A Frame of Reference for Learning Sequential Strokes for Printing Letters

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A Frame of Reference for Children for Learning Sequential Strokes for Printing English Letters

Handwriting is the earliest formal conduit for students to use to convert language into external written characters (Connely et al., 2007). McMaster and Roberts (2015) found that even as the presence of technology increases in classrooms, elementary aged students continue to spend, on average, between 60 to 90 minutes a day engaged in tasks that require handwriting. Despite debates for the last quarter century suggesting that handwriting will become anachronistic, handwriting remains a necessary and consequential skill for students to acquire and employ proficiently in the 21st century (Cahill, 2009; Graham, 2018; McMaster & Roberts, 2015).

Handwriting acquisition, or developing aptitude in handwriting, has been linked with positive enduring academic outcomes in reading, math, and composition (Da Vanzo, 2018; Dinehart, 2014; Mcarroll & Fletcher, 2017). A growing body of research has also demonstrated that taking notes by hand can be more beneficial to learning than using a laptop (Mueller & Oppenheimer, 2014; Horbury & Edmonds, 2021). On the other hand, poor handwriting skills, or handwriting that is messy or laborious has been associated with deleterious academic outcomes including lower grades (Lee & Lape, 2020; Greifeneder et al., 2010; Santangelo & Graham, 2016). Difficulty with handwriting may also contribute to low self-esteem, reduced participation in classroom activities (Engel et al., 2009) and negative attitudes about writing (Lifshitz & Har-Zve, 2014).

It has been estimated that up to 27% of school age children have difficulty with handwriting acquisition and exhibit handwriting dysfunction (Feder & Majnemer, 2007; Van Hartinsveldt et al., 2011). Handwriting dysfunction may be manifested in poor legibility (messy

writing) or slow writing (Graham et al., 2016). When students have difficulty printing in the classroom, they are often referred for occupational therapy services. Significantly, handwriting difficulty is reportedly the most common reason school-aged children are referred for occupational therapy services (Schneck and Amudson, 2010) accounting for upwards of 40% of the referrals received by school-based occupational therapists (Roston, 2010).

Handwriting Acquisition: Learning to Print Letters

In the United States, it is common practice for students to begin learning to print letters in kindergarten and then learn to write in cursive in the third grade (Asher, 2006; Donica, 2009; Schwellnus et al., 2012; "National Poll Reveals," 2013). Print letters, also known as manuscript, are disconnected characters and resemble the letters that are typically found in printed books (Bara et al., 2016). Cursive writing, conversely, consists of letters that are linked together to form words and is characterized by continuous hand movement with limited lifts of the writing utensil (Bara et al., 2016; Schwellnus et al., 2012). This frame of reference addresses handwriting acquisition for children learning to print the English alphabet, as such, the terms handwriting acquisition, handwriting intervention, or handwriting instruction indicate learning to print letters by hand.

Enigmatic Problem

Some children exhibit difficulties when learning to print letters. Notably, when they print letters, they may initiate the letter at the base rather than the top and are inconsistent in the sequence that they execute the motor task. This frame of reference provides guidelines for instruction and intervention for children, both right and left-handed, who do not consistently print letters with the standard genesis and trajectory. This frame of reference does not address prewriting skills and assumes children entering kindergarten at age 5 are able to produce basic

vertical, horizontal, circular, and oblique strokes (Beery & Beery, 2010). Children appropriate for this intervention would be identified by the teacher or parent as having difficulty learning to print letters. This frame of reference is also suitable as a guideline for initial handwriting instruction with children ages of 5 and up. The children will demonstrate use of a dominant hand, a mature grasp, ability to self-monitor and self-correct the amount of pressure applied with a writing utensil, be able to follow simple verbal and visual instructions, and be able to correctly identify allographs (letter forms) for upper and lower case printed English letters.

A fundamental assumption for this frame of reference is that printing letters in a consistently sequential pattern improves habituation and the efficiency, fluency, and quality of printed letters.

Theoretical Base

Rosenblum (2018) describes the occupation of handwriting as involving an intricate fusion of cognitive, perceptual-motor, and kinesthetic components. Specifically, Rosenblum defines the "transcription phase" as a process that includes cognitive retrieval of "letter forms…and motor planning that enables the hand movements required to graphically generate the letters" (p. 2). In this light, a frame of reference for handwriting intervention and instruction should include the marriage of both motor planning and motor learning theories. This frame of reference incorporates the motor planning theory of graphic behavior (Goodnow & Levine, 1973; Nihei, 1980), and motor learning theory of the challenge point framework (Guadagnoli & Lee, 2004)

