

Transfer of learning of a pattern drawing task in typically developing children

Kinsuk Maitra, Martin S. Rice, Hae Yean Park

ABSTRACT

Aims: The purpose of this study was to explore whether typically developing children learn a motor skill better if the skill is first learned by the proximal motor apparatus and then transferred to the distal motor apparatus. **Methods:** Thirty-one typically developing children were randomly assigned to either proximal or distal muscle group. The children in the proximal muscle group learned to draw a large pattern using the proximal muscle groups (shoulder and elbow) and transferred the skill to the distal muscle group (wrist and hand) by reproducing a similar but smaller pattern. The children in the distal muscle group did the opposite. A two-way ANOVA is used for data analysis. **Results:** The results showed that the interaction between the main factor of direction and condition yielded significance. Also, skill was transferred in both in proximal to distal (P2D) and distal to proximal (D2P) children group. Error units were decreased between original learning (OL) and transfer

learning (TL) in P2D children group. **Conclusion:** The results further suggest that children would be able to learn a novel motor task using either their proximal motor apparatus that is shoulder and elbow or using their distal motor apparatus that is wrist and hands. Future study should focus on indicating if it would help for child with intellectual disabilities or motor impairments to learn drawing tasks.

Keywords: Children, Drawing, Handwriting, Intervention, Transfer of learning

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INTRODUCTION

In a pediatric setting, occupational therapists work routinely with fine motor problems in children. Examples include addressing problems with managing buttons, zippers, shoelaces, self-care, tool use, leisure occupations, and most importantly handwriting. Therapists use a number of strategies including a range of graded fine motor activities to promote in-hand manipulation and functional performance in children [1, 2]. Some of the examples to address poor hand skills are: a) picking up small objects such as cereal and M&M's with tweezers;

b) pinching a ziplock bag while using each finger with opposition of the thumb; c) using the ulnar digits to hold a small tube of toothpaste while twisting open the cap using the thumb, index, and middle finger; d) transferring a key or other small objects from the palm to the fingertips of one hand; and e) rolling small balls of clay, Silly Putty, or Play Dough between the tip of the thumb and tips of the index and middle finger [3].

While occupational therapists frequently use the fine motor apparatus to improve fine motor skill, motor control and motor learning, researchers have found that skill acquisition is not limb specific rather goal specific. In other words, a skill that has been acquired by one limb is not restricted to that limb [4]. For example, one can write his/her name with a toe on the sand in a beach despite that fact that one has not practiced this skill before with the toe. This phenomenon is called skill or motor learning transfer and is well studied in persons without disability [5]. Past researchers have shown that practice of a novel motor task with one hand facilitates the performance of the same task of the unpracticed opposite hand [6]. This limb-to-limb relationship is known as intermanual transfer, lateral transfer of motor learning, or cross education [5]. Nagel and Rice (2000) investigated intermanual transfer in their study where subjects were randomly assigned to a training or control group. In the training group, subjects completed a toy maze with either their right or left hand. In the control group, the subjects did not practice the maze. Results revealed a significant decrease in movement time and force oscillations in the untrained limb of the trained group, indicating a transfer advantage of the skill to the untrained limb when the contralateral limb acquires a skill [7]. In addition, Andree and Maitra (2002) investigated intermanual transfer with a writing occupation in young adults without disabilities. The subjects learned to write a foreign alphabet letter with either their left or right hand. Later in the study the subjects were asked to write the letter with the unpracticed hand. The researchers discovered a transfer advantage of the task between hands when movement time and movement size was measured and the transfer did not depend on the hand dominance [5].

