
Grip Form and Graphomotor Control in Preschool Children

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Key Words: gross and fine motor skills • handwriting • single craft assessment tool

Objective. The purpose of this study was to examine the utility of the grip scale presented by Schneck and Henderson, the effect of grip form on drawing accuracy, and the effect of implement diameter on grip form and drawing accuracy.

Method. Sixty boys and girls who were 3, 4, and 5 years of age performed 20 trials of a precision drawing task, 4 trials each with five implements of varying diameters (4.7, 7.9, 11.1, 14.3, and 17.5 mm).

Results. First, all 1,200 grips could be coded according to Schneck and Henderson's 10-grip whole-configuration assessment system, but the interrater reliability was lower than expected (.67 proportion of perfect agreement). Second, using Schneck's five-level scoring system, the level of grip significantly affected drawing accuracy, with the highest grip level used most often with the highest accuracy scores and the lowest observed grip level used most often with the lowest accuracy scores. Third, increasing implement diameter led to significantly lower level grips but did not significantly affect accuracy.

Conclusions. Therapists are recommended to use Schneck and Henderson's 10-grip scale only for documenting the persons' grips and changes in their grips, but if comparisons between individual persons are desired, then Schneck's five-level scale, which affords greater generalizability, should be used. Further, children with graphomotor performance deficits are not likely to benefit from grip manipulations because such strategies were shown to make better only performance that is already good.

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Difficulty with graphomotor skills—handwriting or drawing—is often why children in public schools are referred for occupational therapy service (Diekema, Deitz, & Amundson, 1998; Reisman, 1991; Tseng & Cermak, 1993). To address these types of problems, occupational therapists need to be able to assess graphomotor performance, identify the grip on the writing or drawing implement, and understand the variables that may affect the performance or the grip. Focusing on three issues subsumed under the last two categories, this study was designed to examine (a) the utility of the grip scale presented by Schneck and Henderson (1990), (b) the effect of grip form on drawing accuracy, and (c) the effect of implement diameter on grip form and drawing accuracy.

First, Schneck and Henderson's (1990) developmental grip scale has been often cited and recommended for use by occupational therapists (e.g., Amundson, 1992; Amundson & Weil, 1996; Tseng & Cermak, 1993; Ziviani, 1995), but there has been no published confirmation of the utility of the scale for categorizing all variations of grips and the generalizability of the relative occurrence of each grip for chil-

dren 3 to 5 years of age. Second, grip is often mentioned as a possible source of graphomotor problems, but the extent to which an atypical grip can contribute to poor writing or drawing has not been clearly established (Benbow, 1995; Graham & Weintraub, 1996; Tseng & Cermak, 1993). Third, manipulating the size of the writing or drawing tool has been suggested as an ergonomic therapeutic strategy to facilitate a better grip or improve graphomotor performance (Amundson, 1992; Amundson & Weil, 1996; Tseng & Cermak, 1993), but little empirical evidence supports this recommendation.

Researchers have reported two general types of grip assessment systems: component and whole configuration. In component systems, separate components of the grip—the position of each finger and the thumb, the relative position of the grip along the length of the implement, or the forearm position relative to the table—are evaluated. Researchers using a component assessment system include Blote and colleagues (Blote & van Gool, 1989; Blote & Van Haasteren, 1989; Blote, Zielstra, & Zoetewey, 1987); Sassoon, Nimmo-Smith, and Wing (1986); and Martlew (1992). In whole-configuration systems, all of the components of an observed grip are described together, and the grip, considered as a discrete behavior, is given an appropriate label. A good example of a whole-component assessment system is Schneck and Henderson's (1990) scale. The main advantage of a component system is that the many combinations of possible features allow just about any grip, even unusual configurations, to be coded. Conversely, the primary advantage of a whole-configuration system is that a single judgment from a limited set of choices is made, rather than from a series of judgments. A key assumption

in whole-configuration systems is that the identified grips represent the most common component combinations and account for most grip possibilities.

Schneck and Henderson's (1990) developmental grip scale describes 10 pencil and crayon grips (see Table 1 and Figure 1). To test their developmental grip progression, they had 320 children who were 3, 4, 5, and 6 years of age perform two trials of a drawing task and two trials of a coloring task. Based on their results, Schneck and Henderson labeled the first five grips "primitive" because they were rarely observed after 4 years of age; the next three grips "transitional" because their use decreased with age but still continued into the 6th year; and the last two grips "mature" because their use increased with age. However, Schneck and Henderson acknowledged that a developmental progression from immature to transitional to mature grips for individual children was not a reasonable expectation. The authors reported a reliability of .90 but did not specify the type of reliability coefficient used. Their 10-grip assessment system offers the simplicity needed by clinicians, but does it account for all grip possibilities? The first purpose of the present study was to examine this question.