Graphic Behavior: Graphic Rules and Graphic Organization Principles

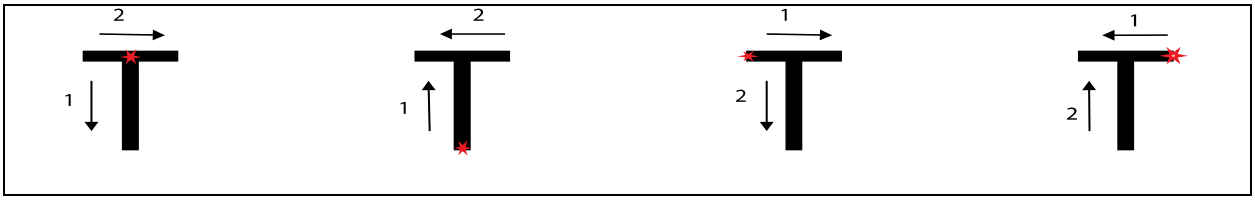
Learning to fluently print letters that are readable is a complex task. Among the requirements, a novice writer must access the correct allograph and efficiently apply an

appropriate motor plan. Motor planning for printing letters entails choosing a starting point for the first stroke and subsequent starting points for all successive strokes; choosing the direction, shape, and length of the strokes; and choosing the sequence of strokes. The most basic units of a letter are the strokes (Berninger et al., 2006). Strokes can be vertical, horizontal, diagonal, or half circle shapes (Simonnet et al., 2017). The starting point is the location at which the student begins drawing the letter and directionality indicates the trajectory taken once the letter has been initiated. Sequencing the strokes refers to the ordering of the components of movement pattern (Meulenbroke et al., 1996).

As Ellenblum (2019) notes, “there is nothing inherent to a shape of a letter that dictates the order or direction of production of the strokes needed to produce it” (p. 5). Therefore, there are a multitude of ways in which a letter can be produced. The number of sequencing strategies ultimately increases as the number of strokes, or segments in a letter increases (Meulenbroek et al., 1996). Consider for example the two strokes that form the capital letter ‘T’ (Figure 1). This shape can be produced by starting the vertical stroke from the top or the bottom, and the horizontal stroke can be drawn from the left to right or from the right to the left. Likewise, there are no intrinsic clues to determine which of the two strokes should be drawn first. However, Ellenbaum continues, “the stroke patterns used to produce written characters do not seem to be chosen arbitrarily. Instead, they seem to follow some organizing principles” (p. 7).

Figure 1

Possible Stroke Sequencing Strategies for Capital 'T'



Note. Four possible sequencing strategies for the capital letter 'T'. The red star indicates the starting point, the arrows indicate stroke direction, and the numbers indicate the stroke sequence.

In attempts to catalogue and analyze how children choose stroke patterns, researchers have studied children's graphic behavior which reflects the organization and arrangement of start positions and sequence of strokes (Ellenblum, 2019; Goodnow & Levine, 1973; Ivancevic et al., 2020; Khalid et al., 2010; Nihei, 1983; Ninio & Liebich, 1976). In a seminal study, Goodnow and Levine (1973) found that when copying simple geometric patterns, children choose paths that follow a limited set of strategies or rules that specify where to start and how to proceed. Furthermore, they suggest that these strategies stabilize as children age. The authors described this behavior as the "grammar of action" (p. 82).

Goodnow and Levine discovered that the behavioral tendencies could be concentrated to a set of seven rules based on three collection criteria:

(1) Strategic commonality that applied to as many designs as possible.

(2) Variations that displayed differences between age groups and designs.

(3) Strategic options that consist of binary choices as often as possible.

The seven rules prescribe starting points, starting strokes, and general progressions (Table 1).

Table 1

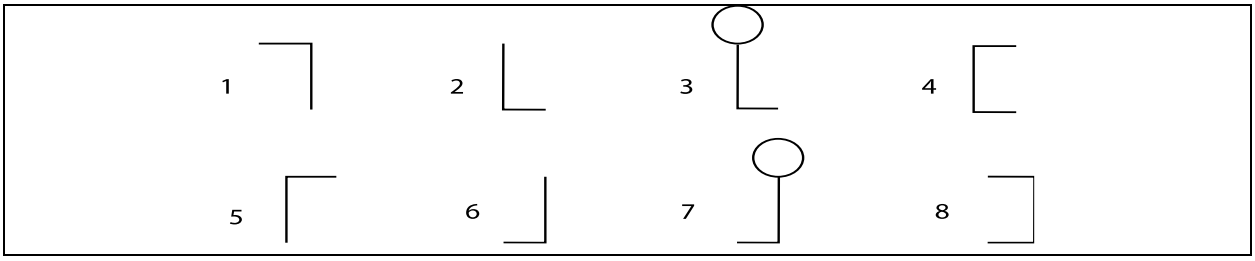
Grammar of Action Rules for Copying Simple Geometric Shapes (Goodnow and Levine, 1973)

Starting points	1. Start at a leftmost point. 2. Start at the top.
Starting strokes	3. Start with a vertical line. 4. Given a figure with an apex, start at the top and come down the left oblique.
Progressions	5. Draw all horizontal lines from left to right. 6. Draw all vertical lines from top to bottom. 7. Thread (continue subsequent strokes without lifting the pen)

Another pivotal study, completed by Nihei (1980), examined the specific organization principles that apply to the production of geometric figures and letters for various age groups. In Nihei's study, children and adults were divided by age into six groups (five-year-old kindergarteners; six-year-old kindergarteners; seven-year-old first graders; nine-year-old third graders; eleven-year-old fifth graders; and college students with a mean age of 21). The students were asked to copy eight simple figures (Figure 2) while a trained observer recorded the order and direction of the strokes. Nihei (1980) found that just three types of stroke organization were utilized in all of the drawings across all the ages. The first type of organization Nihei labeled as *Fixed anchoring.* This type of organization is characterized by using the starting point of the first stroke as an anchor, or second starting point, for the second stroke. The second type of stroke organization, *Fluid anchoring*, is characterized by starting the second stroke at the end point of the first stroke without lifting the pencil (previously referred to as "threading"). Finally, the third type of stroke organization, *Ballistic strokes*, are characterized by starting the second stroke at a point that is disconnected from the first stroke (Figure 3).

