Comparisons Among Tools, Surface Orientation, and Pencil Grasp for Children 23 Months of Age

Janet E. Yakimishyn, Joyce Magill-Evans

OBJECTIVE. The purpose of this study was to determine whether writing tool type and angle of writing surface affect grasp.

METHOD. Fifty-one children 23 to 24 months of age who were typically developing drew with a primary marker, colored pencil, and small piece of crayon on a table and an easel. The marker and pencil were presented pointing left, right, and toward the child. The order of writing tool presentation was counterbalanced. Grasps were scored with a 5-point rating system and analyzed with dependent t-tests.

RESULTS. Children used a more mature grasp when drawing with a piece of crayon than with a pencil. No difference in grasp maturity was found when using a pencil compared with a marker. A more mature grasp when drawing on the easel compared with the table was used with the crayon but not with the marker or pencil.

CONCLUSION. Results imply that a short writing tool combined with a vertical surface can influence the grasp of young children.


Pencil grasp development has been discussed extensively in theoretical and empirical occupational therapy literature. Studies have described the pencil grasp of children as young as 1 year of age through mature adulthood (Bergmann, 1990; Blöte & van der Heijden, 1988; Blöte & van Gool, 1989; Blöte & van Haasteren, 1989; Blöte, Zeilstra, & Zoetewey, 1987; Burton & Dancisak, 2000; Goodgold, 1983; Readick, 1994; Rosenbloom & Horton, 1971; Saida & Miyashita, 1979; Schneck & Henderson, 1990; Tseng, 1998). However, only a few studies (Burton & Dancisak, 2000; Readick, 1994) examined the effect of writing tool on grasp. Sources addressing interventions for preschoolers with fine motor difficulties suggest that the use of special writing tools, such as a small piece of chalk, and adapted writing environments, such as a vertical surface, influence the use of tripod pencil grasp (Benbow, Hanft, & Marsh, 1992; Myers, 1992). Empirical support for the effect of special writing tools and adapted environments on young children is lacking.

Grasp Development

Typical pencil grasp development may be understood in terms of dynamic systems theory. In light of this theory, pencil grasp development is dynamic, and the behavior (grasp used) has many component parts or subsystems that act together within the constraints of the environment and the task (Thelen, 1995). The grasp used reflects the interaction of components of the organism (musculoskeletal system, central nervous system) with components of the environment (available surfaces,
height of the chair) and the task (size of the paper, diameter of the writing tool) (Kamm, Thelen, & Jensen, 1990). As the components change (muscle coordination improves, a different tool is used), the stability of the system may be disrupted, and a different grasp (behavior change) may be used (Thelen, 1995). The most efficient grasp will be used for a particular task in a particular environment (Kamm et al., 1990). Thus, dynamic systems theory suggests that certain pencil grasps may be elicited by altering the task or the environment (Kamm et al., 1990; Mathiowetz & Haugen, 1994; Newell, 1986).

To apply dynamic systems theory to pencil grasp development, the typical progression of pencil grasp must be understood first. Several researchers (Readdick, 1994; Saida & Miyashita, 1979) have reported four general grasp patterns demonstrated by 2- to 6-year-olds, with one study including children as young as 18 months (Rosenbloom & Horton, 1971). Although the terminology varied, the four general grasp patterns were (a) a fist or supinate posture (also called palmar supinate), (b) a pronate grasp (also called digital pronate), (c) a tripod, and (d) a dynamic tripod. These studies did not include all possible grasps used during pencil grasp development. Schneck and Henderson (1990) described 10 specific grasp patterns within three grasp categories: 5 primitive grasps (radial cross palmar, palmar supinate, digital pronate, brush, grasp with extended fingers), 3 transitional grasps (cross thumb, static tripod, four finger), and 2 mature grasps (dynamic tripod, lateral tripod). Tseng (1998) added 3 interdigital grasps to the primitive grasp category and included the quadrupod grasp as another mature grasp for a total of 14 grasp patterns, thus providing a more detailed description of pencil grasp progression (see Table 1).

