Perceptual-Motor Coupling in the Development of Grasp

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Key Words: gross and fine motor skills • object manipulation evaluation • touch and tactile sensation

Objective. The purpose of this study was to investigate the effect of haptic attributes of objects on infants' grasping patterns and evaluate whether this effect is influenced by the infant's age (i.e., phase of motor development).

Method. Grasping patterns of 180 infants who were typically developing were measured by the Posture and Fine Motor Assessment of Infants (PFMAI); the PFMAI-I was administered to infants 2 months to 6 months of age (n = 60), and the PFMAI-II was administered to infants 6 months to 12 months of age (n = 120). Grasping patterns were compared for ages by month and for three objects, each with differing haptic features. The interaction between age and object was analyzed.

Results. Grasping patterns were significantly different when scores by age in months were compared. In addition, grasping patterns differed depending on the object and its haptic features and were influenced by the interaction between object held and age. Certain haptic features were associated with primitive grasp at younger ages and precision grasp at older ages. More mature skills were observed when the objects' haptic features appeared to match an infant's perceptual-motor skill.

Conclusion. The haptic features of objects influence an infant's grasping patterns, and this influence changes with the infant's age. These results suggest that therapists attempt to match the haptic features of objects to the infant's perceptual-motor skill in intervention in order to enhance grasping patterns.

Theories on how motor skills develop in infancy have expanded in recent years, influencing the ways that occupational therapists conceptualize and apply motor interventions in practice with young children. Original studies of motor development focused on describing the sequence of skills development. Gesell (1939, 1945), McGraw (1943), and their colleagues based their studies on the premise that neuromaturation drives the unfolding of motor skills. They devoted their research to documenting the sequence of motor milestones that define normal development, believing that each step was predetermined by the infant's neuromotor capability. The consistency of motor milestone achievement across infants with no disabilities was emphasized, and variation in skill performance was perceived as a possible indication of abnormality.

Today, the acquisition of movement patterns for effective interaction with the environment is seen as much more complex. The focus of research has shifted from an emphasis on neuromaturation to an emphasis on factors within the environment and the individual (e.g., Case-
Smith, 1996; Darrah & Bartlett, 1995; Heriza, 1991; Thelen, 1995). Movement patterns are believed to result from interaction between the environment as a source of sensory processing experience and the infant's neurodevelopmental abilities. In addition to examining the influence of the environment on motor performance and development, current research is focusing on the unique patterns demonstrated by individual infants rather than documenting the regularity and uniformity of motor development. The interest is on how the infant learns to move rather than what skills are learned at certain ages.

Phases of Infant Motor Learning

The sequence of motor milestone development, as documented 50 years ago by Gesell (1945) and McGraw (1943), continues to accurately reflect the steps in motor skill achievement. However, the research of Thelen (1987, 1995) and colleagues (Kelso, 1984; Thelen & Fogel, 1989; Thelen, Kelso, & Fogel, 1987) demonstrated that the methods used to learn new motor skills are quite variable and unique to individual infants. Hence, although most infants become mobile between 7 months and 9 months of age, their first pattern of mobility is varied and can include crawling, creeping, or scooting. This variability was also observed in the movement patterns of reaching in a study of four infants 3 months to 5 months of age (Thelen et al., 1993). Each infant achieved accurate reaching with a unique style (e.g., a slow cautious approach vs. a rapid, ballistic approach). All the infants seemed to proceed by first exploring a variety of motor patterns and then selecting one that seemed most efficient (e.g., a direct reach-and-grasp pattern).

