skills in kindergarteners with graphomotor difficulties compared to no intervention.
- Varied practice with an identical trial volume achieved superior gains over constant practice in feature copying, spatial relations, and visual–motor precision.

What is the implication of the main finding?

- Introducing systematic variations in task parameters enhances cognitive-motor processing and promotes superior skill transfer.
- Structured, varied dot-connecting activities may serve as a useful component of early graphomotor interventions for kindergarten children with graphomotor difficulties.

Abstract

Background/Objectives: Despite the high prevalence of graphomotor difficulties in young children, the therapeutic efficacy of dot-to-dot tracing practice remains underexplored. This study evaluated the impact of constant versus varied practice protocols on the visual–motor skills of 85 Arab Israeli kindergarteners (M_{age} = 68.86 months, *SD* = 3.93; 35 girls) exhibiting graphomotor challenges. **Methods**: Participants were randomly assigned to constant practice (n = 28), varied practice with an identical trial volume (n = 29), or a no-intervention control group (n = 28). Varied practice involved systematic changes in the spatial orientation of the dot-connecting pattern, while constant practice involved repetition of the same configuration. Visual–motor abilities were assessed pre- and post-intervention using four subtests of the Developmental Test of Visual Perception (DTVP-2): Eye–Hand Coordination, Copying, Spatial Relations, and Visual–Motor Speed. **Results**: Results demonstrated that both intervention groups achieved significantly greater gains on all DTVP-2 subtests than the control group. Furthermore, the varied practice group outperformed the constant practice group on three key measures, supporting the varied practice hypothesis in motor learning. **Conclusions**: These findings indicate that structured dot-connecting tasks effectively enhance graphomotor capabilities, with varied practice offering distinct advantages for visual–motor precision, feature copying, and spatial skill transfer. These findings suggest that varied dot-connecting practice may be a useful component of early graphomotor interventions. However, the results should be interpreted cautiously, as functional handwriting was not directly assessed and the contribution of increased visuospatial demands cannot be excluded.

Keywords: handwriting; constant practice; intervention; occupational therapy; DTVP-2

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1. Introduction

Fine motor skills refer to the ability to perform precise and coordinated movements using the small muscles of the hands and fingers [1–3]. These skills support various functional activities and contribute to children's readiness for school-related tasks [4,5]. Visual–motor integration refers to the coordination of visual perception and motor output and represents a distinct but related developmental construct [2,4]. Graphomotor skills involve translating visual-spatial information into controlled and sequenced hand movements required to produce graphic forms, such as strokes, shapes, and patterns [5,6]. Handwriting represents a more complex, language-related application of these foundational abilities, additionally involving the learning and execution of conventional letter forms and motor sequences. Insufficient development of these foundational graphomotor abilities during early childhood significantly hinders a child's readiness for formal handwriting instruction upon entering primary school [7,8]. Consequently, graphomotor and early handwriting difficulties represent one of the most prevalent reasons for referring young children to occupational therapy services [4,7,8]. Children who struggle with graphomotor tasks in early childhood often exhibit lower task endurance, heightened frustration, and difficulty keeping pace with developmental peers, factors that can negatively impact both their academic trajectory and psychosocial well-being [4]. Therefore, investigating early interventions that target graphomotor skill acquisition in kindergarteners before formal academic demands escalate is important.

Despite the increasing prevalence of digital devices in modern classrooms, handwriting remains a fundamental medium through which young children engage with the educational curriculum. The functional significance of this skill becomes evident when considering the substantial proportion of the school day dedicated to pencil-and-paper activities; specifically, elementary school children spend 30% to 60% of their instructional time engaged in handwriting and fine motor tasks [9]. As a complex motor skill trained through procedural memory mechanisms, handwriting relies on the precise integration of visual-perceptual, cognitive, and fine motor abilities [10,11]. Estimates of handwriting and graphomotor difficulties vary considerably across studies, partly due to differences in age groups, assessment criteria, and definitions of difficulty [10,12]. Research specifically addressing preschool children indicates that handwriting development is associated with multiple factors, including motor skills, letter knowledge, executive functions, and writing-surface characteristics [13]. Assessing graphomotor development in this age group also requires developmentally appropriate instruments. Although specialized tools such as GRAFOS-2 have been developed for children aged 4–9 years [14], the availability and applicability of standardized assessments remain important considerations in early identification and intervention. Difficulties in foundational graphomotor skills may negatively affect children's academic engagement and performance, highlighting the importance of early support.

Graphomotor abilities in preschool children are associated with subsequent academic achievement and may help identify children at risk for later difficulties in reading and mathematics [15,16]. Although several intervention approaches have been developed to enhance early graphomotor and handwriting skills, repeated task-specific practice remains an important component of effective intervention [4,17]. Previous studies have examined approaches such as systematic instruction in functional writing [18], Response-to-Intervention Tier 1 programs [7,19], sensorimotor interventions [5], and fine-motor and visual–motor activities [3]. Evidence also indicates that multisession dot-to-dot practice can improve children's handwriting performance, demonstrating the potential value of simple and scalable graphomotor training tasks [20].

Nevertheless, the existence of multiple intervention approaches does not clarify which structure of practice is most effective during the preschool years. Motor-learning theories distinguish between constant practice, in which a single motor pattern is repeatedly performed under stable conditions, and varied practice, in which task parameters are systematically modified. Schema theory proposes that varied practice may facilitate the formation of generalized motor representations and promote transfer to novel tasks [21]. Research on contextual interference similarly suggests that greater variability during practice may benefit transfer, although its effects depend on the learner and the characteristics of the task [22]. Practice schedules have also been found to influence children's ability to transfer in graphomotor learning [23]. However, the relative effectiveness of constant and varied practice has not been sufficiently examined among kindergarten children with emerging graphomotor difficulties.

Early identification of graphomotor difficulties and the development of appropriately structured interventions may help reduce the persistence of these difficulties as formal handwriting demands increase [10]. Therefore, examining whether varied practice produces greater improvement than constant practice on untrained visual–motor outcomes assessed 24 h after training may contribute to the development of focused, accessible, and evidence-based early graphomotor interventions.