Knowledge of this progression allows researchers to identify the most efficient grasps used (attractor state) at various stages of development. Of most interest in the current study are the typical grasps of children 1 to 4 years of age. The Peabody Developmental Motor Scales (Folio & Fewell, 2000) places the digital pronate grasp between 15 and 16 months of age. The Erhardt Developmental Prehension Assessment (Erhardt, 1994) places the digital pronate grasp at 2 to 3 years of age and the static tripod grasp at 3 1/2 to 4 years of age. As well, in Schneck and Henderson’s (1990) and Tseng’s (1998) studies, almost half

### Table 1. Grasp Categories and Five-Point Scoring System

<table>
<thead>
<tr>
<th>Score</th>
<th>Grasp Categories</th>
<th>Definition</th>
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<tbody>
<tr>
<td>1</td>
<td>Radial cross palmar</td>
<td>Pencil across palm projecting radially, hand fisted, forearm in full pronation, full arm movement (Morrison, 1978, as cited in Schneck &amp; Henderson, 1990)</td>
</tr>
<tr>
<td>2</td>
<td>Palmar supinate</td>
<td>Pencil across palm projecting ulnarly, hand fisted, slight wrist flexion and supination, full arm movement (Erhardt, 1982)</td>
</tr>
<tr>
<td>2</td>
<td>Interdigital (variation 1)</td>
<td>Fingers flexed into palm, pencil across palm and projecting ulnarly from between the index and middle fingers, movement mostly in metacarpophalangeal and proximal interphalangeal joints of the fingers and at the wrist, forearm may be resting on table (Tseng, 1998)</td>
</tr>
<tr>
<td>2</td>
<td>Interdigital (variation 2)</td>
<td>Fingers flexed into palm, pencil across palm and projecting ulnarly from between middle and ring fingers (Tseng 1998)</td>
</tr>
<tr>
<td>2</td>
<td>Interdigital (variation 3)</td>
<td>Fingers flexed into palm, pencil across palm and projecting ulnarly from between ring and little fingers (Tseng, 1998)</td>
</tr>
<tr>
<td>2</td>
<td>Digital pronate, only index finger extended</td>
<td>Pencil in palmar grasp with index finger extended along pencil toward tip, arm not resting on the table, full arm movement</td>
</tr>
<tr>
<td>3</td>
<td>Brush</td>
<td>Pencil held in fingers with eraser end against palm, hand pronated with both wrist and whole arm movement, forearm not resting on table (Schneck &amp; Henderson, 1990)</td>
</tr>
<tr>
<td>3</td>
<td>Grasp with extended fingers</td>
<td>Pencil held in fingers, wrist straight with pronation and slight ulnar deviation, forearm moves as unit (Schneck &amp; Henderson, 1990)</td>
</tr>
<tr>
<td>4</td>
<td>Cross thumb</td>
<td>Fingers loosely flexed into palm, pencil held against index finger, with thumb crossed over pencil toward index finger; finger and wrist movement present; forearm rests on table (Gesell, 1940, as cited in Schneck &amp; Henderson, 1990)</td>
</tr>
<tr>
<td>4</td>
<td>Static tripod</td>
<td>Pencil stabilized against radial side of middle finger by thumb pulp, with index pulp on top of pencil shaft; thumb stabilized in full opposition; slight wrist extension and hand moves as unit; pencil rests in open thumb web space; forearm rests on table (Rosenbloom &amp; Horton, 1971, as cited in Schneck &amp; Henderson, 1990)</td>
</tr>
<tr>
<td>4</td>
<td>Four-finger</td>
<td>Pencil held with four fingers in opposition, wrist and finger movement, forearm rests on table (Schneck &amp; Henderson, 1990)</td>
</tr>
<tr>
<td>5</td>
<td>Lateral tripod</td>
<td>Pencil stabilized against radial side of middle finger, with index finger on top of pencil shaft; thumb adducted and braced over or under anywhere along lateral border of index finger; wrist slightly extended; ring and little fingers move with tripod and wrist on tall and horizontal strokes; forearm rests on table (Schneck, 1987, as cited in Schneck &amp; Henderson, 1990)</td>
</tr>
<tr>
<td>5</td>
<td>Dynamic tripod</td>
<td>Pencil stabilized against radial side of middle finger by thumb pulp, with index pulp on top of pencil shaft; thumb stabilized in full opposition; slight wrist extension; ring and little fingers flexed to stabilize metacarpal arch and middle finger; localized movement of tripod and wrist movements on tall and horizontal strokes; forearm rests on table (Rosenbloom &amp; Horton, 1971, as cited in Schneck &amp; Henderson, 1990)</td>
</tr>
<tr>
<td>5</td>
<td>Quadrupod</td>
<td>Identical to dynamic tripod grasp except pencil stabilized against radial side of ring finger by the thumb pulp, with index and middle finger pulps on the pencil shaft; thumb stabilized in full opposition; intrinsic muscle movements used in a coordinated manner; forearm rests on table (Tseng, 1998)</td>
</tr>
</tbody>
</table>
of the children 36 to 42 months of age had developed a static tripod pencil grasp compared with about 30% of children 30 to 35 months of age (Tseng, 1998). Both the assessments and these studies imply that 2 years is a reasonable age to expect a pronate grasp and that many children will use a tripod grasp by 4 years of age.