On the other hand, the transfer of a motor skill from either the proximal to the distal effector group or vice versa is called intramanual transfer. Vangheluwe et al. (2004) reported intramanual transfer when participants learned a new task of drawing (star-line drawing paradigm) [8]. Participants performed two different tasks with the right and left limb in parallel. Thirty-six undergraduate students were assigned to two different groups. In the first group the participants practiced the star-line drawing task with the proximal motor apparatus using the shoulder and elbow joints, and then transferred the performance to the distal motor apparatus using the wrist and finger joints. In the second group the participants practiced the star-line drawing task with the wrist-finger joints (distal) and then transferred the

performance to the shoulder-elbow joints (proximal). The participants practiced the star-line task for 25 trials per day for three days. The results showed that there was a transfer advantage of the skill of line performance (error of orientation angle) from the proximal to the distal motor apparatus.

Imamizu and Shimojo (1995) have theorized that transfer of a skill takes place at the task (cognitive) level rather than at the effector (hand) level [9]. Teixeira and Caminha (2003) tested this hypothesis in three groups of young participants [10]. Twenty-nine participants were pseudorandomly assigned to one of three groups: symmetric force, asymmetric force, and control group. The participants in the asymmetric group performed strength training with a dumbbell for nine weeks on their dominant (right) hand. Thus after nine weeks they had unequal strength between their dominant and non-dominant hand. The participants in the symmetric group received no strength training and thus they were assumed to have equal strength in both hands. Both asymmetric and symmetric group practiced a novel learning task all of pushing a small cart across a metallic track way by flexing the dominant wrist, striving to achieve a velocity of 70 cm/s. A third control group did not participate in the novel learning task. Results revealed that the symmetrical group attained a higher transfer of learning compared to the asymmetric and control groups when directional trend of error was used as the outcome measure. The asymmetrical group had a significant target overshoot compared to the symmetric group. These findings suggested that force characteristics are learned at the cognitive (task) level in the brain and there is an active interaction between the brain and the hand (manipulator) in achieving the task goal [10].

Brinkman and Kuypers (1973) suggested that transfer advantage might be different when the brain learns a task using the proximal muscle system [11]. It is known that the contralateral cerebral hemisphere controls distal movements while both the contralateral and ipsilateral hemispheres are involved in proximal movements [12]. When the main movements in a motor act are controlled with the proximal muscles versus the distal muscles a transfer advantage of learning is to be expected because both cerebral hemispheres are activated in the original motor learning task. One can also theoretically argue that certain aspects of the task might promote the transfer advantage of a fine motor skill if it is first acquired using the proximal muscles. It is known that the cortical motor representations of the shoulder and elbow muscles are smaller than the hand muscles [12].

Fewer muscles in the proximal motor apparatus allow fewer degrees of freedom compared to the many degrees of freedom in the hand motor apparatus. When learning a new skill with the fine motor apparatus more muscles are used to manipulate an object, and requiring the brain to learn the pattern entailed by the muscles, initiating a complex motor learning. According to Rose (1997),

during the advance stage of learning the skill, the learner begins to re-establish or release additional degrees of freedom, adding variability to the skill [13]. This release of additional degrees of freedom allows the joint and associated muscles to move more independent of each other as the performance of the skill becomes more fluent and adaptable to a changing environment. Since the hand has more degrees of freedom (approximately twenty) compared to the proximal arm (approximately five) one could speculate that when learning a new skill with the proximal arm, the learner has fewer degrees of freedom to control. This condition might prove beneficial at least in the acquisition stage of motor learning.

A proximal to distal transfer advantage of a motor skill might have important occupational therapy implication, for example, whether handwriting is better learned using the proximal muscles first in children. On a practical side, whether a child with poor handwriting skills would have an advantage if he/she practices a writing skill on the chalkboard first which requires the use of the proximal muscle group and then transfers the skill on paper, which requires the distal muscle group.