2. Theoretical Framework

2.1. Motor Learning Theory as the Primary Framework

Motor Learning Theory provides the primary theoretical foundation for the present study because it addresses how practice conditions influence skill acquisition and generalization. Motor learning refers to relatively lasting changes in the capacity to perform a skill that result from practice or experience. It distinguishes temporary performance effects from learning assessed through retention or performance on unpracticed tasks [24].

A central distinction relevant to the present study is between constant and varied practice. Constant practice involves repeatedly performing the same movement under stable task conditions and may promote consistency in the specifically practiced movement. In contrast, varied practice systematically changes task parameters or movement requirements across trials. According to Schema Theory, experience with different movement variations may support the development of more flexible motor representations that can be adapted to unfamiliar task conditions [21].

In the present study, practice variability was examined by comparing repeated practice of a constant graphomotor configuration with practice involving systematic variations in its spatial orientation.

Practice variability is particularly relevant to graphomotor learning, which requires the integration of visual information, spatial planning, movement sequencing, and fine-motor control. Previous research using the Invented Letter Task (ILT) has shown that structured, multisession dot-to-dot practice can support graphomotor learning and handwriting-related performance [23,25], and that practice conditions can influence children's generalization to novel graphomotor task conditions [20]. However, whether varied practice provides an advantage over constant practice in generalization to untrained visual–motor tasks among kindergarten children with graphomotor difficulties remains unclear.

2.2. Literacy Development as a Supporting Framework

The literacy-development perspective provides the educational rationale for studying early graphomotor learning. Handwriting is an important component of written-language development. As handwriting becomes more fluent and automatic, fewer working-memory resources are required for letter production, allowing greater attention to spelling, idea

generation, organization, and text composition [26,27]. Handwriting fluency and legibility are also associated with the quality and quantity of children's written work [28], while early fine-motor and graphomotor abilities have been associated with subsequent academic achievement [15,16]. Explicit handwriting instruction and practice can further improve handwriting performance and aspects of written composition.

This perspective establishes the educational significance of identifying practice conditions that support early graphomotor development. However, it serves as a supporting rather than explanatory framework in the present study, because the specific comparison between constant and varied practice is derived from Motor Learning Theory.

2.3. Developmental Psychology as a Supporting Framework

Developmental psychology provides additional context by situating graphomotor learning within the rapidly developing cognitive and motor abilities of kindergarten children. During early childhood, substantial development occurs in fine-motor coordination, visual–motor integration, spatial organization, and symbolic representation, all of which contribute to the production of shapes, letter-like forms, and conventional letters [29,30].

Because these abilities and motor representations are still developing, findings concerning practice schedules in adults or older children cannot necessarily be generalized to kindergarten children. The effects of practice structure may depend on developmental level, prior experience, and task difficulty. Piaget's account of the preoperational period further emphasizes the development of symbolic representation during early childhood [31], providing developmental context for the emergence of written symbolic forms. However, this perspective does not directly predict differences between constant and varied practice and therefore remains secondary to the motor-learning framework.

2.4. Integration and Research Gap

Motor Learning Theory provides the primary theoretical basis for comparing constant and varied practice [21,22,24], while handwriting research highlights the importance of explicit instruction and structured practice in the acquisition of graphomotor skills. Previous intervention studies have demonstrated that systematic handwriting instruction can improve handwriting performance in beginning writers [32,33]. These findings underscore the value of structured learning opportunities that combine clear task instructions with repeated practice, allowing learners to acquire and progressively refine the relevant movement sequences. Establishing these sequences may provide a foundation for their progressive consolidation and automatization through practice.

Graphomotor learning may involve both the acquisition of internal representations of movement patterns and the refinement of their physical execution. Di Brina and Cerni [34] demonstrated that, among adult writers, execution-related aspects of handwriting, including fluency and automatization, were strongly dependent on the performing hand, whereas the stability of a well-learned letter form showed smaller differences between hands. These findings suggest that certain aspects of motor pattern representation may be shared across effectors, while efficient execution remains dependent on practice and motor experience. Although these findings concern well-established handwriting skills in adults rather than initial graphomotor learning in children, they highlight the importance of distinguishing the representation of a movement sequence from its repeated physical execution.

In the present study, constant practice involved repeated execution of the same dot-to-dot configuration, whereas varied practice involved systematic modifications of its spatial orientation while maintaining the underlying graphomotor task. According to Schema Theory, exposure to different movement variations may facilitate the development of adaptable motor representations and support performance under unfamiliar task conditions [21].

Although previous research indicates that structured graphomotor practice can support handwriting-related performance [11,23], it remains unclear whether varying the spatial characteristics of a practiced graphomotor task offers advantages over constant repetition among kindergarten children with graphomotor difficulties. In particular, limited evidence is available regarding the short-term generalization of these practice conditions to untrained visual–motor tasks. The present study addresses this gap by comparing constant and varied practice using the Invented Letter Task (ILT).

2.5. The Current Study

Building on the theoretical and empirical framework outlined above, the present study examined whether the structure of graphomotor practice influences generalization to untrained visual–motor tasks among kindergarten children with graphomotor difficulties. Specifically, we compared constant and varied practice using the Invented Letter Task (ILT), a structured dot-connecting task previously used to investigate graphomotor learning in children [35–38].

The study compared two ILT practice conditions: constant practice, involving repeated execution of identical dot-connecting patterns, and varied practice, involving systematic variations in the spatial orientation of the practiced patterns. Both conditions were compared with a no-practice control group. Visual–motor performance was assessed before and after the intervention using four subtests of the Developmental Test of Visual Perception (DTVP-2): Eye–Hand Coordination, Copying, Spatial Relations, and Visual–Motor Speed.

These DTVP-2 tasks were not directly practiced during the intervention and were therefore used to examine short-term generalization beyond the trained ILT configurations. Although the subtests assess visual–motor processes relevant to graphomotor performance, their similarity to the trained task varies. In particular, Spatial Relations shares a dot-connection component with the ILT. Accordingly, improvements on these measures were interpreted as generalization to untrained visual–motor tasks rather than evidence of retention of the trained skill or improvement in functional handwriting.

2.6. Research Questions and Hypotheses

2.6.1. Research Question 1

Do kindergarten children with graphomotor difficulties who receive structured ILT practice demonstrate greater improvement in graphomotor abilities than children in a no-practice control group?