Figure 2

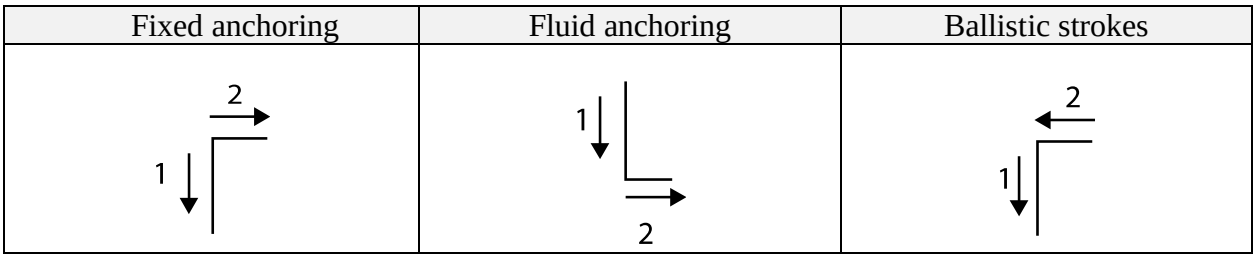
Model of Simple Geometric Shapes (Nihei, 1980)



Note. All figures can be drawn with a continuous stroke.

Figure 3

Organization of Strokes (Nihei, 1980)



Note. The arrows indicate stroke direction, and the numbers indicate stroke sequence.

Determinants of Graphic Behavior

Graphic behavior tends to evolve organically in children from tendencies to use analytic strategies when copying geometric patterns (Kalid et al., 2010, Meulenbroek et al., 1996). Thomassen and Tibosch (1991) discuss the "economy" that guides graphic behavior (p. 270). They describe this type of economy as "spending a minimal amount of effort to achieve satisfactory performance" (p. 270). Specifically, the authors suggest that drawing in preferred movement patterns (rightwards and downwards) can decrease "jerk," (swift changes in the velocity of movements or excess movements) due to the biomechanics of the hand or the nature of the drawing materials, or both (Thomassen and Tibosch, 1991). Furthermore, threading strokes eliminates the visuo-motor control demands that are required to reposition the pencil to

locate a second starting point for the second stroke. Anchoring, similarly, simplifies the determination of the second starting point once the pencil has been lifted (Thomassen and Tibosch, 1991).

Other research on the origin of graphic behavior points to the impact of development, culture, and education. Fischer (2013) suggests that with typically developing children, there is a natural inclination or bias for top to bottom due to the influence of gravity. Additionally, Nihei's research (1980) indicates that younger children tend to prefer using the fluid and fixed principles before using ballistic strokes. Another theory points to cultural factors as motivation for stroke selection. Fisher (2013) theorizes that in cultures that write left to right, with typically developing 5-6-year-olds, there is an implicit right-writing rule and children often reverse left-oriented characters (Fischer, 2016).

When examining the influence of development, culture, and education on graphic behavior, especially as it relates to stroke direction, researchers have looked at the stroke patterns of Israeli students (Ellenblum, 2019; Goodnow et al., 1973; Ninio & Lieblich, 1976; Rosenblum et al., 2003; Tversky et al., 1991). Significantly, and distinctly from English, Hebrew is read and written from a right to left direction. One might expect, as Fisher (2016) suggests, that the right-writing rule would be all but absent for Hebrew writers. Goodnow et al., (1973) however, demonstrated that when comparing the graphic behavior of English-speaking children in the United States and in Hebrew-speaking children in Israel, there were "common developmental trends" (p. 263). The authors found that when copying simple geometric shapes, both groups tended to show a preference for a left to right stroke direction (1973). In 1991, Tversky et al., included both Hebrew-speaking and Arab-speaking Israelis, as well as English-speaking Americans in their study of developmental trends in graphic behavior. The authors point out that

while Hebrew is read right to left, numbers, for Hebrew-speaking Israelis are read left to right. Arabic, on the other hand, is read right to left including numbers (Tversky et al., 1991). The study found that all language groups copied vertical lines from top to bottom. English and Hebrew speakers started horizontal lines on the left and moved rightward, but Arabic speakers (excluding kindergarteners) copied horizontal lines from right to left. The authors found that the tendency for drawing strokes from left to right was strongest with English speakers. The tendency for drawing strokes from right to left, was strongest with Arabic speakers. Hebrew speakers fell in between, "they preferred the dominant direction of writing Hebrew, right-to-left, but not as strongly as Arabic-speaking children. Moreover, in Hebrew speakers, there was a temporary preference for left-to-right over right-to-left just after English was introduced [in third grade] in schools" (p. 519). Tversky et al., suggest that stroke direction preference is impacted by a range of influences (1991). While horizontal stroke direction "seems likely to have a cultural origin," vertical direction appears to be "rooted in physics and biology" (p. 519). As the impact of culture may influence the development of graphic behavior, the cultural background of students should be considered during handwriting instruction.

