Environmental Support and the Development of Grasp in Infants

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Key Words: child development • gross and fine motor evaluation • hand functions

This study examines the acquisition of internal stability as it relates to the development of prehension in normal infants. Thirty-two subjects, 7 to 14 months of age, were observed grasping Cheerios from styrene surfaces that provided different amounts of support to the infants' hands. The subjects were scored on the grasp patterns they used and on their success in securing a Cheerio without dislodging the styrene surface from a platform. Success increased with age, thus demonstrating a developmental progression in the acquisition of upper extremity internal stability. Consistency of grasp also increased with age. Whereas the youngest infants (7 to 8 months old) reverted to immature grasp patterns on the less stable surfaces, the oldest infants (13 to 14 months old) used mature pincer grasp patterns consistently. Infants 10 to 11 months old seemed to be in a transitional stage between the variability of grasp seen in the youngest infants and the consistency achieved by the oldest group.

This article was accepted for publication December 11, 1989.
Although stability and mobility have long been applied to the description of grasp patterns in adults, they have only recently been considered in relation to grasp in children. Traditionally, the power-precision dichotomy has been used to classify mature grasp patterns. In describing his classification system, Naper (1956) stated that “stability is a prerequisite for further activity and without it, all refinements of hand function are of little value” (p. 902). More recently, this same differentiation of grasp patterns into power and precision configurations has been applied to the description of grasp patterns in adults, and to the early development of grasp in infants.

Pier (1956) stated that “stability is a prerequisite for the grasp in young children, Rosenbloom and Horton (1971) related the development of pencil grasp patterns to an increasingly sophisticated interplay between stability and mobility functions within the hand. Can this relationship between stability and skilled movement be applied, then, to the early development of grasp in infants?

The Peabody Developmental Motor Scales (Folio & Fewell, 1983) imply this relationship. For early test items (i.e., prehension of a pellet with the use of primitive raking and inferior pincer grasp), the subject is permitted to stabilize the hand on an external support surface. For items testing the mature superior pincer grasp pattern, however, elevation of the wrist and hand from the tabletop is a scoring criterion.

In the present study, we explored the role of internal upper extremity stability in the development of prehension by requiring infants to grasp small objects from surfaces providing different amounts of support. To test the relationship between age, surface stability, and grasp patterns, the following hypotheses were developed:

1. The ability to successfully grasp a pellet from an unstable surface increases with age.
2. Surface stability will have a different effect on the grasp patterns of 7- to 8-month-olds, 10- to 11-month-olds, and 13- to 14-month-olds.
3. Among 7- to 14-month-old infants, those subjects with the most refined grasp patterns will have the greatest success at grasping a pellet from an unstable surface.

Method

Subjects

The sample consisted of 32 infants aged 7 to 14 months, 23 boys and 9 girls. The subjects were divided into three age groups. The 7- to 8-month-old group (actual ages: 7 months 0 days to 8 months 30 days) consisted of 9 boys and 1 girl (mean age = 8.20 months, SD = 0.47). The 10- to 11-month-old group (actual ages: 10 months 0 days to 11 months 30 days) consisted of 6 boys and 6 girls (mean age = 11.04 months, SD = 0.69). The 13- to 14-month-old group (actual ages: 13 months 0 days to 14 months 30 days) consisted of 8 boys and 2 girls (mean age = 13.73 months, SD = 0.52). All of the subjects were full term (37 to 42 weeks gestation) with no history of birth trauma, prolonged illness, or developmental deficits. The subjects were recruited through day-care centers and through word of mouth (i.e., through students, faculty, friends, and acquaintances) in Connecticut, Massachusetts, and Rhode Island. The subjects were of varied ethnicity and socioeconomic status.