After the 1990 study, Schneck (1991) considered whether first-grade children with difficulties in forming letters show less mature grips than do their peers without handwriting difficulties. For this research, she collapsed the 10 grips in the original scale into five levels by grouping together grips that were found to have mean ages within 2 months of each other (see Table 1). With this five-point scale, she found that the children with writing difficulties obtained a significantly lower mean grip score (4.70) than the other children (4.93), and those with poor propriocep-

Table 1
Descriptions of 10 Grips and Five Grip Levels According to Schneck and Henderson (1990) and Schneck (1991)

Grip		Description
Grip Number ^a	Level Number ^b	
1	1	Radial cross palmar grasp: implement positioned across palm radially (thumb down); implement held with fist; forearm fully pronated; full arm movement
2	2	Palmar supinate grasp: implement positioned across palm projecting ulnarly (thumb up); implement held with fist; wrist slightly flexed and supinated away from midposition; full arm movement
3	2	Digital pronate grasp, only index finger extended: implement held in palmar grasp; index finger extended along pencil toward tip; arm not supported on table; full arm movement
4	3	Brush grasp: implement held with fingers; eraser end positioned against palm; hand pronated with wrist movement present; whole arm movement; forearm positioned in air
5	3	Grasp with extended fingers: implement held with fingers; wrist straight and pronated with slight ulnar deviation; forearm moves as a unit
6	4	Cross thumb grasp: fingers fist loosely into palm; implement held against index finger; thumb crossed over pencil toward index finger; finger and wrist movement; forearm positioned on table
7	4	Static tripod grasp: implement stabilized against radial side of third digit by thumb pulp; index pulp on top of shaft; thumb stabilized in full opposition; wrist slightly extended; hand moves as a unit; implement rests in open web space; forearm resting on table
8	4	Four fingers grasp: implement held with four fingers in opposition; wrist and finger movement; forearm positioned on table
9	5	Lateral tripod grasp: implement stabilized against radial side of third digit by thumb pulp; index pulp on top of shaft of implement; thumb adducted and braced over or under anywhere along lateral border of index finger; wrist slightly extended; fourth and fifth digits flexed to stabilize the metacarpophalangeal arch and third digit; localized movements of digits of tripod and wrist movements on tall and horizontal strokes; forearm resting on table
10	5	Dynamic tripod grasp: implement stabilized against radial side of third digit by thumb pulp; index pulp on top of shaft of implement; thumb stabilized in full opposition; wrist slightly extended; fourth and fifth digits flexed to stabilize the metacarpophalangeal arch and third digit; localized movements of digits of tripod and wrist movements on tall and horizontal strokes; forearm resting on table

^aFrom Schneck and Henderson (1990). ^bFrom Schneck (1991).

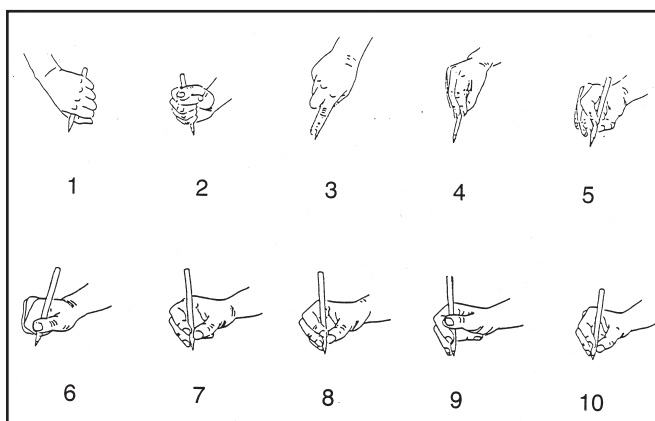


Figure 1. Illustrations of the 10 grip forms from Schneck and Henderson (1990). From “Descriptive Analysis of the Developmental Progression of Grip Position for Pencil and Crayon Control in Nondysfunctional Children” by C. M. Schneck & A. Henderson, 1990, *American Journal of Occupational Therapy*, 44, p. 895. Copyright 1993 by The American Occupational Therapy Association, Inc.

rive-kinesthetic finger awareness obtained a significantly lower mean grip score (4.33) than the others (4.94).

However, other researchers have found limited evidence of a relationship between writing performance and the grip used. In their study of writing skill among 8- to 14-year-olds, Ziviani and Elkins (1984) found that the way their 8- to 14-year-old participants held their pencils did not necessarily affect their speed or legibility of writing. Similarly, Blote et al. (1987) reported only low correlations between 5- to 6-year-olds’ written products and different indices of body movement and grip. The tripod posture has been traditionally viewed as the most effective grip, but Sassoon et al. (1986) found no advantage in terms of writing speed with a tripod grip compared with other grips, and Martlew (1992) found only slight indications that 4- to 5-year-olds using a tripod grip could produce more accurate letter and word forms. In their review of handwriting research from 1980 to 1994, Graham and Weintraub (1996) concluded that “although the studies reviewed here suggest that variations in handwriting grip do not influence how fast or clearly children write, the generality of this conclusion requires further testing” (p. 24). Given the contrasting findings, the second purpose of the study was to investigate the effect of grip on drawing accuracy.