2.6.2. Hypothesis 1

Children who receive ILT practice, whether under the constant- or varied-practice condition, are expected to demonstrate greater improvement in graphomotor abilities from pretest to the post-training assessment than children in the no-practice control group. This prediction is based on evidence that structured, task-specific fine-motor and graphomotor practice can improve children's graphomotor and handwriting performance [20,24].

2.6.3. Research Question 2

Does varied ILT practice produce greater improvement than constant ILT practice on untrained visual–motor outcomes assessed 24 h after training among kindergarten children with graphomotor difficulties?

2.6.4. Hypothesis 2

Children in the varied-practice group were expected to demonstrate greater pre- to post-training improvement than children in the constant-practice group across the four untrained DTVP-2 visual–motor outcomes: Eye–Hand Coordination, Copying, Spatial

Relations, and Visual–Motor Speed. Based on Schema Theory, varied practice was expected to promote more flexible motor representations and greater generalization beyond the specifically practiced ILT configurations [21,22]. This prediction is also consistent with previous evidence indicating that practice schedules can influence children's generalization of graphomotor learning to novel task conditions [23].

3. Methods

3.1. Participants

Eighty-five Arab Israeli kindergarteners (age *M* = 68.85 months, *SD* = 3.93, range = 61–75 months) were included in the study. Of these, 28 children (12 girls; age *M* = 68.79 months, *SD* = 4.24, range = 61–75 months) were assigned to the constant-practice (CP) group, 29 children (12 girls; age *M* = 69.07 months, *SD* = 3.85, range = 62–75 months) to the varied-practice (VP) group, and 28 children (11 girls; age *M* = 68.68 months, *SD* = 3.83, range = 61–75 months) to the control group, which received no ILT practice. Participants were assigned to one of the three study groups using a simple randomization procedure. A random number generator was used to allocate eligible participants to the constant-practice, varied-practice, or control condition. No stratification or blocking by age, gender, or socioeconomic status was applied. These demographic characteristics were examined after randomization to assess group comparability. Based on Ratzon et al. [39], low VMI scores indicate poor visual–motor performance. Scores between the 25th and 75th percentiles are considered to represent average performance [40]. Ratzon et al. [39] used a score at or below the 21st percentile as the cutoff for identifying children with visual–motor difficulties. The same cutoff criterion ($\leq$21st percentile) was adopted in the present study to identify children with graphomotor difficulties who were eligible for participation. A total of 96 children scored at or below the predefined cutoff. Of these, 11 were excluded: eight did not complete all required study tasks, two had visual impairments, and one had a hearing impairment. The final sample therefore consisted of 85 children.

Ethical review approval was obtained from the Israeli Ministry of Education (11544/2021), and the parents of the children provided a signed informed consent form. All participants were native speakers of Arabic and were recruited from three villages in the same geographical region with middle- to low-socioeconomic backgrounds. The children from each area were randomly distributed into three groups. According to parental reports, the children enrolled in the study did not have any known neurological conditions, physical conditions, sleep disorders, or severe sensory loss (i.e., visual or auditory impairment). In addition, children with known emotional or behavioral difficulties were excluded based on teacher reports and available educational records, participation in a special education program and participation in intervention by an occupational therapy or physiotherapy professional were exclusion criteria.

3.2. Measures (Instrumentation)

The Beery VMI test. To evaluate visual–motor integration capabilities, the Beery-Buktenica Developmental Test of Visual–Motor Integration [40,41] was administered. This standardized instrument requires participants to replicate 27 increasingly complex geometric forms, with the final score reflecting the number of accurately reproduced shapes. This assessment served to determine the participants' ability to coordinate visual perception with motor execution, thereby establishing a baseline for graphomotor maturity across the cohort. A certified occupational therapist, the lead author, conducted the screening at the commencement of the academic year, with informed parental consent, to identify children who might benefit from the intervention. The internal consistency of the Beery VMI in this study was high, as indicated by a Cronbach's alpha of 0.90, aligning with the established

reliability of the test (r = 0.89 for test–retest, r = 0.92 for interrater reliability, and r = 0.96 for internal consistency).

The Developmental Test of Visual Perception (DTVP-2) [42]. The DTVP-2 is designed to assess the presence and severity of visual perceptual or visual–motor difficulties in children aged 4–10 years. The test contains eight subtests that measure different but interrelated visual perceptual and visual–motor abilities. For the current study, we administered only four that measure visual–motor performance: (1) Eye–Hand Coordination assesses the ability to draw exact straight or curved lines in compliance with visual limits. (2) Copying assesses the ability to recognize a shape's features and copy it from a model. (3) Spatial Relations assesses the ability to connect dots to reproduce visually displayed designs. (4) Visual–motor speed assesses the number of correct marks that a child can make within large circles (φ 10 mm) or small squares (6 × 6 mm) on a sheet with additional small circles and large squares within a fixed time. The inter-rater reliability of the DTVP-2 is good, as correlations range from 0.92 to 0.99. Criterion-related validity of the DTVP-2 is good, as the test correlates at 0.78 with the motor-free visual perception test (MVPT) [43] and 0.87 with the developmental test of visual–motor integration (VMI). The corresponding author administered the test before and after the intervention, and scoring was completed by an experienced occupational therapist who was not familiar with the study groups or the hypothesis.

The Invented Letter Task (ILT). The ILT [44] was utilized to track the acquisition of visual–motor skills over time. This task involved participants connecting three circular target points to form an invented letter shape. The children were instructed to connect three circled dots with continuous lines (Figure 1A; A→B→C) to create an invented letter. Each target dot was enclosed within a 2 mm diameter circle, with each segment connecting two target points measuring 1.2 cm in length and the total letter width being 6 mm (Figure 1A). The task followed a right-to-left movement pattern, consistent with Arabic and Hebrew writing, progressing from the top row to the bottom. Each training block contained three rows, with five target letters per row (Figure 1B). The ILT has been shown to have high validity and reliability in previous studies, demonstrating strong correlations with handwriting performance [35–38].