Terminology

As an important note, the study of graphic behavior has been conducted internationally in numerous countries and in multiple languages (with multiple alphabets). This diversity, which strengthens the research, can also complicate terminology. For example, Gillespie (2003) from Illinois and Khalid et al., (2010) from Malaysia, borrow from Nihei (1980) from Japan, and use the terms "graphic principles" and "graphic rules" (respectively) to describe the organization of strokes used to copy simple geometric shapes or letters. Similarly, Nihei (1980) uses the term "ballistic stroke" to define the third principle, while other authors have used the terms

"directional" (Gillespie, 2003), "graphic rule flexible" (Gillespie, 2003), or "flexible" (Khlid et al., 2010) to describe the principle.

In their study, Goodnow and Levine (1973) discuss the difference in the terms "rules" and "principles." This author will follow their lead in using the term "rules" when "a principle can be shown to apply to a group of designs" (Goodnow & Levine, 1973, p. 83). The term "principle" will be used when describing a fundamental sequence of behavior or reasoning. Accordingly, the term "graphic rules" will be used to refer to the typical starting point and sequence progression in a predictable direction that children make when copying geometric patterns. The rules for starting a geometrical shape reflect the inclination for children to begin copying the first segment stroke at the top or at the left of the pattern. The rules for progression reflect preferences in children to draw vertical lines downward and horizontal lines rightward (Meulenbroek et al., 1996). The term "*graphic organization principles*" will refer to the procedural arrangement of strokes used to draw multiple line segments. These principles will be applied to the English alphabet and defined as follows:

1. The *fixed principle* states that the second stroke is drawn from the starting point of the first line (e.g. 'N')
2. The *fluid principle* states that the second stroke is drawn from the endpoint of the first line (e.g. 'L').
3. The *flexible principle* states that the second stroke starts at a point in space and is drawn to the first line (e.g. 'K')

Graphic Behavior and Handwriting Acquisition

As children learn to draw, the graphic rules and organization principles are gradually accommodated and become automatic procedural knowledge (Meulenbroek et al., 1996). Children having difficulties printing letters, however, may employ alternative faulty or inefficient strategies. For example, initiating a letter at the bottom and moving upwards or lifting the pencil to begin a second stroke when threading would be more efficient, or in Thomassen and Tibosch (1991) words, more "economic." Children with difficulties learning to print letters may also exhibit inconsistency with implementing effective stroke strategies. Inconsistency implies that the genesis and trajectory of the letter's strokes are not automatic procedural knowledge and therefore require increased cognitive attention. Letter formation that is not automatic and requires conscious attention contributes to slower and more laborious handwriting and distracts from content production (Medwell & Wray, 2014).

According to Guinet & Kandel (2010), poor handwriting is associated with the "lack of mastery in the production process" (P. 327). Khalid et al. (2010) found that the "starting and progressing rules are significantly related to...handwriting proficiency" (p. 1690). When children do not implement graphic rules and organization principles, printing quality is impaired (Khalid et al., 2010). This finding aligned with other studies that found a higher percentage of inaccurate letter forms were produced when children use unconventional stroke patterns (DiBrina et al., 2010; Smits-Engelsman & Van Galen, 1997). In a more recent study, Prunty and Barnet (2017) found that among children exhibiting poor handwriting, 64% drew letters that did not follow typical graphic behavior. The same authors subsequently found that a "non-standard" start position accounted for the most common error made in letter production (Prunty & Barnet, 2020, p. 53).

According to Graham et al., (2006), children's poor letter formation has the greatest effect on the legibility of print. Stott, Henderson, and Moyes (1987) noted the importance "in the early stages of teaching handwriting that the letters be taught as a coordinated sequence of movements (p. 144)." They warn that in the absence of developing fluid movements, "writing may become an ongoing source of tension" (p. 144). Ultimately, if children have difficulty learning to print letters it can lead to decreased written output, frustration, and lower grades (Graham & Perin, 2007).

Motor Learning and Challenge Point Framework

Handwriting acquisition requires motor learning, therefore, instruction and intervention benefit from a motor learning theory. This frame of reference integrates the challenge point framework developed by Guadagnoli and Lee (2004). Their theory uses the concept the challenge point to describe effects of practice conditions on motor learning. According to their theory, if all other factors are held constant, skill improvement is positively related to the amount of practice completed. Importantly, learning is considered a problem-solving process and is dependent on the information that is available. Too much or too little information can impair learning. However, when there is an optimal amount of information available (which is dependent on the skill level of the individual and the difficulty of the task to be learned) learning will occur (Guadagnoli & Lee, 2004). Furthermore, learning is the product of the relationship between the potential available information, or information that is accessible and interpretable, and the understanding that arises from the performance (Guadagnoli & Lee, 2004). Performance depends on the difficulty of the task and the skill level of the performer. The optimal challenge point is the point at which all three factors, difficulty of the task, potential available information, and individual skill level, align. Accordingly, it is possible to increase learning by increasing the

functional difficulty of a task up to this optimal challenge point. Offering information beyond this point, exceeds the capability of the individual and reduces learning.