Bernstein (1967) and Thelen (1987, 1995) suggested that an infant uses a self-organization process to learn new motor skills. Initially, movements are either primitive or disorganized. During transition phases, movements appear particularly unstable, and motor patterns are highly variable. Specifically, more primitive movements are observed when the environmental demands exceed skill levels (e.g., the infant is posturally unstable, the object is difficult to manipulate), and more mature (advanced) motor skills are demonstrated when environmental and task requirements match the infant's abilities (Gilfoyle, Grady, & Moore, 1990). Variable and inconsistent movement patterns characteristic of transition phases allow infants to expand their repertoire of motor strategies and to experience a variety of sensations. Processing of a wide variety of sensations motivates the infant to further exploration and helps to develop the infant's perceptual abilities (Gibson, 1979; McCall, 1974). After this transition phase, the skill acquisition phase is signified by flexible stability and consistency in movement patterns across a variety of environmental conditions.

A Perceptual-Motor Link

Perception of movement and touch combined with visual perception are known correlates of hand skills (Palmer, 1989; Ruff, 1984, 1989; Stilwell & Cermak, 1995). Certain fine motor skills (e.g., reach, object carry) seem linked to vision and proprioception, whereas others (e.g., grasp, manipulation) seem linked to tactile and proprioceptive (i.e., haptic) perception.

Gibson (1979) defined the importance of affordances in influencing hand skill development. An affordance is the reciprocal "fit" between the child's action and the environment's sensory input. In the essential and reciprocal relationship of movement and sensation, maturing perception influences motor development, and, reciprocally, maturing patterns of movement enable the child's perceptual systems to develop. For example, the infant learns to discriminate size earlier than other perceptual attributes because size can be recognized both visually and through simple grasp of the object (Bushnell & Boudreau, 1993). Discrimination of texture requires isolated finger movements: The infant slides his or her fingers over the surface in separate movements to discern the tactile surface. Thus, texture discrimination does not begin until about 6 months of age when the two sides of the hand begin to function separately. Discrimination of shape develops later, between 9 months and 12 months of age, as the child learns to turn and rotate an object in two hands (Ruff, 1989).

Although motor skill influences perceptual development, haptic development (i.e., increased recognition and discrimination of size, weight, contour, shape, consistency, texture) facilitates the development of independent finger movements and the development of two-hand, and later, in-hand manipulation. The haptic information that the infant gains from tactile and kinesthetic exploration of objects influences the grasping patterns that emerge and contributes to the infant's motivation to handle and explore objects (McCall, 1974). The desire to participate in sensorimotor experiences and to process haptic information motivates the infant to use a variety of motor patterns. The resulting increase in motor skill allows the infant to gain perceptual knowledge and to discriminate perceptual attributes within the environment at increasingly higher levels (Bushnell & Boudreau, 1993).

The premise that the hand's movement is linked to haptic perception of the object grasped and manipulated suggests that infants would demonstrate different movement patterns when grasping objects that differ in haptic features (e.g., shape, size, texture). Kimmette, Mick, and Michel (1995) found that 7-month-old to 13-month-old infants use different movement patterns on objects with varying perceptual characteristics. These infants discriminated the toys' physical characteristics and matched
their manipulation patterns to the toys' haptic features. Palmer (1989) demonstrated that from 6 months to 12 months of age, infants develop an increasing repertoire of skills to explore the haptic qualities of objects. Her studies showed that infants act differentially across objects. Infants size, texture, weight, and rigidity. Ruff (1989) found that their manipulation patterns to the toys' haptic features.

Variance in the grasping patterns used with different objects is likely to occur when the patterns are in transition (Thelen, 1995). Theories on perceptual-motor coupling suggest that the variation might be expressed by the infant using different motor patterns when stimulus objects have differing haptic features (e.g., shape, size) (Ruff, 1984). It is expected that when grasping skills are at a primitive level, for example, a palmar grasp in which the fingers move as a unit, this grasp would be observed on any object. More refined grasping patterns, for example, radial digital and pincer grasps, are first observed with objects that afford more precise patterns, such as toys with moveable or easily grasped parts. During this transition phase of skill emergence, the infant demonstrates inconsistency and variability in the patterns used with different objects. After the skill is achieved (e.g., fingertip or pincer grasp), a flexibly stable or consistent movement pattern that adapts to the object's affordances is observed. These concepts about the development of motor skill are largely based on clinical experience with young infants and on incidental findings in studies that were focused on cognitive development (Lockman & McHale, 1989). Research of how infants develop movement patterns and skill is needed to validate these concepts on perceptual-motor learning.