An experienced occupational therapist specializing in handwriting difficulties and learning disabilities for over 20 years conducted the task individually with each child in a quiet kindergarten setting. After introducing himself and explaining the task, the experimenter instructed the child: "Connect the dots as quickly and accurately as possible in a single stroke without stopping. Then move to the next letter shape and continue until all shapes on the page are completed. Ensure you touch all three dots, but if you miss one, do not go back to correct it." The children were guided to start each row from the right side of the page and proceed leftward. Performance on the ILT was recorded using a digitizing tablet (WACOM Intuos 2, 200 Hz sampling rate, 0.02 mm nominal accuracy). The target dots forming a complete task block (Figure 1B) were printed on paper. The Wacom tablet was used as the digital interface for administering and recording ILT performance. Although the tablet enabled digital recording of the children's tracing movements, kinematic measures (e.g., velocity, acceleration, or acceleration alternations) were not analyzed in the present study, as the study focused on the effects of practice schedule on generalization to the DTVP-2 visual–motor outcomes.

Novel orientations of the invented letter [23]. In these three task conditions, the children were asked to generate the letter forms in orientations differing from the one practiced. The novel letters were presented by new configurations of the three target dots comprising the letter (Figure 1). The three novel orientations were mirror-reversed (RO), upward (UO), and downward (DO) (Figure 1C–E).

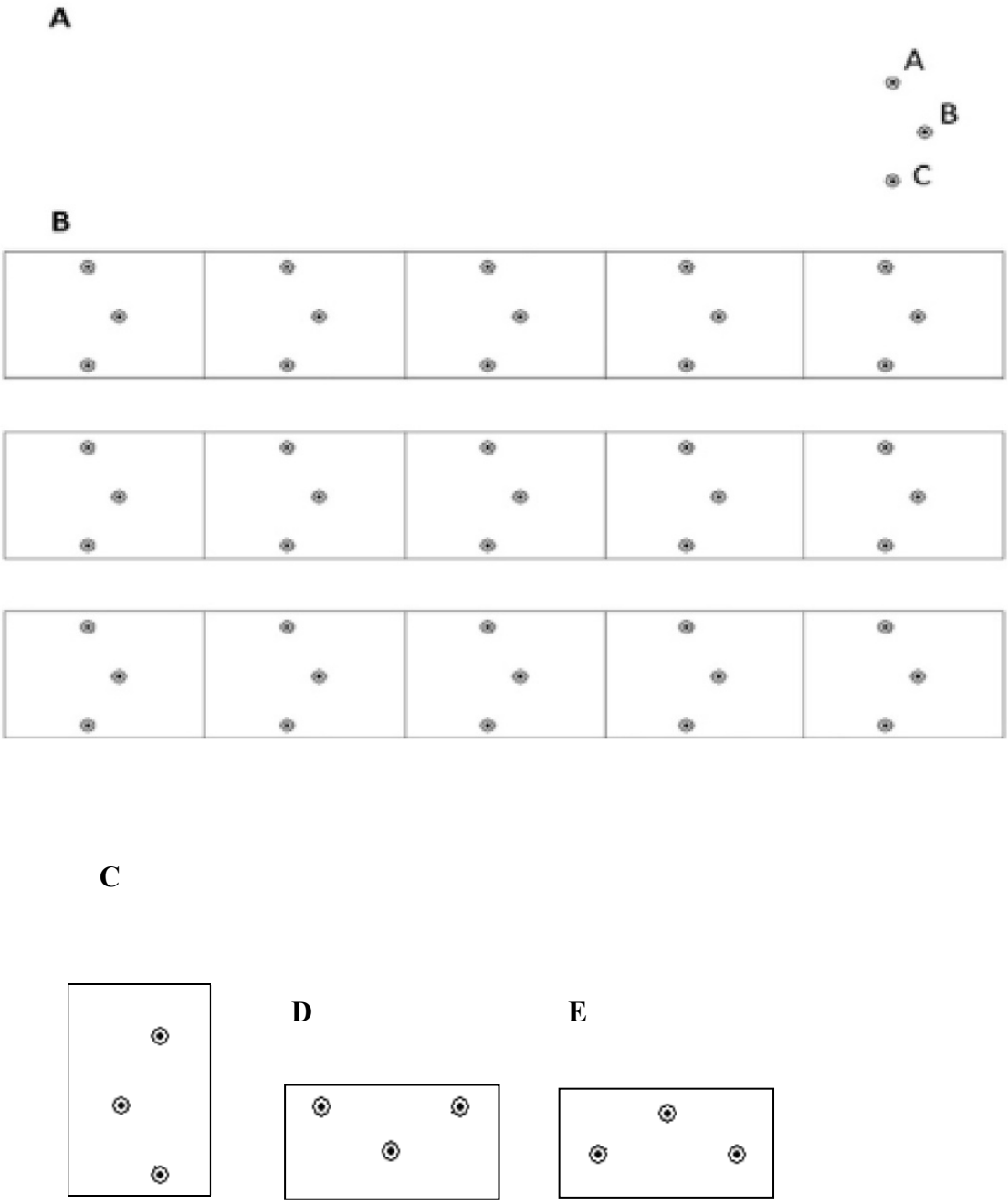


Figure 1. The Invented Letter Stimuli. (**A**) A single stimulus. Participants were asked to connect the three encircled dots A, B, and C with lines (segment length 1.2 cm, circle diameter 2 mm) to form an invented letter. (**B**) An example of the three rows of stimuli used for training and testing that constitute an experimental block. Movement progresses from right to left (as in Hebrew and Arabic writing). (**C**) Mirror-reversed orientation of the Invented Letter Task (ILT). (**D**) Up orientation of ILT. (**E**) Down orientation of ILT.

3.3. Design and Procedure

Participants were randomly allocated to one of three groups: a constant practice (CP) group, a varied practice (VP) group, and a control group. Random assignment was employed to minimize selection bias and ensure group equivalence.

3.4. Intervention Protocols

For the purposes of the training protocol, a trial was defined as one complete attempt at the ILT, in which the child connected the three target dots to produce the required

invented-letter configuration. A block consisted of 15 consecutive trials. Each training session comprised six blocks (90 trials), and the training protocol consisted of eight sessions conducted twice weekly over approximately four weeks. Thus, each child in the practice conditions completed 48 blocks and 720 trials in total.

The CP group practiced the same standard ILT configuration throughout the training protocol, completing 720 trials in total. The VP group followed the same session and block structure but practiced four ILT orientations: the standard orientation and three novel orientations (mirror-reversed, up, and down). Each block contained 15 trials of a single orientation; thus, variation occurred between blocks rather than within blocks. Across the complete training protocol, the VP group completed 360 trials of the standard ILT and 120 trials of each of the three novel orientations, totaling 720 trials. The experimental manipulation was restricted to the spatial orientation of the three-dot configuration. The number of target dots, distances between dots, overall pattern dimensions, and prescribed dot-connecting sequence remained constant across orientations. The order in which the practice blocks were presented was also fixed rather than randomized. The control group participated in their usual kindergarten activities and did not receive ILT training during the study period.