The purpose of the study was to investigate whether typically developing children learn a motor skill better if the skill is first learned by the proximal motor apparatus and then transferred to the distal motor apparatus. It is important to learn a new motor skill through repeated practice. It is also equally important to retain the skill and reproduce it on a future recall. Thus it would be important to investigate whether transfer advantage of a skill remains after a period of time. Using a 2x2 repeated measure mixed ANOVA design (one between subject factor with two directions and one within subject factor with three levels) the following hypotheses were formulated for the present study, in a pattern-drawing task, in typical developing children between 5–13 years old:

1. There will be significant mean differences in the main factor of direction proximal to distal (P2D) and distal to proximal (D2P) for the dependent variables of time and error in motor learning transfer (between subject factor). Here an effect of direction is hypothesized.
2. There will be no significant mean differences in drawing parameters (time and error) for the three levels of learning original learning (OL), transfer learning (TL) and 24-hour delay learning (DL) (within subject factor). Here an effect of conditions is hypothesized. For a learning transfer to occur in pure sense there should not be either degradation or improvement in the dependent variable.
3. There may be a significant interaction between and within subject factor.

MATERIALS AND METHODS

Participants

Thirty-one typically developing children were recruited for the present study (12 boys and 19 girls). Their ages ranged from 5 to 13 years. Twenty-nine participants were Caucasian and two were African American. Inclusion criteria were: a) typically developing children as reported by the children's parents; b) having an ability to understand directions and perform the task; and c) having normal vision with or without corrective lenses. Prior to recruitment, the children verbally assented and an authorized caregiver signed an informed consent form approved by Institutional Review Board (IRB) board. The children were unaware of the experimental hypotheses or purpose. No concerns regarding handwriting or manipulation of small objects were reported by the children's parents.

Apparatus

The primary researcher traveled to homes of the children to conduct the study. The experimental area included a chair and a table, 3 ft by 2 ft white dry erase board, mimio digital recording device (Virtual Ink Corporation, Boston, MA 02135), a laptop computer and a stopwatch. As seen in Figure 1 one the dry erase board was placed in front of the child in the sagittal axis and approximately four inches from the edge of the table. The mimio digital recording device was placed on the left side of the dry erase board (Figure 1).

Procedure

The children were randomly assigned to one of the two possible learning groups for the pattern drawing task: a) proximal muscle group or b) distal muscle group. The researcher used a transparent template to draw the dots of the pattern onto the dry erase board. Numbers were drawn next to or above each dot to give visual cues as to which direction the pattern was to be drawn. The participants used a black marker inserted into the writing stylus. The researcher demonstrated how to hold the writing stylus using either the power grasp (for the proximal group) or the tripod grasp (for the distal group). A flow chart of the procedure is given in Figure 2.

For the children in the proximal group, the dry erase board with the larger pattern containing the numbers for direction was placed in front of the child in midline. The child's non-dominant hand was placed on his/her lap while the dominant hand was placed on the dry erase board at the starting point of the drawing pattern. The researcher verbally told the child to slide the writing stylus connecting the dots in the order from one to five

using the power grasp. Once the child practiced the drawing with the feedback (Practice Learning or PL) and understood the task, the child used the opposite end of the writing stylus (inkless side to avoid feedback) to repeat the pattern for a maximum of 30 trials to learn to draw the pattern correctly following the visual cues of numbers. The researcher then erased the pattern and used the transparency to draw the pattern without the visual cues. After a gap of approximately five minutes, the child was asked to reproduce the pattern twice using the power grasp (OL). After another approximately 5-minute period, the child was asked to draw a smaller version of the pattern twice using a tripod grasp (TL). After a 24-hour period, the researcher went back the child's home and asked the child to produce the pattern twice in the same condition of transfer learning. This trial is called delayed learning. For the distal group, exactly the opposite protocol was followed in terms of grasp as detailed in the flow chart (Figure 2). A maximum of five verbal prompts were provided throughout the experiment if the child required additional help (Figure 3).