The third purpose of this study was to examine the effect of implement diameter on both grip form and performance. Large-diameter pencils became available from school supply houses in the 1920s and were recommended for young children to encourage correct finger position, discourage finger movement, improve control, and reduce cramping (Carlson & Cunningham, 1990; Graham & Weintraub, 1996). However, the advantages of larger diameter implements over standard-sized implements have not been demonstrated in the few studies carried out in this area. Wiles (1942–1943), who had first graders exclusively use pencils of one of three diameters—7.4, 8.6, or 9.8

mm—over an entire school year, reported little correspondence between the quality of handwriting and pencil size at any of the three assessment intervals. Lamme and Ayris (1983) randomly assigned five different writing tools (i.e., large primary pencils, small primary pencils, standard #2 pencil, #2 pencils with triangular grip, fine-line felt-tip pens) to 35 first-grade classes to be used for one semester. They found no significant differences in writing legibility across the five tool groups and concluded that “teacher and/or student differences within each tool group were greater than tool differences, and that both teachers and students varied in their reactions to the different writing tools” (p. 37). More recently, Carlson and Cunningham (1990) examined the effect of pencil diameter (7.5 mm, 10.0 mm) on drawing and writing performance and grip used by 4- and 5-year-olds. Ten grips were identified in a whole-configuration system, but they were reduced to three ordinal grip levels for the analyses. They found no differences in performance or grips related to pencil diameter, but their results and those reported by Wiles (1942–1943) and Lamme and Ayris (1983) must be interpreted cautiously because the range of pencil diameters was quite limited in all three studies.

Accordingly, three sets of hypotheses were established, corresponding to the three purposes of the study. First, in regard to the utility of Schneck and Henderson’s (1990) whole-configuration grip scale, (a) all observed grips were expected to fit into one of Schneck and Henderson’s 10 categories, and (b) the relative frequency of each of the five grip levels (using Schneck’s [1991] simplified system) for 3-, 4-, and 5-year-olds was expected to be within 5% of the values reported by Schneck and Henderson for the same age groups. Second, level of grip was not expected to significantly affect drawing accuracy. Third, contrary to current knowledge, increasing implement diameter was expected to significantly decrease the frequency of higher level grips and significantly decrease drawing accuracy.

Method

Participants

Sixty 3-, 4-, and 5-year-old boys and girls recruited from a public preschool program in metropolitan Minneapolis–St. Paul, Minnesota, participated in this study, with 10 in each of the six age–gender groups. None of the participants had prior formal instruction in writing or drawing grips. Most participants wrote only with their right hand (82%), but 13% wrote only with their left hand, and 5% wrote with both hands. The mean ages of the participants in each group, along with handedness information, are presented in Table 2. A parent or guardian of all participants signed an informed consent form.

Apparatus

The participants were seated in a plastic-and-metal chair

Table 2
Age, Handedness, and Finger Length of the
Participants According to Age–Gender Group

Group	Age		Hands			Finger Length (mm)
	<i>M</i> (Year-Month)	<i>SD</i> (Year-Month)	Number Using Right Only	Number Using Left Only	Number Using Both	
3 years						
Boys	3-8	0-2	8	1	1	42–52
Girls	3-8	0-3	9	0	1	40–52
4 years						
Boys	4-5	0-3	7	2	1	43–54
Girls	4-5	0-3	7	3	0	40–52
5 years						
Boys	5-5	0-2	10	0	0	47–55
Girls	5-4	0-1	8	2	0	43–55

(with the seat 29.2 cm high) at a matching desk with a wood-grain laminate top (66.0 cm square, 50.8 cm high). Each participant was given a booklet composed of 20 half-sheet, standard white pages (21.6 cm x 14.0 cm). At the center of each sheet, a square shape with only three sides was drawn. A 3.2-mm-wide writing path was created by drawing the same three-sided pattern just to the outside of the first. The two open ends of the path terminated in 9.5 mm x 6.4 mm rectangles, with an ant drawn in one and a star in the other (see Figure 2). Finally, the background around the pattern was colored gray to highlight the white writing path. The inside lengths of the three sides were scaled to be approximately 40% of the participant's index finger length (measured from the web of skin between the index and middle fingers to the tip of the index finger) by using three different-sized squares. A small square (15.9 mm long) was used for finger lengths between 40 mm and 43 mm (37%–40%), a medium square (19.1 mm long) for finger lengths between 44 mm and 51 mm (37%–43%), and a large square (22.2 mm long) for finger lengths between 52 mm and 55 mm (40%–43%). If the writing paths were not scaled to finger length, then children with shorter fingers would face relatively longer paths and might need to adjust their hand position or grip more often, which could affect drawing performance (Newell, McDonald, & Baillargeon, 1993; Newell, Scully, McDonald, & Baillargeon, 1989; Newell, Scully, Tenebaum, & Hardiman, 1989).