The DTVP-2 pretest was administered to all participants before the intervention period. The four DTVP-2 subtests were administered individually according to the standardized DTVP-2 administration procedures. Raw scores were recorded for each subtest and used in the analyses. The rationale for using raw rather than age-standardized scores is provided in the Data Analysis section. Children in the constant- and varied-practice groups then completed eight training sessions, conducted twice weekly over approximately four weeks, and were reassessed 24 h after their final training session. Children in the control group did not receive ILT training and were reassessed approximately 4–5 weeks after baseline. Thus, the overall pretest-to-posttest interval was comparable across the three groups (approximately 4–5 weeks).

3.5. Pre-Training Assessment

At the beginning of the school year, all participants underwent screening with the Beery VMI. Participants who scored below the VMI cutoff point then completed the four selected subtests of the DTVP-2 one day before the ILT training commenced.

3.6. Post-Training Assessment

Twenty-four hours after the completion of the ILT training, participants in both the CP and VP groups were retested using the four DTVP-2 subtests. The control group completed the DTVP-2 assessment four to five weeks following their initial assessment.

To maintain participant engagement, children were offered small incentives, such as basic school supplies and simple games, upon completion of each weekly session.

The DTVP-2 was administered at both pre- and post-intervention by the same assessor, who was blinded to participants' group allocation. Scoring was also conducted blind to group assignment.

4. Data Analysis

Raw DTVP-2 scores were used for the pre- to post-training analyses rather than age-standardized scores or percentiles. This approach was consistent with Ratzon et al. [39], who argued that raw scores are appropriate when examining change over a relatively short intervention period and when the applicability of U.S.-based normative scores to Israeli children may be limited. In the present study, the primary objective was to compare within-child change and differences in change among groups over approximately four weeks,

rather than to determine participants' standing relative to U.S. age-based norms. The use of raw scores therefore allowed changes in task performance to be examined directly without introducing a normative transformation based on a population that may not be fully representative of Arab Israeli kindergarten children. However, this approach limits the interpretation of the findings in relation to age-normative performance and reduces direct comparability with studies reporting DTVP-2 standardized scores. Accordingly, the findings are interpreted as changes in raw task performance rather than changes in normative developmental status. As an additional index of change, percentage change from pretest to posttest was also calculated relative to each participant's pretest score, consistent with the approach described by Ratzon et al. [39].

Assumption Testing. The assumptions underlying the statistical analyses were examined before conducting the main analyses. Normality, homogeneity of variance, and independence of observations were assessed and confirmed. Normality was assessed using the Shapiro–Wilk test and Q-Q plots. The homogeneity of variance was tested using Levene's test. Independence of observations was ensured by the study design, where each child's observations were treated independently of others. All assumptions were met (Shapiro–Wilk $p > 0.05$; Levene's test $p > 0.05$).

Prior to the main analyses, a one-way multivariate analysis of variance (MANOVA) was conducted to examine baseline differences among the three groups (constant practice, varied practice, and control) across the four DTVP-2 pretest measures (Eye–Hand Coordination, Copying, Spatial Relations, and Visual–Motor Speed) and the VMI score.

Participants who did not complete the required study procedures were excluded before the final analytic sample was established, as described in the Participants section. Among the 85 participants included in the final analytic sample, there were no missing data for the primary DTVP-2 outcomes; therefore, no imputation or other missing-data procedure was required.

To examine intervention effects, a separate 2 × 3 mixed-design repeated-measures ANOVA was conducted for each of the four DTVP-2 outcomes. Time (pretest vs. posttest) was the within-subjects factor, and Group (constant practice, varied practice, and control) was the between-subjects factor. The primary effect of interest was the Time × Group interaction, which tested whether changes from pretest to posttest differed among the three groups. When a significant Time × Group interaction was identified, follow-up between-group comparisons of posttest scores were conducted to examine differences among the constant-practice, varied-practice, and control groups. These pairwise comparisons were adjusted using the Bonferroni procedure; therefore, all reported pairwise-comparison p-values are Bonferroni-adjusted.

To control the family-wise Type I error rate associated with testing the four DTVP-2 outcomes, the Holm–Bonferroni procedure was applied across the four primary Time × Group interaction tests. Bonferroni-adjusted pairwise comparisons were used for follow-up comparisons within each outcome.

Effect sizes for the repeated-measures analyses were reported as partial eta squared (η_p^2).

As a supplementary analysis, percentage change from pretest to posttest was calculated separately for each participant relative to the participant's baseline score using the formula $[(\text{posttest} - \text{pretest})/\text{pretest}] \times 100$, consistent with the approach described by Ratzon et al. [39]. Group means were subsequently calculated from these individual percentage-change scores. Consequently, the mean percentage-change values are not expected to correspond exactly to percentage changes calculated directly from the group-level pretest and posttest means reported in Table 1. This analysis was included to provide a descriptive index of the magnitude of improvement relative to baseline and was not treated as the primary test of intervention effects. Because percentage-change scores may be sensi-

tive to baseline values, particularly when pretest scores are small, inferential conclusions were based primarily on the Time × Group repeated-measures analyses.

Table 1. Means and standard deviations on the four study tests at the study time points.

	Pre-Intervention			Post-Intervention		
Group Measure	Control M (SD)	Constant Practice M (SD)	Varied Practice M (SD)	Control M (SD)	Constant Practice M (SD)	Varied Practice M (SD)
EHC	106.54 (11.34)	108.64 (14.88)	107.31 (14.69)	106.75 (11.04)	115.75 (14.47)	124.66 (15.05)
CO	9.46 (1.99)	9.14 (2.46)	9.21 (2.19)	9.68 (1.85)	11.04 (2.01)	12.34 (2.04)
SR	8.79 (2.13)	8.57 (2.33)	8.66 (1.95)	9.07 (2.00)	14.25 (2.27)	17.45 (1.96)
VMS	2.93 (1.05)	2.75 (1.04)	2.79 (1.11)	3.04 (0.84)	4.86 (1.99)	6.17 (1.69)

EHC = Eye–Hand Coordination test, CO = Copying test, SR = Spatial Relations test, VMS = Visual–Motor Speed test.