Organismic Environmental Influences

The point at which a child is ready to acquire a more mature pencil grasp partly depends on organismic constraints of the individual, such as age and gender (Blöte & Van Haasteren, 1989). As noted previously, the child’s age (indicator of the maturity of the organismic constraints) is a good predictor of how a child is likely to hold a pencil. Gender also may be a factor, as Saida and Miyashita (1979) found that grasp patterns were more advanced in 3-year-old girls than in 3-year-old boys.

In addition to individual characteristics, the writing environment to which the child is exposed may influence the maturity of a child’s grasp. Although the majority of the studies describing pencil grasp development used standard no. 2 pencils or colored pencils as the writing tool (Blöte & Van Haasteren, 1989; Saida & Miyashita, 1979; Schneck, 1991; Tseng, 1998), the results of some suggest that altering the writing tool may cause enough change in the task constraints to influence the maturity of a child’s grasp. For example, Burton and Dancisak (2000) found that 3- to 5-year-olds used more mature grasps as the diameter of the writing tool decreased. As well, Readdick (1994) found when assessing 20 children (2 years to 4 years 11 months of age) drawing with markers, pencils, and crayons that diameter influenced the grasp used only for standard pencils compared with wider primary pencils. She also found no difference between standard and primary markers or between standard and primary crayons. The standard pencil, which had the smallest diameter of all the writing tools, was not compared with width of either marker or crayon.

Other writing tools to facilitate mature grasp development were preschool crayons and small pieces of chalk (Myers, 1992). The preschool crayon has been reported to provide support for the child’s hand when held in an open web space posture and used on a vertical surface. The short length of the broken chalk requires the child to hold it with the tips of the thumb, index, and middle fingers, precluding a fisted, whole hand or five-finger grasp. Unfortunately, no empirical studies were found assessing grasp changes when preschool crayons or pieces of chalk were used. Overall, some support exists in the literature that thinner or shorter writing tools will facilitate the use of a more mature grasp (Burton & Dancisak, 2000; Myers, 1992). However, a comparison of a short versus a long writing tool with children who are not yet using a mature grasp consistently would expand current knowledge about how a writing tool can influence the grasp used.

Another task constraint that may facilitate the use of a mature pencil grasp is writing on a vertical surface. Myers (1992) suggested that vertical surfaces are important for appropriate hand and wrist position for fine motor and handwriting activities. When working on a vertical surface, the wrist is positioned in stable extension, which supports the thumb abduction and opposition required for a tripod grasp (Strickland, 1995). Benbow (1990) also indicated that wrist extension facilitated balanced use of the hand’s intrinsic muscles. The broken chalk, which facilitates a tripod grasp, and the vertical surface, which encourages wrist extension, combine to provide strong task constraints. Dynamic systems theory and the previous literature suggest that such task constraints would result in the reorganization of the system needed to produce a more mature grasp (Kamm et al., 1990).

A minor change in the orientation of the writing tool on the table also may affect the grasp used. Burton and Dancisak (2000) presented writing tools in four orientations (pointed left, right, toward, and away from the child) because some children did not adjust their grasp after picking up the writing tool. However, they did not indicate whether children used a more mature grasp with any particular orientation. This small task constraint may be a confounding variable and should be controlled for when studying grasp.

Environmental adaptations or task constraints to encourage a more mature grasp may be successful with children as young as 2 years of age. Two-year-old children have the postural stability in sitting needed for controlled hand use and are not already using a mature pencil grasp. Most children will use a primitive or pronate grasp, allowing manipulation of the task (writing tool, drawing surface angle) to prompt the use of a mature grasp. Close to 50% of 3-year-olds are already using a mature tripod grasp (Schneck & Henderson, 1990; Tseng, 1998). Thus, a sample of older children may not demonstrate as much change in response to the environmental adaptations.

