Factors influencing the manual discrimination of orientations in 5-month-old infants

Kerzerho Stéphanie*, Gentaz Edouard**, & Streri Arlette*

*Paris Descartes University, L.P.P. CNRS France
**CNRS and University of Grenoble, France

Key words: posture, haptics, anisotropy, infancy

Running head: manual discrimination of orientations in 5-month-old infants

Corresponding authors: Arlette Streri or Stéphanie Kerzerho “Laboratoire Psychologie de la Perception” 45, rue des Saint-Pères – 75006 Paris, France

Email: arlette.streri@univ-paris5.fr
       stephanie.kerzerho@univ-paris5.fr

Acknowledgements: We thank all the infants and their parents who participated in the experiments. We thank Erik Domellöf for his proofreading. This work was supported by grants from the University Institute of France.
ABSTRACT

This research addresses the question of the factors affecting the manual discrimination of spatial orientations and the orientation preferences in 5-month-old infants by using a familiarisation/reaction to novelty procedure. The first experiment explored whether the “vertical preference” observed in Gentaz & Sterri’s study (2004) and Kerzerho, Sterri, & Gentaz (2005) is an intrinsic preference or whether it is due to the paradigm of familiarisation. The second experiment examined whether the magnitude of the angular deviation to the vertical influences the direction of preference. Results showed that when both gravitational vertical and body axes were aligned, the intrinsic “vertical preference” exists when the angular difference between the two orientations tested in the test phase was 10°. When the angular deviation to the vertical was greater than 10°, the novel orientation was preferred. This modification of orientation preference in the manual discrimination of orientation by 5 month old infants is discussed in relation to the magnitude of the angular deviation to the gravitational vertical and the spatial reference cues available in each condition.
INTRODUCTION

Spatial orientation is a fundamental property of our environment. The physical definition of the orientation of a stimulus is always relative to one or more reference axes that together form a reference frame (Howard, 1982). Our environment and our body are continuously submitted to gravity (Gentaz et al., 2001). This force favours the vertical direction of the oriented objects in our surrounding and constrains, from birth, human activities such as reaching for an object, for example. Indeed, one big task ahead of every newborn infant is to develop a resistance to and a control over the force of gravity. With progressive postural development, increments in this resistance to gravity are quite obvious, first in the region of the head and neck and then of the trunk, until finally the baby is able to support himself or herself (cf. McGraw, 1932, Saint-Anne Dargassies, 1986, and Bayley, 1969). Thus, studies of vertical perception in infants are crucial, because gravity plays a fundamental role in gaze control, reaching and manipulation in this period of human life (cf. Berthenthal & Von Hosten, 1998). Five months is a key age because the babies are able to maintain their head and neck erected and, as a consequence, are able to perceive their environment as submitted to gravity with their visual and haptic modalities.

Several studies have investigated the perception of spatial orientations in the haptic mode in infancy. At about 5 months of age, infants are able to discriminate between several spatial orientations (Gentaz & Streri, 2002, 2004; Kerzerho, Streri, & Gentaz, 2005). However, these studies present some apparent contradictions in their results. Gentaz and Streri’s (2002) experiments revealed that 5-month-old infants were capable of manually discriminating (without visual control) between a vertical (defined gravitationally) rod and a 45°-left oblique rod positioned in the fronto-parallel plane. After familiarisation with a
vertical rod (or a 45° oblique rod), infants held the novel orientation of the rod (45° oblique rod or vertical rod) longer. This result is in accordance with results usually obtained in experiments using familiarisation vs. reaction to novelty procedure (see Pascalis & de Haan, 2003 for a discussion on this subject). In another experiment examining whether an anisotropic perception (i.e., differing according to the value of angular orientation) in the haptic mode was present in 5-month-old infants (Gentaz & Streri, 2004), infants had to discriminate a vertically oriented rod from a 10°-left oriented rod and a 55°-left oblique vs. a 45°-left oblique orientation. For the same 10°-angular value, infants were able to discriminate between a vertical rod and a 10° oriented rod but a similar discrimination was not found between a 55° vs. a 45° oriented rod. These results confirmed that the manual discrimination of spatial orientations is anisotropic in 5-month-old infants. Thus, the perception of space is anisotropic in both infants (Gentaz & Streri, 2004) and adults (cf. Gentaz, Baud-Bovy & Luyat, in revision; Kappers, 1999, 2002). A striking result, therefore, was found: infants always preferred to hold the vertical rod (the familiar stimulus) rather than the 10° oriented rod (the novel stimulus). These observations were reproduced by Kerzerho, Streri & Gentaz, in 2005. Infants could discriminate a vertical orientation from a 10°-left oblique orientation but could not discriminate a 20°-left oblique from a 30°-left oblique orientation. As in the previous experiment, infants preferred to hold the vertical rod (the familiar stimulus) rather than the novel rod (oriented 10° to the left).