The drawing task was designed to require the fine motor skill needed in handwriting and precise drawing, but to minimize nonmotor factors that could affect movement

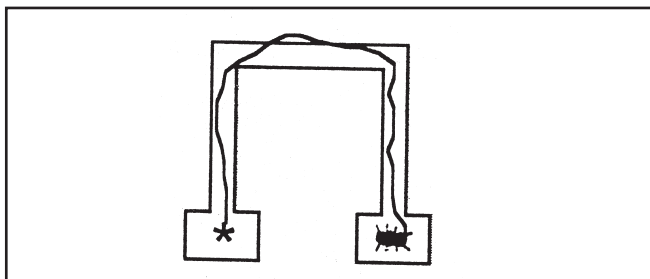


Figure 2. One page from the testing booklet, presenting a medium-sized drawing path (19.1 mm long), with the open end oriented up.

behavior, such as perception and knowledge and understanding of the alphabet, language, and specific types of manuscript or cursive handwriting formats. Additionally, the task was designed for the degree of movement control to be easily and objectively quantified. Amundson and Weil (1996) asserted that fine motor control is an important component of handwriting readiness and that occupational therapists must determine when it is appropriate for a child to work on prerequisite handwriting skills, the functional skill of handwriting, or both.

Each participant performed the drawing task with implements of five different diameters: 4.7 mm (3/16 in.), 7.9 mm (5/16 in.), 11.1 mm (7/16 in.), 14.3 mm (9/16 in.), and 17.5 mm (11/16 in.). The 7.9-mm diameter matched that of a standard pencil or pen, the 11.1-mm and 14.3-mm diameters matched that of a small marker, and the 17.5-mm diameter matched that of a large marker. The implement barrels were made from Plexiglas^{TM1} rods, painted flat black, and fitted with a .5-mm ultra-fine Uni-ball^{TM2} metal-point pen refill (#UBR-5P). All implements were 13.8 cm long. A pen was used instead of a pencil, as reported by Schneck and Henderson (1990), because the special barrels could not easily accommodate pencil inserts, either sharpened or mechanical pencils. The use of a pen rather than a pencil was assumed to have little effect on drawing grips, although some participants were observed to move the implement up to a steeper angle when they discovered that the pen would not write at a shallow angle like a pencil. As the participants performed the drawing task, the palmar aspect of the writing hand was videotaped with a VHS camcorder.

Procedure

Before testing, each participant's index finger length was measured to determine which of the three pattern sizes would be needed. Once seated at the table, participants were instructed to "draw a line from the ant to the star, staying only in the white path." They were given no practice trials and no demonstration by the experimenter. The participants performed 20 trials, four with each of the five implements. On the four consecutive trials with a particular implement, the open end of the square pattern was placed up, down, left, and right. Additionally, before each trial, the writing end of the implement was oriented toward the open end of the pattern. This systematic variation of the implement orientation was designed to prevent any bias of grip forms from the implement orientation. In a pilot study, some 3- and 4-year-olds were observed to not adjust their grip after initially picking it up, consistent with research on in-hand manipulation skills (Pehoski, 1995). The order of the five implements was varied using a Latin-

¹Rohm & Haas Company, 222 West Washington Square, Philadelphia, Pennsylvania 19106.

²Faber-Castell USA, PO Box 7013, Bedminster, New Jersey 07921.

Table 3
Descriptions of Accuracy Levels

Level Number	Level Description
1	Task not completed: lines not within 6.4 mm of starting boxes, ending boxes and/or gaps > 6.4 mm in the middle.
2	One or more large deviations over inside or outside edge of the pattern: (a) the perpendicular distance of deviations to edge or corner > 3.2 mm or (b) the perpendicular distance of deviations to edge or corner > 1.6 mm and < 3.2 mm, and length > 12.8 mm.
3	One or more medium deviations over inside or outside edge of the pattern: (a) the perpendicular distance of deviations to edge or corner > 1.6 mm and < 3.2 mm, and length < 12.8 mm, or (b) the perpendicular distance of deviations to edge or corner < 1.6 mm and length > 12.8 mm, but less than length of side.
4	One or more small deviations over inside or outside edge of the pattern: the perpendicular distance of deviations to edge or corner < 1.6 mm and length < 12.8 mm.
5	All lines within the pattern, with some touching the edge.
6	All lines within the pattern.

square design, with each order repeated twice within each group of 10 participants.

Design and Analysis

This study involved three primary independent variables—age (3), gender (2), and implement diameter (5)—and two dependent variables—grip form and drawing accuracy. Grip form was coded according to the 10 developmentally ordered patterns presented by Schneck and Henderson (1990). In a later paper, Schneck (1991) reduced the scale to five levels, grouping together grips that were achieved within 2 months of each other (see Table 1). One rater coded all 1,200 trials according to Schneck and Henderson's levels, noting all deviations from the specified levels. The rater recoded the trials of two participants from each of the six age–gender groups, yielding a .75 proportion of perfect agreement. When the 10 levels were converted to Schneck's (1991) five-point system, the intrarater proportion of perfect agreement was .87, with a kappa of .75. Similarly, a second rater coded the trials of two participants from each of the six age groups, yielding a .67 proportion of perfect agreement between raters. When the 10 levels were converted to the five-point system, the interrater proportion of perfect agreement was .80, with a kappa of .64.