The literature is incomplete in the area of early pencil grasp development. Studies involving younger children provided little information about the grasp used before age 2, although children use writing tools to mark paper as young as 10 months (Ames, as cited in Blöte & Van Haasteren, 1989). Myers (1992) suggested that early practice with pencils and markers may result in a poor pencil grasp partly because the child may be using writing tools before his or her hands are ready. If too much pencil work is done with
the immature grasp, pencil posture may become fixed at an intermediate level of skill. As such, more study is needed regarding how very young children approach writing tools. As well, very few studies have looked at young preschool child's pencil grasps with any tool other than a standard-sized pencil. The use of a vertical writing surface is suggested in the literature (Myers, 1992), but no studies have evaluated this practice. Therefore, in the current study, we examined how the drawing tool and the drawing surface affect the pencil grasp of young children. The literature suggests that children will use a more mature pencil grasp with a thinner writing tool. Changes in writing surface from horizontal to vertical may produce a more mature grasp. The study addressed the following hypotheses:

1. Children will use a more mature grasp when using a colored pencil compared with a thick marker (comparing two diameters).
2. Children will use a more mature grasp when using a short piece of crayon compared with a long colored pencil (comparing two lengths).
3. Children will use a more mature grasp when drawing on the vertical surface compared with the horizontal surface (comparing two surfaces).

### Method

#### Design

This descriptive study assessed children 23 to 24 months of age using a primary marker, colored pencil, and small piece of crayon to draw on both a table and a tabletop easel for a total of 14 writing tool presentations. The marker and pencil were presented pointing left, right, and toward the child to control for bias associated with the orientation of the tool when presented. The order in which the writing tools were presented was counterbalanced to control for any order effect. The children were videotaped and their grasps scored later. The grasps were assigned to one of 14 categories (see Table 1) and scored with a 5-point rating system.

#### Sample

Children for the current study were part of a convenience sample of a longitudinal study of development that followed 120 children 9 to 23 months of age who were typically developing. The parents were contacted, and those interested brought their child in for the current study. The 51 children (22 girls, 29 boys) had a mean age of 23 months 11 days (range = 0–29 days).

During the assessment, 25 children used their right hand to hold the writing tools, 3 used their left hand, and 23 used both hands. Children using both hands tended to use their right hand more (M = 9.3 of 14 presentations). All participants had typical development as determined using the Diagnostic Inventory for Screening Children Preschool Screen or DPS (Parker, Mainland, & Amdur, 1997). Most of the children's parents (90%) classified themselves as White, and the remaining 10% did not specify racial background. Most (81%) reported an annual family income of $40,000 ($26,000 American) or higher. The average education was 15.7 years for mothers (47% had a college or university degree, 16% had a graduate degree) and 16.0 years for fathers (47% had a college or university degree, 12% had a graduate degree).

#### Procedure

The first author or designee met the parents after their child had completed the DPS and explained the study before obtaining consent to participate. Parents were present with their child during the study. All children were tested individually in a quiet room. The three writing tools were a small piece of a regular-sized crayon (20.0 mm in length, 10.2 mm in diameter), a primary marker (110.0 mm in length, 16.9 mm in diameter), and a colored pencil (180.0 mm in length, 8.6 mm in diameter). The crayon was chosen instead of the piece of chalk suggested in the literature so that the same surface could be used for all tools. As well, the diameter of the crayon is closer to that of the colored pencil. The primary marker was chosen as a thick tool that is familiar to children. The colored pencil was chosen rather than the standard pencil commonly used in previous studies because a pilot study revealed that children this young were more interested in colored tools.

Letter-sized, office-weight white paper was taped down to both surfaces. The horizontal surface was a small table at a height of 380 mm. The vertical surface was a slanting tabletop easel placed on the table, the top edge reaching a height of 238 mm above the 380-mm tabletop at a 75° angle from horizontal. A tabletop easel was chosen to allow more control over the child's position. The child was sitting for both the table and the easel trials, keeping the testing environment as similar as possible. The chair was 188 mm in seat height and appeared appropriate for all the children. One video camera was to the left of the child and another to the right, both level with the table and zoomed to include the entire height of the easel.

