Temporal patterns of hand and body movement during the transition to reaching
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INTRODUCTION

In early infancy, attention is coupled to fluctuations in spontaneous body movement on a scale of minutes\(^1\) (Figure below). This coupling also has been described on a time scale of seconds.\(^2\) How emerging arm control\(^3\) is integrated into this coupled, dynamic organization between attention and overall body movement during the transition to reaching is unknown. The analyses presented here were designed to examine (a) developmental change in various features of hand and body movement, and (b) the temporal relationships between hand and body movement as reaching onset nears.

Questions
1. Do hand and body movements co-occur during the weeks preceding reaching?
2. What are hand movements like during different phases of body movement?
3. When the hand moves closer to the toy, what is body movement like?

Goal
This work seeks to understand the emergence of a new behavior (reaching) by investigating the contributions of environmental factors (i.e., presence of reachable objects) and organismic factors (i.e., attentional state, body movement) over the weeks prior to infants' reaching to grasp nearby objects.

METHOD

Subjects and procedures. Healthy, full term infants (N=20; data from 7 have been analyzed) were observed at 8, 12, 16 wks then every 2 wks until reaching was observed. While seated in an infant seat reclined at 30 from vertical, infants were presented with brightly colored, illuminated toys (5-7 cm) at chin height ~15 cm from the infant's chest.

Trials. Infants were presented with: 1 toy, 2 toys or No toy in a series of four 4-min trials. Trials had two parts: no toy or 1 toy was presented for 1 min, then 1 toy or 2 toys was presented for the remaining 3 min.

Samples. Samples of body and hand movement were taken from periods of looking On the toy, Off the toy and when No Toy was present. Mean duration of the datasets was 17 sec (SD=5.5; range=7.5 – 27.1).

Developmental age. Age 1 represents ages 6-12 weeks before reaching; Age 2 represents ages 1-4 weeks before reaching.
Data Reduction: Measurements

Hand movement. Two synchronized cameras recorded two, 2D images of the hands used to derive the 3D position of the passive reflective markers on the hand. Marker position was tracked (30 Hz), transformed into 3D coordinates and smoothed. Analysis done on the right hand (except one sample). The word “hand” is used because the measurement was based on tracking the hand; however, the movements described here involve the arm. General body movements. Sensors in the infant seat measured general body movements (60 Hz). Portions of the sensor output reflecting respiratory movements were eliminated. Movement time series were integrated to 1 Hz. Visual attention toward a nearby toy. A third camera, synchronized with the others, recorded infants’ faces. Looking at and away from the toy was coded using a frame-by-frame analysis.

Characteristics of hand movement measured

Amount of hand movement: the average distance (cm) traveled every 1/6 sec.
Variability in hand movement: the average of the absolute differences in amount for successive 1/6 sec intervals.
Hand-toy distance: the straight-line distance between the toy position and the current hand position. In the No Toy condition, the toy location used was the position that was occupied by the preceding toy.

Characteristics of body movement measured

Amount of body movement: the average values of sensor output, rescaled (x100).
Variability in body movement: the average of the absolute differences in successive 1/2 sec intervals.
Fluctuations in body movement: the number of sustained peaks in body movement. Peaks = periods of increased movement that exceeded the median of that sample for at least one half a second.

1. Timing of hand and body movements
Do hand and body movement co-occur?

Approach 1: Look for evidence that arm movements, detected by video analysis, occur in the absence of body movement. When body movement signal was ≤ its median, the number of hand movements above ≥3cm were counted.

Result: 38% of hand movements (76 of 200) occurred when body movement was below its median. See figure at left.

Example of hand and body movement time series.
Approach 2: Compare correlations between the time series of the amount of hand and the amount of overall body movement. Many large and positive correlations might indicate confounding of the measures, yet large correlations could also indicate coordination.

Result: Only 14 of the 40 correlations were large and positive (p<.02). None were large and negative; no patterns by infant, age or condition were detected. See figure at left.

2. Phases of body movement

What are arm movements like during different states of body movement?

Approach 1: Peaks in the amount of hand movement (≥3cm) were tallied when body movement was above and below its median.