To validate current theory about how fine motor skills develop, the following research questions were investigated in our study:

1. Are grasping skills in transition between 3 months to 12 months of age?
2. As evidence of a basic perceptual-motor coupling in the development of grasping patterns, do infants demonstrate different grasping patterns when handling objects with different haptic attributes?
3. If grasping patterns are influenced by the infant's age and the object held, are the infant's grasping patterns affected by the interaction between age and object? In other words, is the effect of the object's haptic attributes on grasping patterns influenced by the infant's age?

**Method**

**Sample**

The sample consisted of 180 healthy, full-term infants who were typically developing. The 60 infants 2 months to 6 months of age and the 120 infants 6 months to 12 months of age were recruited from child-care centers in central Ohio (see Table 1). Informed consent and basic information about health and development were obtained from the infants' parents.

**Instrument**

The research questions were investigated with the Posture and Fine Motor Assessment of Infants (PFMAI-I and II) (Case-Smith, 1992; Case-Smith & Bigsby, 1993, 1996). These scales measure the quality of posture and fine motor skills in infants who are 2 months to 12 months of age. Components of movement are rated on a five-point ordinal scale, using noninvasive observation.

Test-retest and interrater reliability were evaluated for each item on the PFMAI in a larger study (Case-Smith & Bigsby, 1996). On the basis of intraclass correlations and measurement of the grasping patterns 4 days to 7 days after an initial evaluation, test-retest reliability was shown to range from .40 to .51 for the grasping items on PFMAI-I and from .44 to .61 for the grasping items on PFMAI-II. The interrater reliability coefficients from pairs of raters who observed infant responses together and scored the PFMAI items separately range from .81 to .97 for the items used in this study. The scales are highly related to age (r = .65–.74 for subscales) (Case-Smith & Bigsby, 1996).

<table>
<thead>
<tr>
<th>Table 1 Sample Demographics</th>
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<td>Female</td>
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<tr>
<td>Ethnicity</td>
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<tr>
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<tr>
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<td>Asian</td>
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<td>12</td>
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</table>

*Note. PFMAI = Posture and Fine Motor Assessment of Infants. n = 60 for PFMAI-I sample; n = 120 for PFMAI-II sample.*

*Six-month-old infants who were sitting independently were evaluated with the PFMAI-II, those who were not, with the PFMAI-I.*
In this study, the PFMAI-I scale was administered to infants 2 months to 6 months of age who were not yet independent in sitting. The PFMAI-II scale was administered to infants 6 months to 12 months of age who were independent in sitting for at least several seconds. Only the Fine Motor scale items were analyzed. The infants were seated in an infant seat (PFMAI-I) or in a high chair (PFMAI-II) for administration of the Fine Motor scales. Objects were presented one at a time, and reach or approach, grasping patterns, and manipulation of each object were scored after 2 min to 3 min of observation with each toy.

Three items on each Fine Motor Scale measure grasping patterns and the movements of fingers and thumb during object manipulation. Individual subscale scores were summed for each item, allowing for comparison of grasping patterns by object. The entire range of grasping patterns were rated: primitive squeeze, palmar grasp, radial palmar grasp, inferior pincer grasp, and superior pincer grasp. On the basis of an interval scale of 0 (most primitive grasping patterns) to 4 (highest level of grasping patterns), each item measures specific finger and thumb movements in grasp of three different objects. The objects used to elicit grasping patterns in PFMAI-I are a cube (a medium-sized, single-unit object with edges), a moveable parts toy (a medium-sized object with rounded surfaces) and red rings with rounded moveable parts). PFMAI-II measures grasping patterns with several cubes (medium-sized, single-unit objects that can be combined), a moveable parts toy with rounded surfaces, and a pellet (tiny, single-unit object with rounded surfaces). Therefore, the objects vary in contour (rounded surfaces vs. edges), size (1/2 in. to 1 in.), and mobility of parts. The objects are similar in weight, hardness, and texture (firm and smooth surfaces). Only the haptic features of the objects were considered in this research. Other perceptual features not considered were visual—all the objects were the same colors (red, blue, or both)—and auditory—the moveable parts toy and red rings each produced a muffled rattle (see Figure 1 and Appendix).