Each child drew on each surface (vertical and horizontal) using each of the three writing tools (crayon piece, colored pencil, primary marker). To prevent bias due to orientation, the markers and the colored pencils were presented in three different ways with each surface: pointing left, pointing right, and pointing toward the child. Because the easel did not allow room on the table for a pencil or marker to be placed pointing toward the child, the tools were...
placed to the left or right of the easel, depending on handedness as indicated by the parents. If the parents were uncertain of handedness, the tools were placed to the right of the child. Because the crayon was so short, orientation was not a factor, and the crayon was presented only one way on each surface.

Presentation of the tools was counterbalanced to control for any order effect. The three orientations of the colored pencil and marker were not counterbalanced. The flat surface was presented before the vertical surface because a flat surface was more familiar to most children. Each child completed three trials each of the marker and colored pencil and one trial with the crayon on both the horizontal and the vertical surface for a total of 14 trials per child.

Measures. The measure used in the study combined the categories described by Schneck and Henderson (1990) and Tseng (1998) (see Table 1). Schneck and Henderson described 10 grasp categories, using previous research and a descriptive study of 320 children 3 years 0 months to 6 years 11 months of age. For this study, Schneck and Henderson’s categories were modified to include Tseng’s 4 other categories (3 interdigital grasps, 1 quadrupod grasp) for a total of 14 grasp types. Further modification was necessary to accommodate the vertical surface, which prevented some of the grasps from meeting all the rating criteria. Forearm position was removed from the scoring criteria. Thus, wrist position and prehension were the two most salient criteria when scoring the grasp used on the easel.

According to Schneck (1991), each of Schneck and Henderson’s (1990) grasp categories can be assigned a score from 1 to 5 (Table 1). In this study, the interdigital grasps were scored as 2, the same score as the palmar supinate and digital pronate grasps, on the basis of Tseng’s (1998) presentation of the grasps in developmental order. The quadrupod grasp was assigned a score of 5. Thus, all 14 grasps could be scored. However, none of the grasps scored as 5 were used by children in this study.

Limited historical information is available about the reliability of the measurement approach used here. In an unpublished pilot study, Schneck (as cited in Schneck & Henderson, 1990) found an intrarater reliability of .90 for the 10 grasp categories. The 5-point scale was added for Schneck’s 1991 study, though intrarater reliability was not reported. Burton and Dancisak (2000) reported 67% agreement for the 10 categories using the 5-point rating scale. They noted some finger positions that did not match Schneck and Henderson’s (1990) descriptions but were categorizable on the basis of general characteristics of the grasp. Tseng (1998) used the modified version of Schneck and Henderson’s categories and found an intrarater reliability kappa coefficient of .96. The 5-point rating system has not been used with the 14 grasps, so no reliability information was available for the actual measure used here. No test–retest reliability data are available.

The descriptions of the grasps used were consistent with other independent studies (Blöte et al., 1987; Blöte & van der Heijden, 1988; Blöte & van Gool, 1989; Blöte & van Haasteren, 1989; Goodgold, 1983; Readdick, 1994; Rosenbloom & Horton, 1971; Saida & Miyashita, 1979). Evidence for the content validity of Schneck and Henderson’s (1990) categories was found by Burton and Dancisak (2000), who were able to fit all 1,200 trials from 60 participants into 1 of the 10 categories.

Scoring. Each trial had only one grasp score. If the child changed grasps during the trial, the most mature grasp was scored (consistent with Saida & Miyashita, 1979). The mean for the three orientations (pointing left, right, toward the child) was used for the table–marker, table–pencil, easel–marker, and easel–pencil conditions because some children used a different grasp depending on the orientation. Using the mean of the three orientations generated 1 data point for each condition for each child. Each trial also had only one handedness score. If the child switched hands during the trial but used the same grasp, the hand scored was the one the child most frequently used during the assessment. The grasps and handedness scores were determined independently from the videotape by the first author.

Intrarater reliability between the first author and another trained occupational therapist was established, and then 25% of the grasps (all 14 trials of every 4th child) were independently double-coded from the videotapes. The percent agreement for the scores on the 5-point scale was 90.1%. To assess intrarater reliability, 51% of the grasps (all 14 trials of every 2nd child) were double-coded from the videotapes 2 months later by the first author, with a percent agreement of 95.1%.