5. Results

Baseline comparisons indicated no significant differences among the three groups in age, F (2, 82) = 0.07, p = 0.920, Eye–Hand Coordination, F (2, 82) = 0.17, p = 0.845, Copying, F (2, 82) = 0.16, p = 0.849, Spatial Relations, F (2, 82) = 0.07, p = 0.931, or Visual–Motor Speed, F (2, 82) = 0.21, p = 0.809. There were also no significant differences in gender distribution among the groups, $\chi^2(2, N = 85) = 0.02$, p = 0.989, Cramér's V = 0.02.

Table 1 presents the means and standard deviations for the four DTVP-2 visual–motor subtests across the three groups at pretest and posttest.

5.1. Comparisons of Raw Scores

For Eye–Hand Coordination, the repeated-measures ANOVA revealed a significant main effect of time point (F (1, 82) = 345.87, $p < 0.001$, $\eta_p^2 = 0.81$). In addition, the results show a significant main effect of group (F (2, 82) = 3.42, p = 0.037, $\eta_p^2 = 0.08$). Moreover, the results reveal a significant time point X group interaction (F (2, 82) = 127.73, $p < 0.001$, $\eta_p^2 = 0.76$). Follow-up analyses indicated that there were no significant differences between the groups at the pre-intervention time point, whereas significant group differences were observed at the 24 h post-intervention assessment time-point (F (2, 82) = 12.25, $p < 0.001$). Bonferroni-adjusted pairwise comparisons indicated that the varied-practice group had higher post-intervention scores than the control group ($p < 0.001$) and the constant-practice group (p = 0.048), while the constant-practice group also had higher scores than the control group (p = 0.047). The latter two comparisons were close to the 0.05 significance threshold and should therefore be interpreted cautiously. Notably, the two practice groups showed significant improvements between the two time points (F (1, 28) = 198.52, $p < 0.001$, $\eta_p^2 = 0.88$ and F (1, 27) = 421.12, $p < 0.001$, $\eta_p^2 = 0.94$; for the varied and constant practice, respectively) while the control group maintained its performance (F (1, 27) = 0.85, p = 0.364, $\eta_p^2 = 0.03$).

For Copying, the analysis revealed a significant main effect of time point (F (1, 82) = 793.55, $p < 0.001$, $\eta_p^2 = 0.91$). Notably, the three study groups showed significant improvements between the time points (control group: F (1, 27) = 7.36, p = 0.011, $\eta_p^2 = 0.21$, constant practice: F (1, 27) = 213.64, $p < 0.001$, $\eta_p^2 = 0.89$ and varied practice: F (1, 28) = 846.23, $p < 0.001$, $\eta_p^2 = 0.97$). The results also show a significant interaction (F (2, 82) = 187.05, $p < 0.001$, $\eta_p^2 = 0.82$). Follow-up analyses indicated that there were no significant differences between the groups at the pre-intervention time point, whereas significant group

differences were observed at the post-intervention assessment (F (2, 82) = 12.91, $p < 0.001$). Bonferroni-adjusted pairwise comparisons indicated that the varied-practice group had higher post-intervention scores than the control group ($p < 0.001$) and the constant-practice group ($p = 0.044$), while the constant-practice group had higher scores than the control group ($p = 0.037$). The difference between the two practice groups was close to the 0.05 significance threshold and should therefore be interpreted cautiously. However, the results show no significant main effect of group (F (2, 82) = 2.40, $p = 0.098$, $\eta_p^2 = 0.06$).

For Spatial Relations, the repeated-measures ANOVA revealed a significant main effect of time point (F (1, 82) = 511.82, $p < 0.001$, $\eta_p^2 = 0.86$). Both practice groups showed significant improvements between the two time points while the control group did not show significant improvement (F (1, 27) = 3.48, $p = 0.073$, $\eta_p^2 = 0.11$, F (1, 27) = 91.53, $p < 0.001$, $\eta_p^2 = 0.77$ and F (1, 28) = 623.10, $p < 0.001$, $\eta_p^2 = 0.96$, for the control group, the constant group and the varied practice group; respectively). In addition, there was a significant main effect of group (F (2, 82) = 27.21, $p < 0.001$, $\eta_p^2 = 0.40$). Moreover, the analysis shows a significant interaction (F (2, 82) = 156.76, $p < 0.001$, $\eta_p^2 = 0.79$). Follow-up analyses indicated that there were no significant differences between the groups at the pre-intervention time point, whereas significant group differences were observed at the post-intervention assessment (F (2, 82) = 83.24, $p < 0.001$). At the post-intervention time point, the varied practice and the constant practice outperformed the control group (both $ps < 0.001$), and the varied practice group was superior to the constant practice group ($p < 0.001$).

For Visual–Motor Speed, the repeated-measures ANOVA revealed a significant main effect of Time (F (1, 82) = 163.48, $p < 0.001$, $\eta_p^2 = 0.66$) and a significant main effect of Group (F (2, 82) = 11.65, $p < 0.001$, $\eta_p^2 = 0.22$). The Time × Group interaction was also significant (F (2, 82) = 42.79, $p < 0.001$, $\eta_p^2 = 0.51$). Follow-up analyses revealed no significant between-group differences at pretest, whereas significant differences were observed at posttest (F (2, 82) = 28.01, $p < 0.001$). Bonferroni-adjusted pairwise comparisons indicated that both practice groups achieved higher posttest scores than the control group (both $ps < 0.001$). The varied-practice group also outperformed the constant-practice group ($p = 0.007$). Both practice groups showed significant improvements between the two time points (F (1, 28) = 198.02, $p < 0.001$, $\eta_p^2 = 0.88$ and F (1, 27) = 36.22, $p < 0.001$, $\eta_p^2 = 0.57$; for the varied and constant practice, respectively), whereas the control group maintained its performance (F (1, 27) = 1, $p = 0.326$, $\eta_p^2 = 0.03$).

All four Time × Group interactions remained statistically significant after application of the Holm–Bonferroni correction.