All infants were tested in child-care centers after obtaining informed consent from their parents. Six occupational therapists were trained in test administration and scoring before data collection. The training consisted of instruction in item administration, followed by scoring of two videotaped infants and three live infants to check reliability with the first author. Agreement was 85% or higher.

Data from the tests were entered into a database. Using total scores for the three items on the PFMAI-I and for the three items on the PFMAI-II that measured grasping patterns with each object, means were computed by age group. Means were also calculated for grasping patterns by object. Scores for the PFMAI-I were compared using a 3 X 4 two-way analysis of variance (ANOVA) with repeated measures, and scores for the PFMAI-II were compared using a 3 X 6 two-way ANOVA with repeated measures. Age and object were the independent variables.

Results
The ANOVA determined that grasping patterns were significantly different according to the infant’s age in months (see Table 2). Scores were significantly different for the grasping patterns on each part of PFMAI-I, F(3, 56) = 19.45, p < .0005, and PFMAI-II, F(5, 114) = 41.07, p < .0005.

To determine whether the grasping patterns varied with respect to the object handled, scores for each object were compared (see Table 3). The ANOVA results revealed significant differences on the basis of the object grasped for PFMAI-I, F(2, 112) = 13.6, p < .0005, and PFMAI-II, F(2, 228) = 32.67, p < .0005.

The two-way ANOVA was also used to examine the influence of the interaction between the object held and the infant’s age on grasping patterns used. The interaction between the object and age had a significant effect on PFMAI-II grasping scores, F(10, 228) = 4.62, p < .0005, and approached significance on the PFMAI-I grasping scores, F(6, 112) = 1.96, p = .078 (see Figures 2 and 3, Tables 4 and 5).

Discussion
The results indicate that the grasping patterns vary by age and by the object grasped. Furthermore, grasping patterns may be influenced by the interaction between the object grasped and the infant’s age.

Effect of Age on Grasping Patterns
In the first analysis, we determined that the grasping pat-
tern scores for both parts of the PFMAI changed over the 9-month period measured by the scales. This finding indicates that the PFMAI is sensitive to age-related improvements in grasping patterns. Examination of mean scores by month reveals two specific phases of skill transition or periods of rapid skill development. PFMAI-I scores suggest that grasping patterns transition between 3 months and 5 months of age (see Table 4, Figure 2), proceeding from a palmar to radial digital grasping pattern. PFMAI-II scores suggest that grasping patterns transition between 6 months and 9 months of age (see Table 5, Figure 3), proceeding from a radial digital to pincer grasping pattern. The transition periods are characterized by variable patterns, followed by stable patterns observed at 5 months to 6 months and 10 months to 12 months of age. They may reflect development shifts that are well documented at 4 months and 8 months of age (McCall, 1974; McGraw, 1943).