Results
The mean grasps for each condition are given in Figure 1. The data were analyzed using repeated measures two-way analysis of variance (ANOVA). Parametric statistics were chosen to address Windsor’s (2000) critique of Burton and Dancisak’s (2000) study, which used a chi-square analysis. ANOVAs allow interaction effects to be identified and are more powerful analyses (Glass & Hopkins, 1996). Chi-square analysis ignores differences between groups (e.g., that a grasp score of 2 is greater than 1 but less than 3), whereas an ANOVA uses this information. The data in the current study were collapsed within participants, increasing the normality of the data points. Where possible, a non-
parametric test (e.g., Wilcoxon signed rank test, Friedman \(X^2\) test) also was used to confirm the results.

An ANOVA revealed a significant interaction effect between the writing tool and surface variables, \(F(1.385^1, 69.247) = 16.02, p < .001\). Therefore, the main effects were analyzed with dependent \(t\) tests. Given the increase in Type I error inherent in performing seven comparisons (pencil vs. marker over two surfaces, pencil vs. crayon over two surfaces, horizontal vs. vertical surface over three tools), the significance level was Bonferroni-adjusted from .05 to .007 (i.e., .05 divided by 7). No significant difference in grasp used between marker and pencil for either the table or the easel was found, so Hypothesis 1 was not supported. However, the comparison of pencil and crayon showed a significant difference in grasp used on the easel and the table, indicating support for Hypothesis 2. The marker was not compared with the crayon because the pencil was closer to the crayon in diameter. Furthermore, the literature suggests that thin tools elicit a more mature grasp than thick tools, so it was not necessary to compare the marker to the crayon. When comparing table and easel, a significant difference was found in the grasp used for the crayon, with more mature grasps used on the easel, but no significant difference was found for the pencil or the marker, yielding partial support for Hypothesis 3. The results of the dependent \(t\) tests are given in Table 2. A Wilcoxon signed rank test showed the findings to be identical. The same three comparisons were significant (each \(p < .002\)), whereas the other four were not (each \(p > .05\)).

The frequency of grasps used for 11 of the 14 categories observed was examined (see Table 3). The most commonly used grasps were the digital pronate grasp and the grasp with extended fingers. The three interdigital grasps were collapsed into 1 category because only one interdigital variation 3 was scored, and no interdigital variation 1 grasps were scored.

The effect of presenting the writing tools in three different orientations was not a research question for the study, but orientation appeared to have implications for the maturity of a child’s grasp. Therefore, the grasp used on the pencil or the marker on both surfaces also was categorized by the orientation of the tool when presented. A repeated measures ANOVA revealed that orientation had a significant effect, \(F(2, 100) = 8.04, p = .001\). Post hoc testing (least significant difference method, Bonferroni adjusted) indicated that the mean grasp score when the tool was presented pointing toward the child (\(M = 2.74, SD = 0.58\)) was greater than when the tool was pointing to the left (\(M = 2.49, SD = 0.57\)) or to the right (\(M = 2.58, SD = 0.58\)) of the child. Thus, tool orientation had an effect on the maturity of the grasp used. A nonparametric test corroborated these results, Friedman \(X^2(2) = 12.98, p = .002\).

Secondary analyses also were done to assess gender and order effects. Using an ANOVA, we found a significant gender effect, \(F(1, 49) = 4.98, p = .03\), with girls scoring higher than boys (\(M = 2.97\) and 2.70, respectively; \(ES = .61\)). No significant two-way interactions were found between gender and surface or gender and writing, and no three-way interaction was found among gender, surface, and writing tool (each \(p > .05\)). The counterbalancing of the marker, the colored pencil, and the piece of crayon had no significant effect on mean grasp used among the six possible orders of presentation on either surface, \(F(5, 45) = 0.99, p > .25\).

**Discussion**

Dynamic systems theory suggests that the behavior change (maturity of grasp) observed when a piece of crayon is used on a vertical surface may be a result of the task constraints it places on the musculoskeletal subsystem. The short piece of crayon requires the child to prehend the crayon with the tips of the thumb, index, and middle fingers, precluding a fisted, whole hand or five-finger grasp. The vertical surface requires wrist extension, and the combined result is a more mature grasp. Perhaps this behavior pattern is preferred because it requires the least amount of energy and is most efficient given the task constraints (Kamm et al., 1990).