Materials

The subjects were encouraged to grasp a pellet (a Cheerio1) from a 9 in. by 6 in. (22.9 cm by 15.2 cm) styrene surface. Three separate surfaces were used, each of a different thickness. When placed individually on a raised platform, these surfaces provided varying degrees of support for the subject's hand. The thickest styrene surface, .06 in (.15 cm), had minimal flexibility; it did not bend at all when the subject's hand rested on it. The .06 in. surface, therefore, was designated as the control surface. The two additional surfaces,.01 in (.025 cm) and .02 in (.05 cm), provided less support for the subject's hand and were therefore designated as the two test surfaces. The .02-in. surface could support approximately 3 oz (85 g) of static pressure on the platform; the .01-in. surface, approximately 0.75 oz (21 g). The styrene sheets were placed on a platform made of two 12 in. by 2 in. by 2 in. (30.5 cm by 5.1 cm by 5.1 cm) pieces of balsa wood fixed on a flat metal sheet 7 in. (17.8 cm) apart (see Figure 1). Raised corner guards on the platform prevented lateral slippage of the styrene sheets. During testing, one of the three styrene sheets was placed on the platform between the corner guards so that a 6 in. by 7 in. (15.2 cm by 17.8 cm) surface was left unsupported, spanning the distance between the two pieces of balsa wood. No time were the styrene sheets physically attached to the platform.

Design

Each subject was tested during a single 15- to 30-min session at the child's home or day-care center. The subjects were tested only when alert and not crying. Twelve trials were administered, divided into three sets of four trials per surface. The order of presentation of the two test surfaces was alternated for successive subjects. During rest periods of ½ to 3 min between sets, the caretaker talked to the infant or used bubbles or squeak toys to play with him or her. Longer or more frequent rest periods were permitted when the infant's behavior precluded further testing.

1 Manufactured by General Mills, Minneapolis, MN 55460.
Before test initiation, signed consent was obtained from each caretaker. The subjects were tested while seated on a caretaker's lap at a table that was at or slightly above the infant's waist. If necessary, a pillow was placed on the chair to raise the caretaker and the child to the appropriate height. The styrene surface, when placed on the platform, was at the subject's midchest level. The examiner (the first author) was seated opposite the infant. For each trial, a Cheerio was placed in the center of the styrene surface. The platform assembly was slid toward the child until it reached the edge of the table. If the child spontaneously removed the Cheerio, the hand used, the grasp pattern, and success or failure were recorded. The caretaker was permitted to cue the child verbally or by pointing to the stimulus or both. If necessary, the caretaker or examiner would model reaching for and eating the Cheerio once per trial. After the child reached for the Cheerio, the platform assembly was slid away. The examiner then replaced the styrene sheet and the Cheerio as needed.

Data Analysis

All trials were administered and scored by a single examiner according to the established scoring criteria. Before initiation of the study, interrater reliability was determined through a comparison of the ratings of a second examiner who was trained in the classification of grasp patterns. Agreement rates of 100% for success or failure and 90% for grasp patterns were achieved.

Both success and failure were recorded. The subjects' rate of success (ratio of successful grasps to the total number of grasps) for a given surface reflected his or her skill at removing the pellet without dislodging the styrene sheet from the platform or depressing the sheet to the point of contact with the solid surface below. If either of these events occurred on a given trial, a failure was scored, regardless of whether the subject succeeded in securing the pellet.

Grasp patterns were rated on a 4-point scale, with higher scores representing greater refinement and maturity. The rating criteria were derived from the work of Castner (1932), Lawrence and Hopkins (1976), Hohlstein (1982), and Erhardt (1982). The individual grasps were rated according to two criteria: (a) the use of the digits and (b) the terminal position of the pellet. A score of 1 corresponded to the use of the digits in an unspecialized manner in a raking motion. The pellet was positioned proximally, that is, within the hand. A score of 2 corresponded to some specialization in the use of the digits (i.e., use of the thumb and the index and middle fingers) with the pellet positioned on the lateral or volar surface of the index or middle finger, proximal to the distal interphalangeal joint. A score of 3 corresponded to specialization of the thumb and the index or middle finger for grasp. All digits extended and flexed together. The pellet was positioned on the volar surface of the index or middle finger, distal to the distal interphalangeal joint. A score of 4 corresponded to full specialization of the thumb and index fingers. The ulnar three digits remained flexed during grasp and the pellet was positioned between the volar pads of the thumb and index fingers. A grasp was required to meet all criteria for a given rating. If one or more criteria were not met, the grasp was automatically rated at a lower level. The ratings achieved for all trials with a given surface were summed. The subjects, therefore, had three cumulative grasp scores representing performance with each of the surfaces.