Effect of the Object on Grasping Patterns

The purpose of rating movement patterns with three different objects was to elicit a range of grasping behaviors; thus obtaining qualitative information about how fine motor skills develop. The analysis confirmed that scores for grasping patterns, finger movements, and thumb movements varied according to the object held. In general, the young infants evaluated by the PFMAI-I used more mature grasping skills to explore the medium-sized toys with moveable parts and dynamic surfaces (red rings and moveable parts toy) than they did with the cube (single-unit object with edges). The older infants evaluated by the PFMAI-II exhibited more mature grasping patterns with the moveable parts toy and cubes than with the pellet (tiny object with rounded surfaces). This finding that the infants' actions varied according to the haptic attributes of the object was similar to the findings of Palmer (1989), who examined differences in action on 12 objects of varying size, rigidity, texture, shape, and weight. She found that infants "act distinctly on objects" (p. 889) according to the objects' haptic features. Ruff (1984) examined differences in the duration and frequency of fingering on the basis of the visual and haptic qualities (i.e., color, weight, texture, shape) of the object held. She found that the infant's fingering strategies varied according to the haptic features. For example, a change in the object's texture resulted in increased individual finger movements; a change in shape was associated with increased rotating and transferring.

Effect of the Interaction Between the Object's Perceptual Qualities and Age

The influence of the object on the infant's grasping patterns varies at different ages in the first year of life. Which patterns the infant uses to grasp different objects can be an indication of his or her motor learning phase. Initially, when the infant has only basic or primitive grasping skills, the same movement patterns are demonstrated with all objects across all situations, that is, young infants (2 months old) tend to use a palmar grasp with all objects (Gilfoyle et al., 1990). However, the PFMAI-I was not able to capture such an initial pattern. Our youngest subjects ($M = 3$ months of age) used differential grasping patterns according to the object held. This evidence that the infant is exploring new motor patterns suggests that more mature patterns are emerging. During this transition phase, the infant may demonstrate a skill with certain objects (certain haptic features) and not others. The infant may demonstrate more primitive grasping patterns when there is a mismatch between the object prehended and grasping skill. Grasping patterns may be highly influenced by the haptic qualities of the object during this phase, given the explorative nature of play at this time. After this transition phase of inconsistent performance, if the infant successfully attains a higher skill, he or she may begin to demonstrate more consistent grasping patterns across situations and objects. This sequence of skill development (motor

### Table 2
Mean Scores of Grasping Items on the PFMAI by Age

<table>
<thead>
<tr>
<th>Age (Months)</th>
<th>n</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFMAI-I</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>3.95</td>
<td>1.7</td>
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<tr>
<td>4</td>
<td>13</td>
<td>5.44</td>
<td>2.7</td>
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<tr>
<td>5</td>
<td>10</td>
<td>9.00</td>
<td>1.5</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>9.34</td>
<td>1.7</td>
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<tr>
<td>PFMAI-II</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>6–7</td>
<td>16</td>
<td>5.64</td>
<td>2.0</td>
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<tr>
<td>8</td>
<td>20</td>
<td>6.35</td>
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<td>9</td>
<td>12</td>
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<td>10</td>
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<td>11</td>
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<tr>
<td>12</td>
<td>25</td>
<td>10.70</td>
<td>1.3</td>
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</table>

Note. PFMAI = Posture and Fine Motor Assessment of Infants. $n = 60$ for PFMAI-I sample; $n = 120$ for PFMAI-II sample.

### Table 3
Mean Scores for Grasping Items on the PFMAI by Object

<table>
<thead>
<tr>
<th>Object</th>
<th>M</th>
<th>SD</th>
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</thead>
<tbody>
<tr>
<td>PFMAI-I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cube</td>
<td>6.43</td>
<td>3.6</td>
</tr>
<tr>
<td>Red rings</td>
<td>7.32</td>
<td>3.3</td>
</tr>
<tr>
<td>Moveable parts by toy</td>
<td>7.15</td>
<td>3.2</td>
</tr>
<tr>
<td>PFMAI-II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moveable parts toy</td>
<td>8.93</td>
<td>2.3</td>
</tr>
<tr>
<td>Cubes</td>
<td>8.98</td>
<td>2.3</td>
</tr>
<tr>
<td>Pellet</td>
<td>7.84</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Note. PFMAI = Posture and Fine Motor Assessment of Infants. $n = 60$ for PFMAI-I sample; $n = 120$ for PFMAI-II sample.
learning) is similar to that proposed by Thelen and colleagues for attainment of motor skills in increasingly more challenging contexts (Thelen, 1995; Thelen et al., 1993; Thelen & Fogel, 1989).