The challenge point framework also addresses optimal practice conditions. The two practice variables described are blocked practice and random practice. Blocked practice occurs when one distinct motor skill is repeatedly practiced before progressing to another distinct motor skill. Random practice occurs when there is no specific order to the practice and/or when multiple motor skills are practiced at a performance instance. According to the challenge point framework, blocked practice will increase performance during the acquisition trials. However, random practice will produce better retention performance than blocked. By providing the learner with optimal challenge conditions while movement representation is acquired, the facilitation of complex skill learning can occur (Guadagnoli & Lee, 2004).

Graphic Behavior, Challenge Point Framework, and Handwriting Acquisition

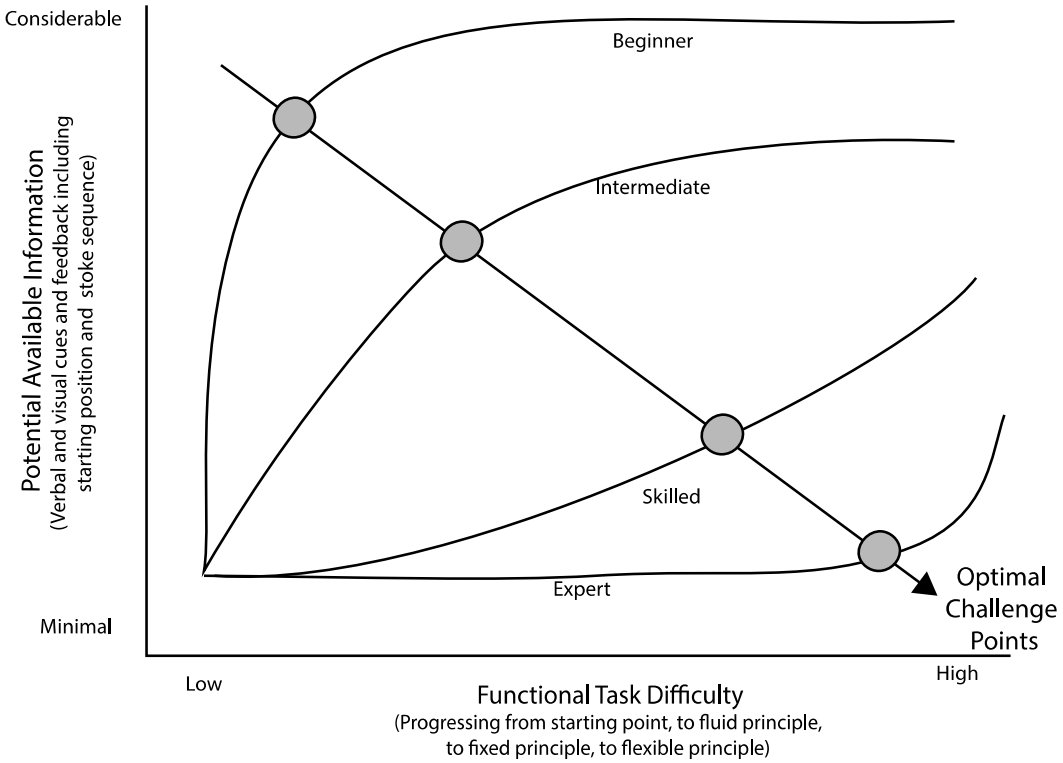
Three specific dynamic postulates from the challenge point theory provide the theoretical underpinning for this frame of reference. First, and most fundamentally, according to the challenge point theory, when all other factors are held constant, learning (specifically skill development) is positively related to the amount of practice completed. Second, the optimal challenge point can be maintained by increasing the functional task difficulty as the individual's skill level increases. Third, blocked practice produces better results during skill acquisition, whereas random practice improves retention once rudimentary skills are obtained (Guadagnoli & Lee, 2004).

More specifically, utilizing the challenge point framework with handwriting acquisition skills can be beneficial in teaching kindergarteners proper letter formation. This framework suggests the importance of finding the optimal challenge point for kindergarteners exhibiting

difficulty learning to print letters. It is essential to coalesce all components of the challenge point framework: individual skill level, task complexity and available information, and conditions of practice. To this end, the students' skill level should first be evaluated by assessing their working knowledge of graphic rules and organization principles, as well as assessing the quality of their handwriting (i.e., printing) product. Next, it is necessary to provide the optimal information with the optimal practice conditions. Information can be altered by the number of cues and type of feedback provided during the practice instance. The task complexity can be adjusted by teaching the least complex of the graphic rules and organization principles before moving progressively to the most complex graphic rules and organization principles.

Table 2

Optimal Challenge Point for Learning Graphic Rules and Organization Principles



Note. Adapted from Guadagnoli and Lee (2004). Optimal challenge points for learning graphic rules and organization principles for printing letters, linked to different skill levels, functional task difficulty, and potential available information.