Drawing accuracy was measured by a six-point ordinal scale developed for the study and designed to discriminate between levels of drawing deviations from the specified path (see Table 3). For example, the sample presented in Figure 2 would be scored as a 4. All 1,200 trials by all participants were judged by two independent raters, yielding an interrater proportion of perfect agreement of .80 and a kappa value of .73. One of the raters also reevaluated the performance of 12 participants (2 randomly chosen from each age–gender group), yielding an intrarater proportion of perfect agreement of .90 and a kappa value of .87.

Because of the ordinal nature of the grip and accuracy scores, chi-square analyses were used to address the experimental hypotheses related to the effects of age, gender, and implement diameter. An alpha of .01 was chosen rather than the traditional .05 to minimize the degree of error potentially created by conducting repeated chi-square analyses.

Results

Grip Form

The predominant grips used by all three age groups were Levels 4 and 5, accounting for 79.5% (3-year-olds), 92.3% (4-year-olds), and 98.8% (5-year-olds) of all trials (see Figure 3). No participants showed a Level 1 grip and no 5-year-olds showed a Level 2 grip. The chi-square analysis of the effect of age on the frequency of all four observed grip levels (2–5) was significant, $\chi^2(6, N = 1,200) = 125.7, p < .001$. In addition, the chi squares for each grip level (2–5) were significant, $\chi^2(2, n = 71) = 73.4, \chi^2(2, n = 47) = 14.6, \chi^2(2, n = 450) = 22.6, \chi^2(2, n = 632) = 15.2, ps < .001$, with 5-year-olds by far showing the most Level 5s, 4-year-olds showing the most Level 4s, and 3-year-olds showing the most Levels 2s and 3s.

The chi square analyzing the effect of gender on the frequency of the four grip levels also was significant, $\chi^2(3, n = 1,200) = 64.3, p < .001$. Subsequent chi squares on the individual grip levels showed that boys demonstrated significantly more Level 4 grips, $\chi^2(1, n = 450) = 6.6, p < .01$, but the girls demonstrated significantly more Level 5 grips, $\chi^2(1, n = 632) = 10.8, p < .001$. Thus, the overall grip levels were higher for girls than boys.

Figure 4 shows that Level 4 steadily increased over the four largest diameters and Level 5 decreased over the three largest diameters. The effect of implement diameter on the

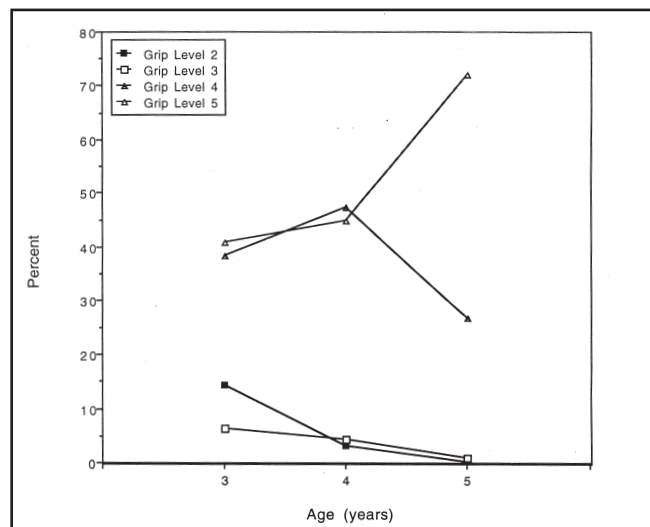


Figure 3. Percentage of grip levels by age group.

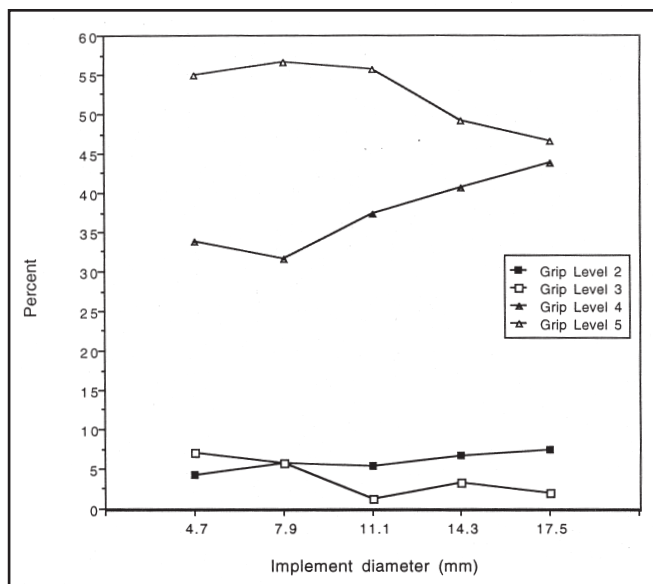


Figure 4. Percentage of grip levels by implement diameter.

frequency of the four grip levels was significant, $\chi^2(12, n = 1,200) = 27.5, p < .01$, but only the individual chi square for Level 3 was significant, $\chi^2(4, n = 47) = 15.0, p < .01$. The significant decrease of Level 3 and general increase of Level 2 as the implement became wider, coupled with the general decrease in Level 5 and increase in Level 4, indicated that lower level grips were used as diameter increased. The average percentage difference across the five grips was 4.3% for 3-year-olds, 5.7% for 4-year-olds, and 3.3% for 5-year-olds (10 of the 15 differences were less than 5%).