As an example of these motor learning phases, the results of the PFMAI-II indicate that the infants (6–8 months of age) first use a primitive squeeze or raking pattern on the pellet and more mature radial digital grasps on the cube and the moveable parts toy. As the infants approached 12 months of age, they exhibited more precise and more mature grasping patterns with the pellet than the other objects. Because tiny objects can produce either primitive or precise movement patterns according to the infant’s age, motor skills, and haptic discrimination, therapists should select and use tiny objects in activities only when the infant’s emerging skills appear appropriately matched to the challenge.

Implications for Practice

Evaluation

These results of the study suggest that grasping patterns vary according to the object’s haptic attributes. Evaluation using only one object or objects with similar haptic features will probably not elicit the full range of skills in the infant’s repertoire. One goal of the evaluation process is to determine what skills are in transition and what patterns are emerging. When selecting objects to assess grasping patterns, toys with a range of haptic qualities (e.g., size, shape, contour, with and without moveable parts) should be sought. Variation in the grasping patterns may indicate that the infant is learning new grasping skills or is in transition and using more mature grasping patterns. Observation of the infant’s actions on objects also provides information about the infant’s haptic development. What types of exploratory movements are made? How long is the toy held with sustained interest? Are the surfaces explored with the palm, fingers, and thumb, or is the object repeatedly transferred between hands? The infant’s interest in and exploration of toys can inform the therapist about the infant’s perceptual development and play level as well as his or her motor function.

In the past, therapists have often viewed inconsistency in performance as a negative indication that performance was unreliable or unstable (Bobath, 1980). Our results support the normalcy of variation in performance during early development of grasping skills. They further demonstrate that the development of grasping patterns is dynamic rather than linear and appears to be coupled with haptic development. For example, a tiny round object that elicited the most primitive grasping patterns in the 6-month-old infants elicited mature and precise motor patterns in the 12-month-old infants.
Intervention

The results of this study suggest that careful attention be given to the toys and materials selected for intervention activities with young infants. The haptic features of the toys themselves seem to influence how the infant grasps, manipulates, and sustains attention. Toys that require precision grasp produce a more primitive grasp if the infant does not yet have the motor capability for precision grasp or the perceptual discrimination of tiny objects. Toys with moveable parts seem to elicit more mature grasping patterns and more independent movements of fingers and thumbs than single-unit toys at a younger developmental age. Toys with moveable parts also seem to allow the expression of a variety of grasping patterns across all age groups from 3 months to 12 months. As documented by Kimmerle et al. (1995), Palmer (1989), and Ruff (1984, 1989), toys with multidimensional surfaces and moveable parts facilitate haptic development and motor skill by affording the infant a variety of surfaces to explore and by sustaining the infant's interest. Because of their apparent perceptual appeal and possibility for motoric exploration, such toys seem to be ideal for promoting perceptual-motor skill.

Facilitation of a variety of movement patterns in intervention may foster attainment of flexible skill across objects and situations. Variation in motor patterns may enable the infant to fully explore the perceptual attributes of the environment and lead to growth of perceptual-motor function (Exner, 1995; Pehoski, 1995).