Specifically, the starting position is the simplest of graphic rules. It focuses on just a single line segment with directions to start at the apex and draw downward. It is important to master this rule first because the other graphic rules and organization principles build on the starting point rule. The addition of a second stroke, inherent in the letters that follow the graphic organization principles, increases task complexity further. The fluid principle is the least complex of the three graphic organization principles because the first stroke fluently leads to the predetermined second stroke without lifting the pencil. This principle builds on the knowledge already learned with the starting point rule, but slightly increases the difficulty by adding a second stroke where the first stroke ends. Next, the fixed principle increases the task difficulty even more because the second stroke starts back at the starting position of the first stroke. Therefore, students are required to lift the pencil from the paper and restart to continue the letter. Because the second stroke of the fixed principle uses the same starting point as the first stroke, it is not as complex as the letters that follow the flexible principle. Letters that follow the flexible principle, have the greatest task difficulty because the second stroke is not inherently predetermined and starts away from the first stroke. Students not only have to lift the pencil up to start the second stroke, but they must also judge the placement of the second stroke in relation to the first. Practice conditions can also vary between blocked and random practice. Blocked practice can be used for novice writers when learning the letter formation of one or just a few letters. After the kindergarteners demonstrate proper letter formation during those trials, random

practice with the few selected letters would increase retention. Clearly, by implementing the fundamental components of the challenge point framework to practice the graphic rules and organization principles of learning to print letters by hand, it is possible to optimize the learning process and improve skill acquisition (i.e. learning to print).

A Note About Handedness

It has been estimated that around 10% of the population is left-handed (Searing, 2019). Just as there are scissors designed specifically for left-handed students, one might reasonably question the need for a specific frame of reference for printing letters that reflects left-handedness. It has been noted that right-handed writers, due to the biomechanical nature of the hand, have "better control of motion" producing horizontal strokes from left-to-right; left-handed writers have "better control of motion when producing strokes in the opposite direction" (Ellenblum, 2019, p. 75). Printers of English letters, however, are also influenced by the overall direction of reading and writing (left-to-right). Ellenblum (2019) found that with most letters, right and left-handed writers "produced much the same stroke patterns" (p. 70). It was only with two letters that the author found a statistically significant difference between the horizonal direction that left-handed writers used to produce the stroke (lowercase f and t). Importantly, this frame of reference is not based on the directionality of horizontal lines. Instead, this frame of reference addresses the starting point of the first stroke and the sequence of subsequent starting points in relation to the first stroke. Therefore, this frame of reference is suitable for both right and left-handed students.

Function - Dysfunction Continua and Indicators of Function and Dysfunction

Graphic Behavior

Functional: Consistently follows graphic rules when writing upper and lowercase letters	Dysfunctional: Uses ineffective strategies when writing upper and lowercase letters

Indicators of Function	Indicators of dysfunction
Initiates letters' hasta at apex before completing the letters' coda for 20 uppercase letters	Inconsistently initiates letters' hasta at apex before completing the letters' coda for less than 20 uppercase letters
Initiates letters' hasta at apex before completing the letters' coda for 20 lowercase letters	Inconsistently initiates letters' hasta at apex before completing the letters' coda for less than 20 lowercase letters
Completes second stroke of letters using fixed principle for 6/9 applicable uppercase letters	Completes second stroke of letters using the fixed principle for less than three letters
Completes second stroke of letters using fluid principle for all four applicable uppercase letters	Does not use fluid principle to complete second stroke of any applicable uppercase letters
Completes second stroke using flexible principle for 6/9 applicable uppercase letters	Completes second stroke of letters using the flexible principle for less than three uppercase letters
Uses graphic rules independently to write at least 20 letters in uppercase	Requires visual and verbal cues to apply graphic rules

Legible Letters

Functional: Writes recognizable readable letters that represent the actual shape of the letters	Dysfunctional: Letters are difficult to decipher as they do not represent the actual shape of the letters
Indicators of function	Indicators of dysfunction
Writes 20 uppercase letters that can be recognized out of context	Writes less than 20 uppercase letters that can be recognized out of context
Writes 20 lowercase letters that can be readily deciphered out of context	Writes less than 20 lowercase letters that can be recognized out of context
Writes readable sentence using all letters of the alphabet	Written sentence using all letters of the alphabet is difficult to decipher

Printing Speed

Functional: Prints at a fluid and consistent rate	Dysfunctional: Printing is slow and uneven
Indicators of Function	Indicators of Dysfunction
Copies a sentence using all letters of the alphabet in less than three minutes	Unable to copy sentence using all letters of the alphabet in three minutes
Free-writes all letters in alphabetical order in uppercase in under one minute	Requires more than one minute to free-write the alphabet in uppercase
Free-write all letters in alphabetical order in lowercase in one minute	Requires more than one minute to free-write the alphabet in lowercase

Prints all letters in uppercase dictated out of alphabetical order in under two minutes	Requires more than two minutes to print all letters in uppercase dictated out of alphabetical order

Evaluation

In this frame of reference, close observation is critical for determining compliance with conventional graphic behavior. Performance can be further assessed by determining the readability of the text and the speed of writing. While there are many standardized tests available to assess the end product of handwriting quality (Evaluation of Children's Handwriting, Amundson, 1995; Minnesota Handwriting Test, Reisman, 1993), no published measures could be located to assess the confluence of writing speed, legibility, and process of complying with conventional graphic behavior. Therefore, to assess compliance with conventional graphic behavior, an evaluation specific to this frame of reference was developed to assess each of the continua.