Drawing Accuracy

The two highest drawing accuracy scores (5 and 6) increased with age, and the three lowest scores (1, 2, and 3) decreased with age (see Figure 5). The chi-square analysis of the effect of age on the frequency of all six accuracy scores was significant, $\chi^2(10, N = 1,200) = 252.6, p < .001$. In

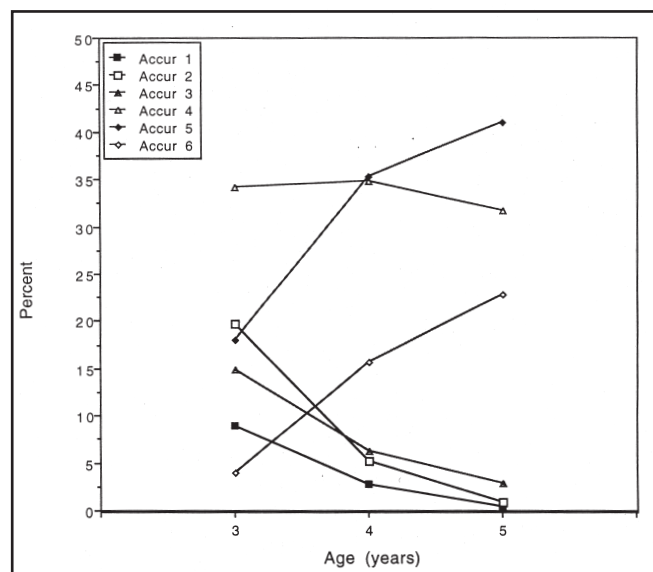


Figure 5. Percentage of accuracy scores by age group.

addition, the chi squares for scores of 1, 2, 3, 5, and 6 were significant, $\chi^2(2, n = 49) = 37.6, \chi^2(2, n = 104) = 89.1, \chi^2(2, n = 97) = 38.2, \chi^2(2, n = 377) = 36.5, \chi^2(2, n = 170) = 50.7, ps < .001$. Clearly, the older children demonstrated more accurate drawings than did the younger children.

More girls showed the three highest accuracy scores (4, 5, and 6), and more boys showed two of the lowest accuracy scores (2 and 3), but the chi square analyzing the effect of gender on the frequency of the six accuracy scores was not significant ($p > .05$).

The percentages of the poorest accuracy scores (1, 2, and 3) were low and consistent across the five implement diameters, all less than 10.0% and varying by 3.3% or less. The most common scores—4 and 5—averaged 32.4% across the first four diameters, with the difference between the two always 6.7% or less, but at the 17.5-mm diameter, the percentage of 4s increased to a high of 39.2% and the percentage of 5s decreased to a low of 27.1%. The chi square analyzing the effect of diameter on the frequency of the six accuracy scores was not significant ($p > .05$).

The question of whether certain grips allowed for more accurate drawing was answered by examining the relative occurrence of the four grips (2–5) for each accuracy score (1–6). The chi-square analysis of the effect of accuracy score on grip percentages was significant, $\chi^2(15, n = 400) = 61.1, p < .001$ (see Figure 6). Subsequent chi-square analyses of individual accuracy scores were significant only for the most accurate score (6), $\chi^2(3, n = 38.9) = 16.2, p < .01$, and the least accurate score (1), $\chi^2(3, n = 20.3) = 23.3, p < .001$. For an accuracy score of 6, the highest level grip (5) was used almost as often (19.0%) as the other three grip levels combined (19.9%), and for an accuracy score of 1, the lowest level grip observed (2) was used more than one-and-a-half times as often (19.7%) as the other three grip

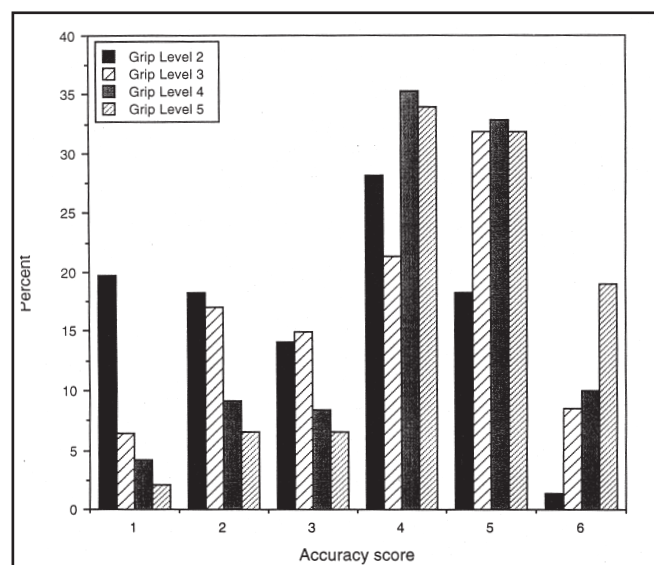


Figure 6. Percentage of grip levels by accuracy score. For each grip level separately, the frequency of each accuracy score was divided by the total frequency of the grip level and then multiplied by 100.

levels combined (12.7%). Additionally, Spearman's rho, quantifying the relationship between grip level and accuracy score, yielded a value of $-.305$.