5.2. Percentage-Change Comparisons

As a supplementary analysis, univariate ANOVAs of the individual percentage-change scores indicated significant group differences across all four measures (Table 2). Both the varied-practice and constant-practice groups showed greater percentage change than the control group across all four outcomes. The varied-practice group also showed greater percentage change than the constant-practice group for Eye–Hand Coordination, Copying, and Spatial Relations, but not for Visual–Motor Speed. For Visual–Motor Speed, this pattern differed from the posttest pairwise comparison reported above, in which the varied-practice group had significantly higher posttest scores than the constant-practice group ($p = 0.007$). This difference reflects the distinct metrics examined: the posttest comparison evaluates absolute performance at the post-intervention assessment, whereas the percentage-change analysis evaluates improvement relative to each participant's individual baseline score. Because percentage-change scores are sensitive to baseline values, these analyses were

treated as supplementary, and the Time × Group repeated-measures analyses constituted the primary tests of intervention effects.

Table 2. Percentage Change From Pretest to Posttest by Study Group.

Percentage of Differences				
Group Measure	Control M (SD)	Constant Practice M (SD)	Varied Practice M (SD)	Differences between the groups (F (2, 82)
EHC	22 (1.10)	2.27 (1.98)	13.94 (5.10)	127.47, $p < 0.001$ VP > CP > CG
CO	2.48 (4.90)	18.37 (3.66)	26.19 (6.71)	86.24, $p < 0.001$ VP > CP > CG
SR	3.16 (9.99)	31.91 (16.38)	50.41 (9.24)	107.15, $p < 0.001$ VP > CP > CG
VMS	4.46 (20.84)	39.28 (26.69)	52.91 (23.11)	31.59, $p < 0.001$ VP > CG and CP > CG

EHC = Eye–Hand Coordination test, CO = Copying test, SR = Spatial Relations test, VMS = Visual Motor Speed test, VP = Varied Practice group, CP = Constant Practice group, CG = Control Group. Percentage change was calculated separately for each participant as [(posttest − pretest)/pretest] × 100.

Correlations between baseline performance and percentage change from pretest to posttest are presented in Appendix A.

6. Discussion

The primary objective of this study was to evaluate the efficacy of a dot-connecting intervention, the Invented Letter Task (ILT), and to compare the impact of constant practice (CP) versus varied practice (VP) schedules on visual–motor skills among Arab Israeli kindergarteners with graphomotor difficulties. Overall, the findings supported the first hypothesis and partially supported the second. Both the constant- and varied-practice groups demonstrated significantly greater improvements than the control group across all four DTVP-2 measures. Although varied practice resulted in significantly higher post-intervention scores than constant practice on all four measures, the supplementary percentage-change analysis revealed significantly greater improvements in three of the four measures (Eye–Hand Coordination, Copying, and Spatial Relations), but not in Visual–Motor Speed. Thus, the findings for Visual–Motor Speed differed depending on the metric examined. Taken together, these findings indicate that the relative advantage of varied practice should be interpreted cautiously, considering the outcome measures and statistical metrics used, rather than as evidence of a uniform benefit across all aspects of graphomotor performance.

6.1. Efficacy of Dot-Connecting Practice in Early Childhood (Hypothesis 1)

The findings supporting the first hypothesis suggest that structured dot-connecting practice effectively drives graphomotor and visual–motor improvement. Post-intervention assessments revealed that both the CP and VP groups achieved significantly greater visual–motor gains across all four DTVP-2 subtests compared to the control group. These results align with prior research showing that targeted line-tracing and symbol-practice protocols improve graphomotor execution, pencil control, and handwriting readiness in early childhood [20,45]. Furthermore, these findings support broader occupational therapy literature establishing that structured, task-specific motor interventions facilitate substantial visual–motor skill acquisition in young children [2,39,46].

The modest developmental gains observed in the control group likely reflect typical maturation over the approximately 5-week study period, alongside standard kindergarten

graphomotor activities embedded in the national curriculum. However, the marked superiority of both intervention groups highlights the specific therapeutic value of structured, multi-session dot-connecting routines over general classroom exposure. Multi-session motor practice provides repeated opportunities for procedural memory consolidation; offline memory consolidation between sessions, potentially facilitated by sleep, may strengthen task-procedural associations and refine motor execution schemas [23,47,48].

6.2. Varied Practice and Generalization to Untrained Visual–Motor Outcomes (Hypothesis 2)

The varied-practice condition demonstrated advantages over constant practice on several untrained visual–motor outcomes assessed 24 h after training. These findings suggest short-term generalization beyond the specifically practiced ILT configurations. However, because the post-training assessment occurred after only 24 h and the DTVP-2 subtests do not directly assess handwriting performance, the findings should not be interpreted as definitive evidence of durable motor transfer to functional handwriting. Specifically, the VP group achieved significantly higher posttest performance than the CP group across all four outcomes, including Visual–Motor Speed. However, whereas the supplementary percentage-change analysis also favored VP over CP for Eye–Hand Coordination, Copying, and Spatial Relations, the two practice groups did not differ significantly in percentage change for Visual–Motor Speed. This distinction indicates that the evidence for an additional advantage of varied practice on Visual–Motor Speed was less consistent across analytic metrics than for the other three outcomes.

The advantage of varied practice on several visual–motor outcomes is consistent with predictions derived from Motor Learning Theory Framework [22–24]. Importantly, the present study assessed behavioral performance and did not directly examine the neural, neuromuscular, or cognitive mechanisms underlying these effects. The following mechanisms should therefore be considered theoretical explanations rather than processes demonstrated by the present findings. From a motor-learning perspective, variability during practice has been proposed to require repeated adjustment and reconstruction of motor plans [49,50]. Similarly, the encoding variability hypothesis proposes that practicing under diverse conditions may contribute to the development of broader and more flexible representations of the practiced motor task [51,52]. Motor-learning accounts further propose that such variability may facilitate the retrieval and parameterization of adaptable motor schemas when learners encounter novel task demands [53,54]. These theoretical processes could potentially account for the stronger performance observed following varied practice on some untrained visual–motor outcomes. In particular, the stronger and more consistent advantage of the VP group on Eye–Hand Coordination, Copying, and Spatial Relations may be consistent with greater flexibility in responding to visual–motor demands that differed from the specifically practiced ILT configurations. These findings are consistent with those of Ste-Marie et al. [45] and suggest that varied letter-like practice may facilitate generalization to untrained graphic or visual–motor task demands in early childhood. However, the mechanisms underlying this pattern were not directly measured in the present study and therefore cannot be established from the current data.