There are four essential components to the assessment:

1. Environment and materials
2. Content assessed
3. Instructions and testing
4. Scoring

Environment and Materials

First, the environment should be a quiet room with a table and chair that is appropriate for the size of the student. Materials required for the assessment include paper, a sharpened pencil, a card with a hand printed sentence, and a stopwatch. The paper should have solid bottom and top lines and a dashed middle line for orientation. The writing utensil should be a simple standard sharpened No. 2 pencil. The card should have the handwritten sentence "the zany hare

quickly jumps by and vexes a wild frog." This pangram was developed to contain all letters of the alphabet. The print on the card should be neat and large enough to be easily read. For the purposes of this evaluation, the height of a lowercase letter should range from .5 inches to one inch (e.g., the letter 'a' should measure .5 inches and the letters 'b' or 'y' should measure one inch). The pangram should be written using the same line structure as the test page (solid bottom and top lines with a dashed middle line.

Content

It is important to keep in mind that a child's speed for producing letters can vary with context and instructions. Therefore, all phases should be assessed: copying from a prompt, freewriting from memory, and writing from dictation. Because kindergarteners are beginning to learn to read and spell as well as print, it is imported for the assessment to focus specifically on printing letters while minimizing the more complicated tasks of reading and spelling. Therefore, this assessment uses letters of the alphabet for both freewriting and dictation (reading and spelling skills are not required). However, it is appropriate to assess copying speed with a sentence encompassing all the letters of the alphabet because the child will be able refer, as needed, to the card and will not be limited or aided by reading or spelling abilities.

Instructions and Testing

After the student is comfortably seated, the test paper should be placed on the table in front of the student, and the student should be informed simply and generally about the handwriting (i.e., printing) assessment. The occupational therapist might simply say: "Today I want to see how you print your letters. Here is a piece of paper and a pencil that I want you to use for this activity" [the paper can be placed on the table in front of the child, but the therapist should hold on to the pencil]. "Before each section, I will give you instructions on what you

should write and when to begin. Use your best writing. Do you have any questions?" Once the instructions for the first assessment are given, a pencil should be provided to the student.

The first phase of the assessment will address printing the letters of the alphabet in the order they are dictated. The order will follow the graphic rules and organization principles: the occupational therapist will begin with letters that contain only one stroke (C, O, S, U), then continue with letters that follow the fixed principle (A, B, D, E, F, M, N, P, R), then progress to letters that follow the fluid principle (L, V, W, Z), and finish with the letters that follow the flexible principle (G, H, I, J, K, Q, T, X, Y). The student will be instructed to write a letter after the occupational therapist verbalizes the letter. The therapist might say: "I would like you to print the letters that I read to you. Print the letters in uppercase. Remember to write each letter as clearly and neatly as you can." This phase, as with the next two phases, should be timed. With careful observation, the occupational therapist notes how often the student completes a letter following the graphic rules of production.

In the second phase, the student should be asked to write all letters of the alphabet from memory and in alphabetical order, in uppercase first and next in lowercase. The occupational therapist might say: "I would like you to write the alphabet in uppercase and then continue writing the alphabet again, this time in lowercase. Concentrate on each letter as you write it and remember to write as clearly as you can." During this phase, the occupational therapist should provide visual and/or verbal cues for following the graphic rules and organization principles when necessary. Again, with careful observation, the occupational therapist should note how often the student requires verbal and/or visual cues for compliance with the graphic rules and organization principles.

In the third phase, the student should be asked to copy a sentence that uses all letters of the alphabet. A card with the sentence “the zany hare quickly jumps by and vexes the wild frog” should be placed on the table in front of the student’s paper. The student will be asked to copy the sentence as he or she is timed. The occupational therapist should show and read the card to the student and say: “I would like you to copy this sentence as you see it, on the paper you have in front of you. Please write as clearly as you can.” For this phase, legibility should be assessed on whether each letter can be identified out of context.

Scoring

The first phase of the assessment focuses on graphic rules and speed. When scoring this phase, the occupational therapist should tally how many letters the student prints that follow the graphic rules for production. The occupational therapist notes how often the student follows each graphic rule (i.e., x/26 for initiation of the letter at its apex, x/9 for the fixed principle, x/4 for the fluid principle, and x/9 for the flexible principle). The time required for the student to complete the phase will also be noted. This phase will have five total scores.

The second phase focuses on graphic behavior, speed and legibility. The occupational therapist will count how often cues are required for the student to follow the graphic rules and organization principles, with a possible score of 52 (both upper and lowercase will be considered). There will be a binary distinction regarding scoring compliance with graphic rule and organization principle. Each letter will be counted only once: either a verbal/visual cue was needed, or it was not. Again, the time required to complete this phase should be noted. This phase will have a third score which evaluates legibility. Each letter that is readable and recognizable will be considered legible. Upper and lowercase letters will be scored separately. This phase will have four scores.

The last phase focuses on speed and legibility. The therapist will time how long it takes to copy the pangram sentence and will tally how many letters (out of 44) are recognizable and readable. This phase will have two scores.

Postulates Regarding Change

General

- Kindergarteners develop the ability to comply with standard graphic behavior in an environment where the optimal challenge point is maintained, and they have opportunities to practice.