Study design and data analysis

The study used a randomized, counterbalanced, repeated measure design. A one within subject repeated measure ANOVA with the dependent variables of time and error was conducted for proximal to distal transfer and another set for distal to proximal transfer with three levels i.e., OL, TL, and DL. A contrast analysis of the levels was intended if ANOVA yielded significance. Movement time consisted of the amount of time it took the child to draw each pattern. A stopwatch was used to record movement time. The total errors calculated were a combination of three different errors. The first error examined was whether the participant made a directional error while drawing the pattern. Directional error was defined by drawing a line in the wrong direction. The second error examined was target error. Three different types of target were categorized. A missed target, that is the line of the drawing failed to touch the dot of the pattern. The maximum missed target errors in each pattern were five. The child was required to touch the four dots within the pattern and then return to the first dot to complete the pattern. An overshoot error that is, the line of the drawing went passed the dot the child was supposed to touch. An undershoot error occurred if the pattern was short of the dot. The last error that was recorded was form error. This error was determined by placing a straight line connecting each dot, over each of the lines in the pattern. The number of spaces created when the straight line was placed over the drawn line was counted as form error. The procedure of calculating errors is shown in Figure 4.

RESULTS

The means and standard deviations for the drawing time and total errors by the directions are presented in Table 1. It can be seen that the mean time taken to produce the drawing by proximal apparatus (OL) is longer than the time taken by the distal apparatus both in TL and in DL. On the other hand, mean time taken to produce the drawing by distal apparatus (OL) is less than the time taken by proximal apparatus in both TL and DL (Figure 5). The results of the ANOVA for draw time and drawing errors are presented in Table 2. The results indicated that the main factor of directions and main factor of conditions (3 levels of learning) yielded no significance. However, the interaction between the main factor of direction (between subject factor) and condition (within subject factor of learning conditions) yielded significance with low effect size. Contrast analysis revealed a significant difference in this interaction effect between original learning and transfer learning ($F(1, 28) = 9.421, p=0.005$).

Table 1 shows that participants made fewer errors when they practiced with the distal motor apparatus in contrast to practicing with the proximal motor apparatus. The results of total errors are also presented in Table 2. The results indicated that the main effects of direction yielded significance with large effect size. Thus, the differences in error between proximal original learning and distal original learning conditions were significant. However, the main effects of learning yielded no significance. In both cases, the skill learning was transferred and retained although no transfer advantage was indicated. The interaction between the two main factors failed to reach significance on any dependent variables.

DISCUSSION

Results revealed that skill was transferred when children practiced either with the proximal apparatus first or with the distal apparatus first. However, transfer advantage of the skill was not found in any direction. The results supported the hypothesis that there will be

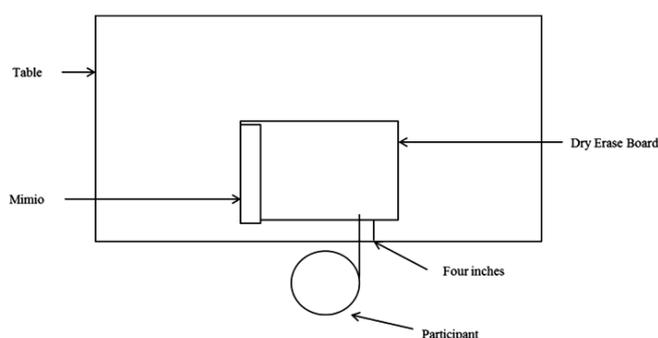


Figure 1: Schematic representation of the experimental set up.