Discussion

Utility of Schneck and Henderson's Grip Scale

As hypothesized, all observed grips in the 1,200 trials fit into one of Schneck and Henderson's (1990) 10 categories. However, individual participants often showed idiosyncratic finger positions that did not match any of the grips described by Schneck and Henderson, but the general characteristics of the grip allowed it to be classified according to the 10-level system. For Grip 8—four fingers grasp—13 participants held the implement with three instead of four fingers on 74 trials, and 3 participants pronated their wrist as in Grip 1 on 10 trials. For Grips 7 to 10, 10 participants did not place their forearm on the table on 54 trials.

The interrater reliability on the 10 categories, as measured by proportion of perfect agreement, was considerably lower (.67) than expected and likely was accounted for by these variations from the specified grip descriptions. The interrater reliability coefficient reported by Schneck and Henderson (1990) was .90, but they did not indicate exactly what type of measure was used.

Schneck and Henderson (1990) reported the relative occurrence of 10 grips for 3-, 4-, 5-, and 6-year-olds using a #2 pencil in a drawing task and a crayon in a coloring task. Their percentages of the 10 grips for the drawing task only, considered according to Schneck's (1991) five-level system, were found to be very close to those found in the present study for 3-, 4-, and 5-year olds. Across all implement diameters, the percentage differences between the two studies were not less than 5% as predicted for all grip levels by age, but 10 of the 15 differences were less than 5% and the average percentage difference for each age group was less than 6%. For the standard pencil diameter only (7.9 cm), 11 of the 15 differences were less than 5% and the average percentage difference for each age group also was less than 6%.

Based on the results of this study, use of the Schneck and Henderson's (1990) 10-grip scale is recommended only for documenting the grips of individual persons and changes in their grips. If comparisons between persons are desired, then Schneck's (1991) five-level scale should be used. In addition, two important limitations in the 10-grip scale were identified. First, the description for Grip 8 indicates that the implement is held with four fingers in opposition, but 21.7% of our participants showed a three-finger opposition grip (and were coded as an 8). Second, forearm position relative to the table is mentioned in Grips 3 and 4 and 6 to 10, but this aspect of the grip did not always match the rest of the descriptions. Consistent with this second recommendation, Blote et al. (1987), in their work

with 5- and 6-year-olds, reported that "in most cases the children started writing with their forearm and elbow resting on the table, but only in about half of the cases is their forearm and elbow still on the table at the end of the line" (p. 333). Thus, forearm position appears to be related to the extent of the writing rather than to a specific grip form.

A major limitation of the present study is the use of a ballpoint pen rather than a pencil or marker. Preschool children usually use pencils or colored markers, which can be held at steeper angles than ballpoint pens to make even marks or lines. Some participants were observed trying to write at steeper angles than possible with the pens and then adjusting the angle but not their grip when they saw that they were not making even marks. However, some of the grips reported in this study might not be the same if the children had used pencils or markers of the same diameter. A .5-mm metal-point pen refill was used because, after some exploration of other alternatives, it was found to best accommodate the Plexiglas implement barrels of varying diameters. Additionally, two other advantages of using a pen rather than a pencil was that the point was always the same and never had to be sharpened.

Effect of Grip on Drawing Accuracy

The second hypothesis predicted that the level of grip would not significantly affect drawing accuracy. However, when the relative distribution of accuracy scores for each grip level was calculated and then the grip percentages compared for each accuracy score, the relative occurrence of the grips was not equitably distributed for the most accurate and least accurate scores. Indeed, the highest grip level was used most often with the highest accuracy score (6), and the lowest observed grip level was used most often with the lowest accuracy scores (1–3), but the grips were fairly evenly distributed at accuracy scores of 4 and 5. This nonlinear effect of grip level on accuracy scores—significant only at the two extremes of the accuracy scale—helps explain the fairly low Spearman's rho value of $-.305$ between grip level and accuracy score. This nonlinear effect may have been masked in previous studies that showed only a minimal relationship between grip and graphomotor performance because most of these studies relied on mean performance measures across all levels of skill.

Children who perform at the low end of the accuracy scale are the ones most likely to be treated by occupational therapists and may be able to improve their writing or drawing accuracy by modifying their grip. Teaching or eliciting a different grip by manipulating the writing implement or other variables may be a fruitful strategy when working with persons with poor graphomotor skill, but persons should not be referred to occupational therapists just because of an unusual or "immature" grip (Amundson, 1992; Sassoon et al., 1986; Tseng & Cermak, 1993; Ziviani, 1995).