Directional

- Considerable potential available information (e.g. verbal and visual cues) should be provided when the kindergartener is first learning to print letters. As the kindergartener exhibits proper letter formation, less available information needs to be provided.
- Graphic rules and organization principles should be taught to the kindergartener from least complex rule to most complex rule (i.e., starting rule, fluid principle, fixed principle, flexible principle).
- Blocked practice should be utilized when kindergarteners are first learning to print letters. Once the kindergartener can demonstrate proper letter formation during initial trials, random practice can be employed to improve skill retention.

Specific

- When the occupational therapy practitioner provides opportunities for a kindergartener to engage in writing activities with sensory feedback (e.g. verbal and visual), the kindergartener will learn to comply with graphic rules and organization principles.

- When the occupational therapy practitioner provides writing activities at the kindergartener's skill level with optimal task difficulty, the kindergartener will expand his optimal potential for complying with graphic rules and organization principles.
- When the occupational therapy practitioner provides opportunities for the kindergartener to engage in writing activates with sensory feedback (e.g., verbal, visual, tactile), the kindergartener is more likely to learn to write recognizable readable letters.
- When the occupational therapist provides writing activities at the kindergartener's skill level with optimal task difficulty, then the kindergartener is more likely to learn to write recognizable readable letters.
- When the occupational therapist provides time for the kindergartener to engage in writing activities with sensory feedback (e.g., verbal, tactile, visual), the kindergartener's ability to form letters will become automatic procedural knowledge and writing letters will be more fluid and constant.
- When the occupational therapist provides writing activities at the kindergartener's skill level with optimal task difficulty, then the kindergartener's ability to form letters will become automatic procedural knowledge and writing will become more fluid and constant.

Application to Practice

Consistent with the challenge point theory, skill acquisition requires ample amounts of practice, blocked to begin and then random for reinforcement. Furthermore, for the optimal challenge point to be reached, the occupational therapist should initially provide instruction that has considerable potential available information and is paired with low task difficulty. Importantly, the successful convergence of practice conditions is predicated on the occupational

therapy partitioner's conscious attention to the child's dynamic skill level. As the child demonstrates aptitude, practice conditions should be adjusted to ensure that the optimal challenge point is continuously achieved.

To begin, the occupational therapist must always evaluate and reevaluate the appropriate amount of potential available information and the task difficulty involved in the practice conditions. First, potential available information can be calibrated to provide the appropriate amount and types of cues and feedback for optimal skill acquisition. Cues and feedback should be provided in ample amounts when initially learning a new graphic rule and then taper off as the student becomes proficient with application.

Next, it is essential for the occupational therapist to adjust task difficulty in order to reach the optimal challenge point. Instruction should begin with the learning the least complex of the graphic rules and move progressively through the more complex organization principles in the following order:

1. Starting Point Letters
2. Fluid Letters
3. Fixed Letters
4. Flexible Letters

Explicit instruction of the graphic rules and organization principles can be implemented using the challenge point framework. Occupational therapy practitioners should begin by providing ample potential available information in the form of consistent verbal and visual cues when introducing each new letter. Practitioners can model the correct letter formation, (on chalkboard/whiteboard, or on a sheet of paper next to the student) while verbalizing the motor plan for the correct starting point, stroke direction, and segment sequence. For example, while

constructing the letter ‘L’ the practitioner might say: “start at the top, draw a straight line down to the baseline, and the draw a short line out to the side.” Students should have worksheets with visual cues (such as, lined paper with starting point indicators and directional arrows) that correspond with the instructors directions. After the practitioner demonstrates proper letter formation, students should have plentiful opportunities to practice each letter discreetly as the practitioner continues to provide verbal directions. As students demonstrate skill development, verbal and visual cues can be faded.

Additionally, according to the optimal challenge point theory, blocked and random practice should both be incorporated in the learning process. Blocked practice should be utilized initially with the instruction of each separate letter described by each graphic rule. For example, when teaching the fluid principle, the occupational therapy practitioner should concentrate on each of the four applicable letters separately (e.g., addressing ‘L’ before moving on to ‘V’, then moving to ‘W’ and finally ‘Z’). Some ways to incorporate blocked practice include age-appropriate letter games. Letters might be drawn by playing connect the dots, or line segments can be colored-by-number according to stroke sequence. After the student can form each letter individually, complying with the graphic rules and organization principles, the therapist can introduce random practice by incorporating all the letters that follow the fluid principle.

Furthermore, once the student has shown compliance with following each of the graphic rules and organization principles separately, random practice, with less available information (fewer cues provided) should continue. Random practice can include various developmentally appropriate activities such as practice worksheets or playing letter games (e.g., Hangman).

Successful intervention, according to the challenge point theory, is dependent not only on the quality of practice but also the amount of practice. Opportunities for the child to practice the

graphic rules of production should be liberally provided. The occupational therapy practitioner can provide the initial instructions for practice of new information during a weekly therapy session, and the child's teacher and caregivers can be instructed to provide opportunities to practice the skills throughout the week.

Clearly, implementing appropriate interventions for this frame of reference dovetails with the therapist's conscious use of self. The occupational therapy practitioner maintains a critical role in this intervention process. The practitioner must continuously evaluate the student's skill level to maintain the optimal challenge point. It is likewise important that rapport be developed between the occupational therapy practitioner and the student. The occupational therapy practitioner's relationship with the student must be nurturing and supportive as well as instructive and constructive. Establishing this relationship will promote the best environment to foster learning.

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