Visual–Motor Speed showed a somewhat different pattern across the two analytic approaches. At the post-intervention assessment, the VP group achieved significantly higher scores than the CP group, indicating an advantage of varied practice in absolute posttest performance. However, the supplementary analysis of percentage change from baseline did not reveal a significant difference between the two practice groups. Thus, although both practice conditions produced substantial improvement in Visual–Motor Speed, the evidence for an additional benefit of varied practice was less consistent for this outcome than for Eye–Hand Coordination, Copying, and Spatial Relations. One possible

explanation is that speeded motor performance may be influenced by the overall amount of repetitive practice as well as by practice variability [55,56]. However, given the different pattern obtained across the posttest and percentage-change analyses, and because the mechanisms underlying improvement in Visual–Motor Speed were not directly assessed, this interpretation remains tentative.

6.3. Clinical and Educational Implications

The findings provide preliminary practical implications for pediatric occupational therapists and early childhood educators working with children with graphomotor difficulties. Introducing deliberate variations in task parameters, such as dot configurations and stroke orientations, may encourage flexible visual–motor performance beyond the specifically practiced configurations. Structured dot-connecting activities may therefore represent a potentially useful component of early graphomotor intervention. However, these implications should be interpreted cautiously given the relatively small, culturally specific sample and the short-term assessment period. Moreover, because functional handwriting was not directly assessed, the present findings do not establish that improvements in visual–motor performance translate into better handwriting performance in classroom contexts. Further research with larger and more diverse samples, longer follow-up periods, and direct measures of functional handwriting is needed before the protocol can be considered broadly applicable across clinical or educational settings.

6.4. Limitations and Future Directions

While this study provides important empirical insights into graphomotor skill acquisition and motor learning, several methodological and generalizability limitations warrant consideration.

First, regarding sample characteristics and generalizability, the participant cohort was restricted to Arab Israeli kindergarteners from a relatively homogeneous socioeconomic background within a single geographical region. Although this may have reduced variation in sociocultural and educational factors, it limits the direct extrapolation of these findings to broader, culturally diverse pediatric populations, older children, or clinical cohorts with severe neurodevelopmental conditions (e.g., developmental coordination disorder or autism spectrum disorder). Future studies should recruit larger, multi-site, and socioeconomically diverse samples to verify the generalizability of these practice protocols.

Second, the present study assessed untrained visual–motor outcomes 24 h after the final training session. Because performance on the trained ILT itself was not reassessed after a no-practice interval, the design does not directly test retention of the trained skill. Rather, the findings provide evidence regarding short-term post-training performance and generalization to untrained visual–motor tasks. Future studies should include delayed retention tests of the trained ILT as well as transfer assessments at multiple follow-up intervals to determine the durability and generalizability of the observed effects. Furthermore, while the study utilized standardized, well-validated subtests of the DTVP-2 to capture skill transfer, it did not include direct, real-time kinematic measurements of pencil stroke execution (such as pen pressure, velocity profile, or spatial dysfluency on a digitized graphics tablet) or ecologically valid classroom handwriting measures. Further psychometric and kinematic research is needed to determine how lab-based tracing gains directly translate into functional classroom handwriting legibility.

Future research should build upon these findings by investigating the long-term retention of the trained graphomotor skill and evaluating the feasibility of embedding teacher-led, varied tracing protocols into standard kindergarten curricula.

Because the present study did not directly assess the neural mechanisms underlying practice-related changes, future research incorporating neurophysiological or neuroimaging methods could examine the mechanisms through which varied practice may influence motor learning and neural plasticity [57].

Future studies could extend the present findings by analyzing tablet-derived kinematic measures, such as movement velocity and acceleration alternations, to determine whether constant and varied practice differentially affect movement fluency.

An additional limitation is that the intervention effects were analyzed separately for each of the four DTVP-2 outcomes, without testing a combined Group × Time × Task interaction. Therefore, although the pattern of results varied across outcomes, the present study cannot establish whether the effects of practice condition differed significantly between the visual–motor tasks. These differences should be interpreted descriptively rather than as evidence of statistically confirmed task-specific effects.

7. Conclusions

The present study indicates that structured dot-connecting practice can improve visual–motor performance in kindergarten children with graphomotor difficulties. Both constant and varied practice were associated with greater improvement than no structured practice across the assessed DTVP-2 outcomes, while varied practice showed advantages on several outcomes. These findings suggest that varying the spatial orientation of the task may promote short-term generalization beyond the specifically practiced ILT configurations. However, the observed advantages may also reflect increased visuospatial processing demands associated with changes in task orientation, in addition to potential motor learning effects.

From an applied perspective, structured and varied dot-connecting activities may represent a useful component of early graphomotor programs. However, the present findings should not be interpreted as evidence of durable transfer to handwriting performance, because outcomes were assessed only 24 h after training and functional handwriting was not directly measured. Future research should examine whether these effects are retained over longer intervals and whether they generalize to ecologically valid handwriting tasks.

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Informed Consent Statement: Informed consent was obtained from the parents of all children involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author due to participant privacy and consent restrictions.

Conflicts of Interest: The author declares no conflicts of interest.

Appendix A. The Correlations Between the Initial Performance and the Percentage of Change 24 H Post-Intervention

Regarding the control group, the results show no significant correlation between the pre-intervention performance and the percentage of change 24 h post-intervention in two of four tests; EHC ($r = 0.30$, $p = 0.128$) and SR ($r = 0.36$, $p = 0.059$), but Significant correlations were found for CO ($r = 0.48$, $p = 0.009$) and VMS ($r = 0.66$, $p < 0.001$). However, for the two practice groups, significant correlations emerged in the four tests; EHC ($r = 0.62$, $p < 0.001$ and $r = 0.47$, $p = 0.010$, for constant and varied practice; respectively), CO ($r = 0.91$, $p < 0.001$

and $r = 0.87$, $p < 0.001$, for constant and varied practice; respectively), SR ($r = 0.44$, $p = 0.019$ and $r = 0.86$, $p < 0.001$, for constant and varied practice; respectively), and VMS ($r = 0.45$, $p = 0.017$ and $r = 0.44$, $p = 0.016$, for constant and varied practice; respectively).

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