Empirical evidence from the current study suggests that children will use a more mature grasp when drawing on a vertical surface compared with a horizontal surface but only when using the crayon. No significant difference in grasp use between table and easel was found with either the mark-

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1The degrees of freedom are not reported as integers because sphericity was not present in the data, and as such, the Greenhouse-Geisser adjustment was made to the degrees of freedom. This adjustment had no effect on the significance.
er or the pencil. Accordingly, the results of the current study support Myers’s (1992) suggestion that the use of a small piece of chalk on a vertical surface would facilitate a more mature grasp (a tripod grasp) in children not yet using a tripod grasp.

Myers (1992) also suggested that using a primary marker on a vertical surface may help encourage preschoolers to use a tripod grasp when the child is prompted to place the tips of the fingers on the strip at the base of the marker. The use of this prompt was not assessed in the current study, though results suggest that children will not use a tripod grasp on a marker when drawing on a vertical surface without a prompt for finger placement. Thus, at 2 years of age, a tripod grasp is not automatically used on a vertical surface without manipulating the tool or the instructions.

Dynamic systems theory does not specifically predict that the organismic subsystems of 2-year-old children are unstable enough to move to the attractor state (a mature grasp). However, the task constraints of the crayon paired with the vertical surface appear powerful enough to cause some children to use a more mature grasp, supporting the dynamic systems theory suggestion that if a more mature grasp was used for this task in this environment it was because it was most efficient (Kamm et al., 1990). Other task constraints (the crayon paired with the flat surface, the pencil and marker paired with the easel) were not strong enough to consistently produce a significantly more mature grasp.

The lack of difference in grasp between pencil and marker was inconsistent with Burton and Dancisak’s (2000) study where more mature grasps were used with thinner rather than thicker writing tools by 3- to 5-year-olds. The results of the current study are more consistent with Readick (1994). The 2- to 5-year-old children in her study used the same grasp regardless of the size of writing tool, except for a significantly more mature grasp for thinner standard pencils compared with thicker primary pencils. The difference between current and previous results could be due to methodological differences, such as differences in age and the type of writing tools, among the three studies.

The results of the secondary analysis also suggest that pencil grasp in 2-year-olds can be influenced by the presentation of the writing tool to the child. The children who held the tool differently depending on the orientation tended to use the grasp that was consistent with the orientation of the tool to their hand without adjusting their grasp on the tool. They would then turn their wrist to place the tip on the paper, resulting in either wrist supination or pronation when the tool was oriented to the left or right. Having the tip pointed toward the child facilitated a neutral or more extended wrist position and the tool being held with the fingers rather than in the palm, thus facilitating a more mature grasp.

The gender effects in this study are generally consistent with previous research. For example, Saida and Miyashita (1979) found that 3-year-old girls are significantly more advanced in finger posture than 3-year-old boys. Schneck and Henderson (1990) found in children 3 years 0 months to 4 years 6 months of age that boys used more primitive grasps than girls. Burton and Dancisak (2000) also found that overall grasp maturity was higher for girls than for boys. The lack of gender interaction indicates that no com-

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Comparison</th>
<th>t(50)</th>
<th>p</th>
<th>Effect Sizea</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Marker to pencil</td>
<td>Table–marker to table–pencil</td>
<td>0.67</td>
<td>&gt; .25</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>Easel–marker to easel–pencil</td>
<td>1.72</td>
<td>.09</td>
<td>0.18</td>
</tr>
<tr>
<td>2. Pencil to crayon</td>
<td>Table–pencil to table–crayon</td>
<td>3.54</td>
<td>.001</td>
<td>0.57</td>
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<tr>
<td></td>
<td>Easel–pencil to easel–crayon</td>
<td>9.21</td>
<td>&lt; .001</td>
<td>1.48</td>
</tr>
<tr>
<td>3. Table to easel</td>
<td>Table–marker to easel–marker</td>
<td>-1.45</td>
<td>.15</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>Table–pencil to easel–pencil</td>
<td>-0.30</td>
<td>&gt; .50</td>
<td>0.03</td>
</tr>
<tr>
<td></td>
<td>Table–crayon to easel–crayon</td>
<td>-4.76</td>
<td>&lt; .001</td>
<td>0.94</td>
</tr>
</tbody>
</table>

a Effect size was calculated by dividing the difference of the means by the pooled standard deviation.