The highest level grip (5) was observed in more than

half of the 1,200 trials (52.7%), with 35.3% dynamic tripods (Schneck & Henderson, 1990; Grip 10) and 17.4% lateral tripods (Grip 9). About the same ratio between the two tripod grips was reported by Schneck and Henderson (1990) for the 3- to 5-year-olds (42.5% vs. 15.9%) and 6-year-olds (67.5% vs. 25.0%). Bergmann (1990) reported that 88% of a broad sample of adults used the dynamic tripod grip to write but that about 9% used the lateral tripod grip. Interpreting their own and Bergmann's results, Schneck and Henderson concluded that "until further studies are conducted, the lateral tripod grasp should be considered an acceptable alternative to the dynamic tripod grasp" (p. 898).

This conclusion can be tested in the present study by comparing accuracy scores on the two types of tripod grips. Compared with the lateral tripod, the dynamic tripod yielded a higher percentage of the two highest accuracy scores (56.8% vs. 43.5%) and a lower percentage of the two lowest scores (4.9% vs. 12.0%). However, a chi-square analysis showed that the effect of these two grips on accuracy scores was not significant ($p > .05$). This result based on 632 observations provides further evidence that the lateral tripod should be considered an acceptable alternative to the dynamic tripod. What remains to be investigated, however, is the relative effectiveness of the lateral tripod over long bouts of writing or drawing and its resistance to fatigue (Tseng & Cermak, 1993).

Effect of Implement Diameter on Grip and Drawing Accuracy

The third hypothesis, predicting that increasing implement diameter would significantly decrease the frequency of higher level grips and significantly decrease drawing accuracy, was supported for grip form but not accuracy. Lower level grips, particularly Level 5 instead of Level 4, were used as diameter increased over the four largest implements. One explanation of why these results were different than the null effect reported earlier by Wiles (1942–1943), Lamme and Ayris (1983), and Carlson and Cunningham (1990) relates to the wider range of diameters experienced by the participants in the present study—4.7 mm to 17.5 mm—as opposed to a range of 7.5 mm to 10.0 mm in the other studies. Thus, the use of implements commonly available to preschool children, such as color markers ranging in diameter from 10 mm to 18 mm, may elicit lower level grips.

Even across a diameter range of 12.8 mm, accuracy scores did not significantly change. The most marked change was a decrease in overall scores from the 14.3-mm to the 17.5-mm diameter, but the overall effect was not significant. The grip and accuracy results together indicate that although larger diameter implements may often lead to lower level grips, accuracy changes very little, even on the precision drawing task used in this study. Hence,

teachers and therapists should not be concerned about possible grip changes that may occur as children choose larger writing implements. However, they may encourage children who demonstrate very poor graphomotor skills to use smaller diameter implements, which may elicit higher level grips.

Conclusions

The first issue addressed in this study was the usefulness of Schneck and Henderson's (1990) grip scale for occupational therapy and other professionals working with children on graphomotor skills. The results showed that all grips used by the 3- to 5-year-olds could be categorized according to Schneck and Henderson's system and that the relative usage of the five grip levels (Schneck, 1991) was very close to that reported by Schneck and Henderson. Therapists are recommended to use the 10-grip scale only for documenting the grips of individual persons and changes in their grips, but if comparisons between persons are desired, then Schneck's (1991) five-level scale, which affords greater generalizability, should be used.

The second and third issues addressed in this study were the effect of grip on drawing performance and the effect of implement diameter on grip level and drawing performance. These issues are important for occupational therapists because of the potential implications for helping children with graphomotor deficits. Amundson and Weil (1996) recommend five different approaches to handwriting intervention: neurodevelopmental, acquisitional, sensory integration, biomechanical, and behavioral. The strategies of manipulating grip level or implement size relate to the biomechanical approach or Tseng and Cermak's (1993) "ergonomic" approach.

The key question is whether changing grips can improve graphomotor performance. Our results indicate an equivocal "maybe." Although the lowest observed grip level (2) was used most often with the lowest accuracy scores (1–3), the grip levels were fairly evenly distributed at accuracy scores of 4 and 5. Only at the highest accuracy score (6) did the highest grip level (5) make a difference. Thus, children with graphomotor performance deficits are not likely to benefit from grip manipulations because such strategies were shown to improve only performance that was already good. Moreover, this conclusion also emphasizes the point that persons should not be referred to occupational therapists just because of an unusual or "immature" grip (Amundson, 1992; Sassoon et al., 1986; Tseng & Cermak, 1993; Ziviani, 1995).

A final point on the issue of grip intervention is that "any grip, efficient or inefficient, that has been used over time becomes kinesthetically locked in" (Benbow, 1995, p. 267) and that "by the beginning of the second grade, changing a child's grasp pattern may be so stressful that the effort should be abandoned" (Amundson & Weil, 1996, p. 537). If a child is using an oversized implement (i.e., 11.1-

cm diameter or larger), reducing the diameter—a “bypass strategy” within an ergonomic approach (Tseng & Cermak, 1993)—may help improve the grip form, but decreasing implement diameter from the standard 7.9 cm is likely to change grip form very little. ▲

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