Preliminary one-way analyses of variance were performed to compare the mean grasp scores and mean success rates of the male and female subjects. Because no significant differences were found, the data were pooled for further analysis. To test the first two hypotheses, two-way analyses of variance were used. For both analyses, age was an independent factor and surface was a within factor. Success rate and grasp score were the dependent measures. The Newman-Keuls multiple comparison test was used to compare means within the interactions, when appropriate. The third hypothesis, the effect of grasp patterns on success rate, was tested by a derivation of the mean grasp score for all subjects achieving a given success rate. The Pearson product-moment correlation was used to determine the relationship between mean grasp score and success rate across the age groups. The chi-square distribution was used to analyze consistency of grasp among the three age groups.
Results

Success Rate

The ability to successfully grasp a pellet from an unstable surface did increase with age in infants 7 to 14 months old (see Table 1). There was a significant difference in success rates on the three surfaces and among the three age groups. The interactive effect between success rate, surface, and age was significant as well. All subjects consistently demonstrated the ability to grasp a pellet from the firmest (.02-in.) surface (success rate = 100% for all age groups) without dislodging it from the platform assembly. This surface thus served as a control for the comparison of the effects of decreased surface stability on success rate and grasp pattern. The least stable (.01-in.) surface was more difficult for all groups of subjects than the firmer (.02-in.) test surface. On the .01-in. surface, the youngest and middle groups of infants had minimal success (mean success rates = 0% and 8%, respectively); even the oldest infants were successful on less than half their attempts (mean success rate = 40%). On the more stable .02-in. test surface, success rates were higher and the age differences were more pronounced. The youngest subjects were successful on an average of 24% of the trials. The middle and oldest groups were more successful on the .02-in. surface (mean success rates = 70% and 100%, respectively), and the differences between the three age groups were significant.

Grasp

The effect of surface stability on grasp differed for each age group. Although there were no significant differences in mean grasp scores on the three surfaces, the interaction of surface and age was significant (see Table 1). For the 13- to 14-month-olds, the varying of the stability of the support surface had no effect on grasp scores. Among the youngest infants, grasp was affected by changes in surface stability. These infants tended to use slightly less mature patterns on unstable support surfaces. As a group, the 10- to 11-month-olds tended to use somewhat more mature patterns on the firmer test surface (.02 in.) than on the .01-in. surface or the control surface.

Table 1

<table>
<thead>
<tr>
<th>Measure</th>
<th>df</th>
<th>(M^2)</th>
<th>(F)</th>
<th>(P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groups</td>
<td>2</td>
<td>1.12334</td>
<td>18.31</td>
<td>.0001</td>
</tr>
<tr>
<td>Surface</td>
<td>1</td>
<td>5.63873</td>
<td>110.04</td>
<td>.0001</td>
</tr>
<tr>
<td>Surface x Groups</td>
<td>4</td>
<td>0.40098</td>
<td>7.83</td>
<td>.0001</td>
</tr>
<tr>
<td>Grasp score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groups</td>
<td>2</td>
<td>380.4966</td>
<td>40.09</td>
<td>.0001</td>
</tr>
<tr>
<td>Surface</td>
<td>2</td>
<td>0.97650</td>
<td>1.40</td>
<td>.2558</td>
</tr>
<tr>
<td>Surface x Groups</td>
<td>4</td>
<td>2.84618</td>
<td>4.09</td>
<td>.0055</td>
</tr>
</tbody>
</table>

As expected, grasp scores did increase with age (see Table 2). As shown in Table 3, the youngest group used primarily the two least-mature grasp patterns, whereas none of the subjects in this group used the most-mature grasp pattern. Conversely, the oldest infants used the two most-mature patterns exclusively. The mean grasp scores of the 7- to 8-month-olds and the 10- to 11-month-olds differed significantly \((p < .01)\). The mean grasp scores of the middle and oldest groups, however, did not differ significantly.