Result: Hand movements tended to co-vary with > median body movement, except when the infant was looking at the toy. See figure at left.

Approach 2: Compare features of hand-toy distance across age, condition and phase (see figure below) of body movement. Hand movement measures were: amount of hand movement with respect to toy, variability, number of valleys, and the duration of the sample. Result: The amount of and variability in hand-toy distance were related to Phase only (highest at increasing body movement). Number of valleys in hand-toy distance and the duration of samples were not related to age, condition or phase. See figure at left (amount of hand movement).
3. When the hand moved closer to the toy, what was body movement like?

**Approach:** For hand movements when the hand (a) moved ≥5 cm closer to the toy, and (b) the movement lasted ≤1 sec, look at the phase of body movement.

**Results:** At Age 1, the frequency of hand movements closer to the toy was not different from expected. At Age 2, observed rates were different from expected rates.

<table>
<thead>
<tr>
<th></th>
<th>Age 1</th>
<th>Age 2</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Expected</td>
<td>Observed</td>
</tr>
<tr>
<td>Increasing</td>
<td>17.5</td>
<td>19</td>
</tr>
<tr>
<td>Decreasing</td>
<td>17.5</td>
<td>19</td>
</tr>
<tr>
<td>Low/flat</td>
<td>35</td>
<td>32</td>
</tr>
<tr>
<td>x</td>
<td>n.s.</td>
<td></td>
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</tbody>
</table>

**Results of preliminary analyses:**

**Characteristics of hand and body movement**

**Body movement.** The variability of body movement may increase as reaching nears, p= .063. See figure below. The amount of body movement and number of sustained peaks in body movement did not vary by age or condition.

![Graph showing variability in body movement](image)

**Hand movement.**

Previous analyses showed that:

<table>
<thead>
<tr>
<th>Age 1</th>
<th>Age 2</th>
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<tbody>
<tr>
<td>n.s.</td>
<td>amount greater On vs. Off</td>
</tr>
<tr>
<td>n.s.</td>
<td>more movements closer* On vs. Off</td>
</tr>
<tr>
<td>n.s.</td>
<td>variability greater On vs. Off</td>
</tr>
</tbody>
</table>

*movements closer corrected for overall amount of hand movement

**RESULTS**

**Basic features of hand and body movement**

- Some features of hand movement were related to attention condition and emergence of reaching.
- Most features of body movement were not related to attention condition or emergence of reaching.

**Timing of hand and body movement**

- While increases in hand and body movement tended to co-occur, they were not often positively correlated over a period of (~10-20) seconds.

(continued...)
Hand movement during different phases of body movement

- When body movement was low, so was the amount of hand movement except when the infant was looking at the toy.
- The amount and variability of hand movement with respect to toy position were not related to age or attention condition, yet were related to phase of body movement. The greatest amount and variability were observed during increasing body movement.

Hand movements closer to the toy

- More hand movements closer to the toy occurred (than expected) when body movement was increasing (compared to decreasing and low/flat) and the infant was closer to reaching emergence.

DISCUSSION

- Fluctuations in body activity did not differ by infant’s age or attention condition, yet more hand movement and more frequent movements closer to the toy occurred during periods of increasing body movement (vs. decreasing or < median movement). This suggests that fluctuations in body movement may be linked to emerging arm control. For example, infants may take advantage of waves of general activity to engage the hands and arms in object-related movements.

- Results indicate some differentiation of hand from body movement when infants looked at nearby objects. Although hand movement tended to co-occur with body movement, when infants looked at the toy, they moved their hands just as often regardless of the current level of body movement.

- At these ages, infants appear to be exercising little inhibitory control over their movements. Even as reaching neared, infants moved their bodies and hands at similar levels across attention conditions. For example, within 4 wks of reaching onset, infants exhibited high levels of hand movement even when no toy was present.

- These results are consistent with theories supporting processes of exploration and selection in early motor development. During the weeks before reaching, the characteristics of hand movement could readily be regarded as exploratory especially given the movement that occurs during looking at a nearby object. Also, it could be argued that the hand movements closer to the toy, that become more frequent as reaching neared when infants looked at the toy, represent the selection of more functional movement.

REFERENCES


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