Limitations

This analysis used mean scores to investigate variability in performance among groups of infants. However, variation in mean scores does not necessarily equate to variation in individual infants. Statistics that compare groups can only suggest variability in individuals. Research designed to understand the uniqueness of each infant's perceptual-motor development would require longitudinal analysis of individual movement patterns. Our study's design does

Table 4
Mean Scores for Grasping Items on the PFMAI-I by Object and Age

<table>
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<tr>
<th>Object</th>
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<th>4</th>
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<tbody>
<tr>
<td>Cube</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
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<tr>
<td></td>
<td>3.31</td>
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<td>4.24</td>
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<td>Moveable parts</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>toy</td>
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<td>3.34</td>
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Note. n = 60. PFMAI = Posture and Fine Motor Assessment of Infants.
Table 5
Mean Scores for Grasping Items on the PFMAI-II by Object and Age

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<td>Cubes</td>
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<td>1.6</td>
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<td>2.1</td>
<td>9.4</td>
<td>1.7</td>
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<td>Pellet</td>
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<td>2.1</td>
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<td>1.8</td>
<td>8.5</td>
<td>1.7</td>
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Note. n = 120. PFMAI = Posture and Fine Motor Assessment of Infants.

not allow for interpretation at that level of individual variability. Furthermore, the small sample sizes in each age group limit generalizability of the results. However, our findings do support the motor learning phases described in the literature (Thelen, 1995; Thelen & Ulrich, 1991).

Conclusion
The results of this study suggest that perceptual-motor coupling drives the development of hand skills and that the haptic qualities of objects (e.g., size, shape, contour, moveable parts) afford exploratory behaviors that lead to motor skill. The variability of grasping patterns observed when different objects are used across developmental stages appears to be an integral part of motor development in infants who are typically developing. We speculate that this variation in action allows the infant to explore the perceptual qualities of objects and to refine precision grasping patterns. Therapists who wish to enhance maturation of grasping patterns should consider facilitating these exploratory behaviors in the infant by providing materials and objects that are perceptually interesting to the child and that meet his or her learning needs. By incorporating consideration of the affordances of objects into their intervention approach, therapists are likely to be more successful in eliciting perceptual-motor coupling, thus promoting the emergence of fine motor skills. ▲

Appendix
PFMAI Items That Measure Grasping Patterns

**PFMAI-I**
Items were rated separately for the cube, the red rings, and the moveable parts toy.

Grasp on cube (red rings, moveable parts toy):

0 No grasp attempt
1 Partially opens hand in grasp attempt; does not position palm on cube
2 Places palm or fingers on cube; contact is maintained less than 10 sec
3 Maintains grasp of cube for more than 10 sec by stabilizing cube against mouth or other body part
4 Maintains grasp more than 10 sec with hand unsupported

Type of grasp:

0 Does not attempt grasp

1 Uses unsuccessful primitive squeeze
2 Uses palmar or ulnar palmar grasp to secure and hold the cube
3 Uses radial palmar grasp; thumb adducts to radial palm to secure and hold cube
4 Uses radial digital grasp; thumb adducts to proximal fingers

Finger patterns in grasp:

0 No grasp attempt
1 Fingers move as a unit in a grasp attempt
2 Fingers move together in a successful grasp
3 Fingers move in sequential, or separate but associated, patterns
4 Fingers move independently of each other

**PFMAI-II**
Items were rated separately for two to three cubes, a moveable parts toy, and a pellet.

Type of grasp:

0 Does not grasp
1 Palmar grasp: Object is held in the palm, using mass finger flexion
2 Radial palmar: Object is held in the thumb side of palm
3 Radial digital: Object is held in between the thumb and the radial fingers
4 Inferior or superior pincer grasp: Object is held in between the thumb and the index proximal aspects of the fingers

Thumb movements:

0 Thumb is adducted and flexed into palm
1 Thumb is adducted to the proximal index finger (it lies in the same plane as the palm)
2 Thumb actively abducts and adducts to the proximal index finger
3 Thumb partially opposes the fingers, touches the volar surface of fingers proximal to the tips
4 Thumb opposes the tips of one or more fingers

Isolated finger movements:

0 Uses primitive squeeze; fingers move as a unit
1 Fingers move together; movements seem to be guided by contact with the object's surface
2 Separate but associated finger movements
3 Pokes and probes, using isolated index finger movements
4 Uses a variety of isolated finger movements to probe and poke the toy
References