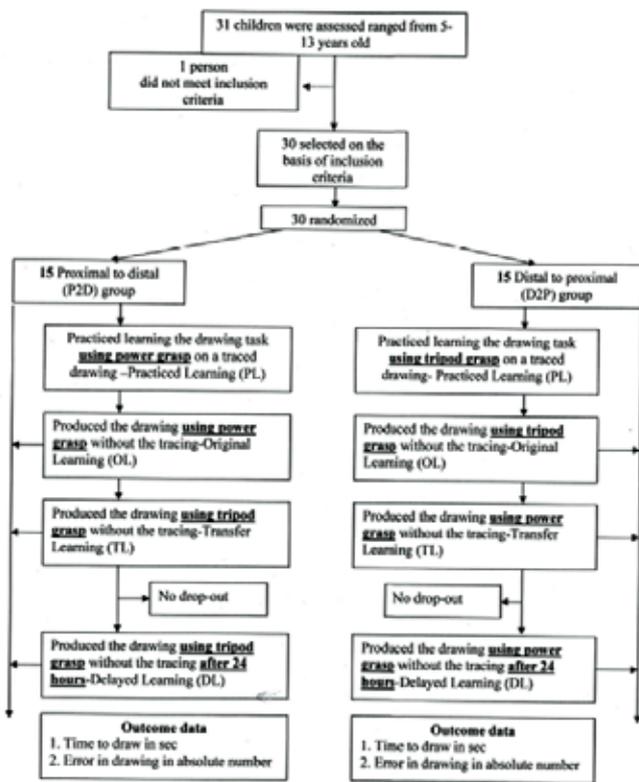


Figure 2: Flow chart of the study.

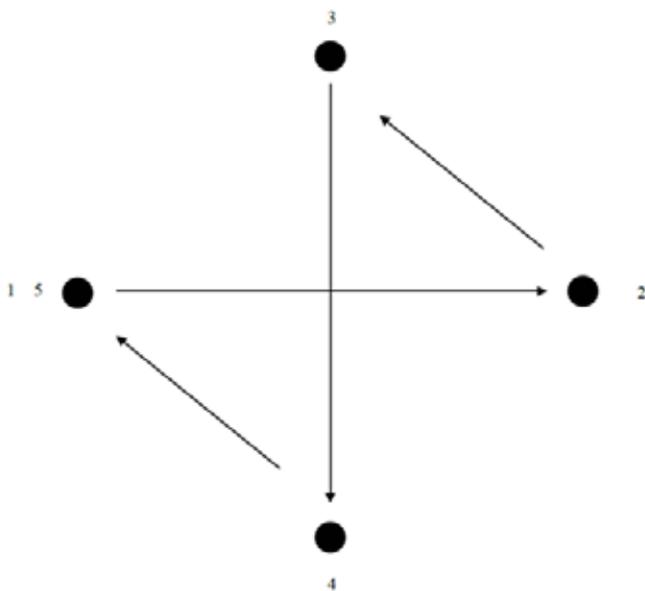


Figure 3: Large pattern with arrows and numbers used during the Practice Learning (PL) period. The arrows represent the direction in which the pattern was to be drawn.

no significant differences in the dependent variables in transferring skill from one limb part to another part of the same limb. These findings are consistent with earlier studies [1, 2] in demonstrating an intramanual skill transfer from proximal to distal apparatus. Similarly, the results also supported the findings of Weigelt et al.

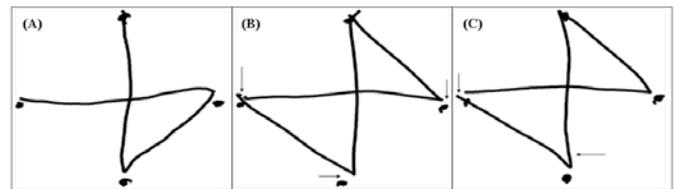


Figure 4: (A) The picture represents an actual drawing of a large pattern drawn during the OL period. Here the child made two errors, as the second line drawn was the diagonal line to the bottom dot and then the last line drawn was the vertical line from the bottom dot to the top dot. Both these lines were drawn in the wrong direction. (B) The picture represents an actual drawing of the large pattern in the OL period. The total number of errors in this drawing was three. The three arrows point to the three errors that were made by the lines not touching the dot. (C) The picture represents an actual drawing of the large pattern of subject 25 during the OL period. The arrow points an undershot error, where the line does not come in contact with the dot. The circled area illustrates an overshoot error, where the line crossed over the dot.