Consistency of grasp also increased with age (see Table 4). Eight out of 10 infants in the oldest group \((n = 10)\) used the same grasp pattern on all trials, and the other 2 infants used two patterns. Conversely, in the youngest group \((n = 10)\), 2 of the infants used three patterns and the other 8 used two patterns. The middle group \((n = 12)\) seemed to consist of two distinct groups. Half of the subjects in this group behaved like the oldest infants, that is, they used fine pincer patterns exclusively and were thus highly consistent in their grasp. The other half behaved more like the youngest infants; they used less mature patterns and were less consistent overall. Unlike the youngest infants, however, whose most-mature patterns were used on the control surface, the subjects in the middle group demonstrated their most advanced grasp patterns on the .02-in. test surface.

The Relationship Between Grasp Patterns and Success Rate

On both test surfaces across all three age groups, those subjects with the most refined grasp patterns had the highest success rate. On the .02-in. surface, there was a positive linear relationship \((r = .81)\) between grasp and success: the higher the grasp pattern, the higher the success rate (see Figure 2). On the .01-in. surface, the relationship was less straightforward \((r = .23)\). Although the highest grasp scores

Table 2

<table>
<thead>
<tr>
<th>Measure</th>
<th>Age Group</th>
<th>Success Rate</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7-8 months</td>
<td>10-11 months</td>
<td>13-14 months</td>
</tr>
<tr>
<td>Grasp score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.06 in.²</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>.02 in.</td>
<td>0.24**</td>
<td>0.71</td>
<td>1.00</td>
</tr>
<tr>
<td>.01 in.</td>
<td>0.00**</td>
<td>0.08**</td>
<td>0.40**</td>
</tr>
</tbody>
</table>

* This surface served as the control.
• Differs from the control, \(p < .05\). **Diffs from the control, \(p < .01\).
Table 3  
Frequency of Grasp Patterns Used by Each Age Group  

<table>
<thead>
<tr>
<th>Age Group</th>
<th>1 (57.5%)</th>
<th>2 (31.67%)</th>
<th>3 (10.83%)</th>
<th>4 (0%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7–8 months</td>
<td>69</td>
<td>38</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>10–11 months</td>
<td>3 (2.08%)</td>
<td>27 (18.75%)</td>
<td>104 (72.22%)</td>
<td>10 (6.94%)</td>
</tr>
<tr>
<td>13–14 months</td>
<td>0 (0%)</td>
<td>91 (75.83%)</td>
<td>29 (24.17%)</td>
<td></td>
</tr>
</tbody>
</table>

* Grasp patterns were rated on a 4-point scale, with higher scores representing greater refinement and maturity.

Discussion  
Success rates on both test surfaces increased with age, thus indicating that, as infants mature, they require less external stability from the support surface in order to grasp. This supports Rood's contention (cited in Stockmeyer, 1967) that, in the development of motor skill, support is first required from contact with an external surface. Thereafter, internal stability is developed, and the distal part is freed to execute skilled movement. The present study suggests that infants do indeed develop internal stability, which allows them to grasp with progressively less support from the external environment. Although they had no difficulty grasping a pellet from the control surface, the youngest subjects, aged 7 to 8 months, were greatly challenged by unstable support surfaces. The middle and oldest groups had greater success in grasping from the test surfaces. The 13- to 14-month-olds actually had equal success (100%) on the control and the firmer test surface, but, like the younger groups, had limited success on the least stable surface. Thus, the development of internal stability in the upper extremities may still be incomplete by 13 to 14 months of age.

Although the development of grasp and internal stability appear to be linked, the relationship between these two phenomena is not a simple one. The hypothesis that those infants with the most refined grasp would also have the highest rate of success was supported by the data (see Figure 2). Nevertheless, many infants with quite refined grasp still had limited success on the .01-in. surface. Thus, internal stability in the upper extremities may still be developing beyond the age at which grasp has matured.

The relationship between internal stability and the development of refined distal skill has important clinical implications. When the demands for skilled function are high, adequate external support for the patient's wrist and hand should be provided. In addition, external support may continue to be required even though prehension may appear quite refined. In fact, the need for support may continue to be an important issue when patients are working on fine motor tasks at a much higher level, as with manipulation and writing skills.

This study also yielded some interesting behavioral observations concerning the development of prehension. The mean grasp scores for each age group were generally consistent with the prehension age norms of published developmental assessments.