<table>
<thead>
<tr>
<th>Grasp Category</th>
<th>Percent Use Over Study</th>
<th>Percent Use on Table</th>
<th>Percent Use on Easel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radial cross palmar</td>
<td>2.0</td>
<td>2.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Interdigital grasps</td>
<td>3.5</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Palmar supinate</td>
<td>7.8</td>
<td>7.8</td>
<td>7.8</td>
</tr>
<tr>
<td>Digital pronate</td>
<td>31.8</td>
<td>31.4</td>
<td>32.2</td>
</tr>
<tr>
<td>Brush</td>
<td>5.3</td>
<td>9.5</td>
<td>1.1</td>
</tr>
<tr>
<td>Grasp with extended fingers</td>
<td>33.1</td>
<td>34.7</td>
<td>31.4</td>
</tr>
<tr>
<td>Four-finger</td>
<td>6.0</td>
<td>3.6</td>
<td>8.4</td>
</tr>
<tr>
<td>Cross thumb</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Static tripod</td>
<td>9.1</td>
<td>5.3</td>
<td>12.9</td>
</tr>
</tbody>
</table>
bination of tool and surface used in this study works better in facilitating a more mature grasp for one gender over the other.

The results of the study provide a picture of patterns of grasp use in individual children at 2 years of age. For example, none of the children used the same grasp for all 14 trials. Children this age were very variable in the grasps they use, which may be partly due to the influence of the orientation on some children (e.g., a digital pronate grasp was seen more often when the tool pointed left for right-handed children than for the other two orientations). Only 4 children used the same grasp pattern for all of the pencil and marker trials, and they changed grasps with the presentation of the crayon. Thus, very few of these 2-year-olds would seem to have a preferred grasp pattern.

Implications for Occupational Therapy Practice

This study provides empirical evidence for the use of short tools with vertical surfaces to encourage mature grasp use, supporting an intervention already in practice (Myers, 1992). However, it is not clear that the exclusive use of these task constraints will develop a more mature grasp across writing tools earlier than if children use a variety of tools and surfaces. The study also suggests that a primary marker on a vertical surface will not encourage preschoolers to use a tripod grasp. Thus, when attempting to facilitate a tripod grasp, the child’s hand position needs to be monitored and prompted. Pairing a vertical surface with a marker or colored pencil is not sufficient to influence grasp use in children at 2 years of age.

The study confirms the use of the digital pronate grasp as a common pencil grasp in 2-year-olds. It also indicates that grasp with extended fingers is common, though this grasp is not addressed in a frequently used preschool fine motor assessment (Folio & Fewell, 2000). This study also illustrates how variable grasp use is in children of this age, as it is influenced by tool length, surface angle, and tool presentation. Thus, developers of standardized tests should specify clearly the writing tool and surface to be used during any grasp assessment.

Limitations and Directions for Future Research

There are a number of limitations in this study that point toward future research. For example, application of the results requires caution because of the use of a young, typically developing sample. Usually, a vertical surface and a short writing tool are used to facilitate a mature grasp in older children who are not using a tripod grasp (Myers, 1992). Thus, to improve the application of current results to this older clinical population, a follow-up study with a more varied sample, including children with disabilities and older children who are not consistently using a tripod grasp, is necessary. Additionally, the writing tools available to young children are quite varied, and the current study only assessed three. A study design that includes various widths versus various lengths, including the preschool crayon recommended in the literature (Myers, 1992), would provide further evidence for the most appropriate writing tool for young children.

Another question that emerges is that of the angle of the vertical surface. The current study used only a horizontal surface and a vertical surface slanted at a 75° angle from horizontal. A study looking at different angles of surfaces, including a completely vertical surface, could determine the optimal surface angle. Furthermore, a standing easel is a more common vertical surface and should be studied to determine how it compares with the tabletop easel used in this study.

This study does not address the long-term effects of using a short piece of crayon and a vertical surface on pencil grasp. A longitudinal study would determine whether these task constraints will facilitate earlier acquisition of a mature grasp and prevent the development of an awkward grasp in children who are delayed in grasp development.

Finally, results from the secondary analysis of tool orientation are important for users and developers of assessments that include pencil grasp. Therapists should be aware that some children will show a more mature grasp if the tool tip is pointed toward them. Developers of standardized tests should include orientation as part of the administration instructions for grasp assessment. However, because tool orientation was not the focus of this study, a study assessing grasp use in response to tool orientation in young children is necessary.

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