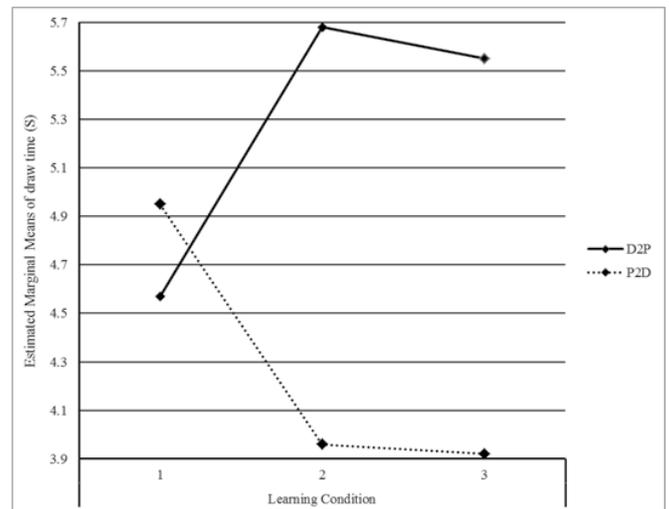


Figure 5: Profile plot of draw time in two directions. In the x-axis: 1 = OL (original learning), 2 = TL (transfer learning), and 3 = DL (delayed learning).

(2000) who found a distal to proximal transfer of skill in a soccer juggling skill with the lower extremities [3].

It is intriguing to note that the children made fewer errors when drawing first with distal motor apparatus compared to proximal apparatus. In addition, drawing errors did not increase or decrease with transfer. In other words, even though the distal apparatus made in general fewer errors the overall number of errors (transfer of skill) was consistent regardless of what apparatus was utilized first. For example, if the participant made n-number of errors when first using the proximal apparatus then he/she made equal errors when the skill was transferred to the distal apparatus. The same phenomenon occurred during the transfer of skill using the distal apparatus first. If the participant made n-number errors when using the distal apparatus first then the participant

Table 1: Means and standard deviations a of dependent variables of task in proximal to distal (p2d) and distal to proximal (D2P) children group

Proximal to Distal Direction children group			
	OL	TL	DL
Dependent Variables			
Movement Time (sec)	4.95 (2.57)	3.95 (2.72)	3.92 (1.66)
Error Units	6.56 (1.23)	6.36 (1.85)	7.06 (2.37)
Distal to Proximal Direction children group			
Dependent Variables			
Movement Time (sec)	4.58 (2.05)	5.67(2.35)	5.52 (1.92)
Error Units	3.16 (1.26)	3.57 (.53)	3.17 (1.01)

Note. aResults in parenthesis indicate the standard deviation. The number above the parenthesis indicates the mean. Abbreviations: OL– original learning, TL– transfer learning, DL– learning after 24 hour delay

Table 2: Results of two-way ANOVA on kinematics variables for the drawing rask of the children

Source	df	SS	MS	F	p	eta
Draw time						
Between						
Direction	1	7.214	7.214	1.947	.174	.065
Error	28	103.770	3.706			
Within						
Condition	2	.133	.063	.033	.097	.001
Error	56	112.653	2.012			
Interaction						
Direction x Condition	2	20.806	10.403	5.171	.009**	.156
Error						
Between						
Direction	1	85.008	85.008	64.119	.0001**	.696
Error	28	37.122	1.326			
Within						
Condition	2	.950	.475	.342	.712	.012
Error	56	77.833	1.390			
Interaction						
Direction x Condition	2	4.550	2.275	1.637	.204	.055

**p < .01.

Abbreviations: df degrees of freedom, SS Sums of squares, MS Mean squares

made equal errors when transferring the skill to the proximal apparatus. The transfer of skill was consistent whether using the proximal or distal apparatus first, thus contradicting the first our hypothesis. In addition, it is possible that less total errors occurred at the distal apparatus because typically developing children, perhaps, have already learned to control the degrees of freedom at the distal apparatus. Therefore, the argument of using the distal apparatus first may be true for typically developing children.