Table 4  
Consistency of Grasp: Number of Subjects Using One, Two, or Three Different Grasp Patterns  

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Three Patterns</th>
<th>Two Patterns</th>
<th>One Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>7–8 months</td>
<td>2</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>10–11 months</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>13–14 months</td>
<td>0</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Note. \( x^2 = 51.73 \).  
* \( p < .01 \).
Although pincer grasp appeared to develop primarily between 7 to 8 and 10 to 11 months of age, the effect of surface stability on grasp differed for each of the three age groups. Of the three groups, grasp varied the most in the 7- to 8-month-olds and appeared to be the most vulnerable to changes in surface stability. The use of unstable support surfaces appears to have placed this age group under a condition of environmental stress and caused them to revert to more primitive and perhaps more intrinsically stable grasp patterns. This tendency, while not great, was consistent. By the age of 13 to 14 months, fine pincer control has been well established. Grasp is highly consistent at this age and is impervious to changes in the stability of the support surface. The 10- to 11-month-olds appear to be in a transitional stage from the variability of grasp of the youngest infants to the consistency of the oldest group. Those subjects in the middle group who used a single grasp pattern on the control surface behaved like the oldest infants and used the same patterns on both test surfaces. The 16- to 11-month-olds who varied their grasp on the control surface behaved differently, however. This group used more mature patterns on the firmer test surface than on the control surface. Perhaps these infants were able to call forth greater refinement of grasp when moderately stressed. When the stress was too great, however, such as on the least supportive test surface, they were unable to maintain this adaptive behavior. Notably, the 10- to 11-month-olds with a consistent grasp pattern had higher success rates than did those whose grasp varied. Consistency of grasp, therefore, despite changes in environmental conditions, may be a useful indicator of prehensile maturity and the development of internal stability.

Although the development of internal stability may be critical to the achievement of fine motor skills, other mechanisms contribute as well. Certainly, the development of specialized function of the digits is essential for the development of grasp and of manipulation skills. In this study, an initial attempt was made to explore the role of digit specialization in grasp. The inclusion of the grasp score of 4 was based on the premise that digit specialization allows the infant to progress not only from a raking pattern to pincer control but beyond this point as well. For a grasp score of 4, the subject was required to extend the thumb and index finger while keeping the other digits flexed into the palm. Although this pattern has not been described by other researchers in infant development, visually, it appears quite different from the other patterns. In the present study, its frequency increased with age. Nearly one fourth of the individual grasps among the 13- to 14-month-olds received a score of 4. Few subjects used this pattern overall, however, which makes it difficult to reach any conclusions about its use. Further research could involve the observation of this pattern in older children performing a variety of tasks.

Likewise, it would be useful to measure internal stability more comprehensively. Future studies might examine proximal points of stability such as the head and trunk as well as the position of the opposite shoulder and arm. In the present study, the development of internal stability was examined cross-sectionally and was inferred from the success rates of infants grasping objects from a variety of surfaces. A longitudinal study might add important observations to the conclusions reached here. In particular, infants in the transitional stage, that is, between immature, variable grasp and mature, consistent grasp (perhaps from 9 to 12 months of age) should be studied longitudinally to explore the dynamics that underlie this developmental phase. In addition, internal stability could be evaluated in a more quantitative manner through the measurement of the amount of pressure applied to a surface during grasp or by the recording of muscle activation patterns during prehension activities. The latter method might also help define what internal stability is and where it is developing within the upper extremity and trunk. Certainly, stability at the most distal joints of the extremity is required for fine prehension and manipulation. Although the interplay between stability and mobility at the wrist and even within the hand itself may appear quite subtle, further research is required to describe this phenomenon and to apply it to the needs of clinicians and their patients.

Conclusion

The results of this study have supported our three hypotheses. The acquisition of upper extremity stability was demonstrated by the discovery of a developmental progression in the ability of 7- to 14-month-old infants to grasp objects from unstable support surfaces. The development of stability seems to be related to the ontogenesis of prehensile patterns in young infants. In particular, the consistent use of mature grasp patterns, despite changes in the support surface, appears to be associated with the acquisition of internal stability. Thus, clinicians should consider the effect of internal stability and external support on skilled distal function when working with patients on the development of functional hand skills.

Acknowledgments

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