Although not significant, the time difference between the three levels of learning could be due to size effect. In actuality the size of the drawing should be a cofactor because the proximal motor apparatus drew a bigger drawing and the distal apparatus drew a smaller drawing. Thus, the timing decline during P2D and timing increase during D2P are probably a drawing size effect rather than a learning effect. This argument is emboldened by the argument that there is no change in drawing errors in one particular group. Thus, not controlling the size of

the drawing as a co variable is a limitation in analysis. In summary, this initial exploratory study indicated that children would be able to learn a novel motor task using either their proximal motor apparatus that is shoulder and elbow or using their distal motor apparatus that is wrist and hands. Additionally, such learning can be transferred distally or proximally.

Although the results of the study are based on typically developing children, further research should be conducted to include children with disabilities. Occupational therapists often work with children who have mental retardation and developmental disorders (e.g., intellectual disability) who frequently display problems with fine motor skills such as handwriting, tying shoes, manipulation small objects, eating, and managing zippers [4]. Intellectual disability/mental retardation is a disorder that is characterized by a significantly below average intelligence and deficits in two or more skill areas, which include occupations of daily living, communication, social, academic, leisure, and homemaking [5]. Children with intellectual disability have deficits in cognitive development such as slower learning ability, shorter attention span, difficulty with problem solving and critical thinking, difficulty generalizing information and mastering abstract thinking, and difficulty storing and retrieving information [6]. Along with cognitive deficits, children with intellectual disability also display deficits in motor development. According to Schmidt and Lee (2005), one problem in general with motor programming is lack of storage capacity [7]. Therefore, future research should focus on determining if it would be advantageous for children with intellectual disability to learn drawing tasks, writing, and other skills by using the proximal apparatus first. This could have important occupational therapy implications. For example working on writing using the chalkboard first using the proximal apparatus might benefit the intellectual disability population to then transfer the skill to the distal apparatus. Through these skills transfer, children with intellectual disability could get more opportunities to participate school-based activity and decrease burden of teachers who teach school functions in a class.

Limitations

There are some noteworthy limitations of the study. For the study, the mimio digital recording device (Virtual Ink Corporation, Boston, MA 02135) was used to record the participants' drawings. Reliability and validity of the device was not calculated into the analysis of the study. Even though parents verbally reported their child as typical developing no formal assessments were conducted to confirm normal development. Since the researcher had to travel to participants' homes, the environment was inconsistent which might have had an effect on the results. Given the small sample size and the geographic

location of the participants, further research should include a larger sample size and extend the geographic location of the participants [14–18].

CONCLUSION

Children with intellectual disability have difficulty with storing information, therefore making new motor patterns difficult to learn. To take the advantage of the principle of motor learning transfer, proximal training of a fine motor task might be advantageous in the intellectual disability population for two reasons: a) it would be a cognitive advantage to use bilateral brain maps as in proximal muscle use and b) it would also be beneficial to start with smaller degrees of freedom to better control the skill learning. It would be useful to examine whether this finding is true for children with fine motor problems. The issue to ponder is whether children with fine motor delay would benefit from using the proximal apparatus first because fewer degrees of freedom are used. Thus, further research to examine this issue is needed.

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Author Contributions

Kinsuk Maitra – Substantial contributions to conception and design, Acquisition of data, Drafting the article, Revising it critically for important intellectual content; Final approval of the version to be published

Martin S. Rice – Substantial contributions to conception and design, Analysis and interpretation of data, Drafting the article, Final approval of the version to be published

Hae Yean Park – Substantial contributions to conception and design, Drafting the article, Revising it critically for important intellectual content, Final approval of the version to be published

Guarantor

The corresponding author is the guarantor of submission.

Conflict of Interest

Authors declare no conflict of interest.

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