These results are striking because, in infancy research, infants usually tend to indicate a preference for the novel object by looking at it or touching it longer than the familiar one after familiarisation or habituation methods (cf. Pascalis & De Haan, 2003). By contrast, in the studies by Gentaz and colleagues, the direction of preference depended on the angular value: when the magnitude of the angular deviation to the vertical was weak (10°) infants preferred the vertical orientation, whereas when the magnitude of the angular deviation is
large (0° vs. 45°), infants preferred the novel orientation (Streri & Gentaz, 2002; Gentaz & Streri, 2004; Kerzerho, Streri & Gentaz, 2005). These results suggest that the spatial reference cues available in each condition play a role in the modification of orientation preference (see also Millar, 1994). When infants were tested with orientations (like the 10°-oblique) which were close to both the gravitational vertical and the body axis of the infant, these reference cues may act as “attractors” (Gentaz et al., in revision) and thus, reinforce the “vertical preference”. According to this line of reasoning, when infants were tested with orientations further away from the gravitational vertical, like the 20°-oblique and the 45°-oblique, the weak availability of these reference cues should not reinforce the vertical preference and thus enabling a novelty preference.

To confirm this hypothesis several issues have to be clarified. Firstly, in the experiments by Gentaz and Streri (2004) and Kerzerho, Streri and Gentaz (2005), the results are ambiguous because it is difficult to determine whether infants prefer the vertical orientation (intrinsic preference) or the familiar stimulus. Secondly, 10° is the critical angular value used in previous studies. For which angular value is a novelty preference observed?

The aim of the research presented here was to investigate the incidence of the gravity factor on the manual discrimination of orientations and the direction of preferences in 5 month-old infants. In Experiment 1, we tested whether the “vertical preference” observed in Gentaz & Streri’s study (2004) in the vertically familiarised group, is an intrinsic preference (in this case, the familiar preference would be a vertical preference) or whether it is due to the vertical rod used in the familiarisation phase (in this case, the vertical preference would be a familiar preference). Thus, we familiarised 5-month-old infants with the 10°-left oblique orientation or with the vertical rod and tested them with the vertical and 10°-left oblique orientation. If the vertical preference is intrinsic, infants should prefer the vertical orientation whatever the familiarisation conditions. If the vertical preference is a familiar preference, we
should observe a familiar 10°-left oblique preference after a familiarisation phase with a 10°-left oblique and a familiar vertical preference after a familiarisation phase with a vertical orientation. In Experiment 2, we investigated whether the magnitude of the angular deviation from the vertical direction influenced the direction of preference. Thus, we tested infants with vertical and 20°-left oblique rods in the test phase after a vertical familiarisation in order to explore the boundaries of the vertical and/or tilted preferences.

Both experiments were approved by the local committee of the Institute of Psychology (Paris V University). The experiments were classified as purely behavioural, and the testing involved no discomfort or distress to the infants. At least one of each infant’s parents gave informed written consent and stayed close to, but behind their baby during the all experiment.

EXPERIMENT 1

METHOD

Participants

Twenty-four infants aged from 4 months 20 days to 5 months 10 days (13 males and 11 females; mean age: 151.1 days) participated in this experiment. All infants came from middle socio-economic backgrounds. Additional infants were eliminated from the study because of fussiness (N=1), mother interventions (N=1), or non-interest for the haptic stimulus (N=1) during the experiment.

Apparatus

The haptic apparatus was composed of a Plexiglas disk (diameter: 30 cm) equipped with a handle-shaped rod (18 cm x 15 cm; Fig 1). This rod (0.5 cm in diameter) was chosen because it was easily handled and explored by the 5-month-old infants in previous studies (Gentaz & Streri, 2002, 2004). The rod, mounted on the center of the disk, could be rotated
360° around its central axis. The rod could also be maintained in a desired orientation in order to prevent involuntary deviation from its position during haptic scanning. The disk was graduated in degrees (the sensitivity threshold of this display was equal to 0.5°) and was attached to a wooden plank supporting the device. The rod and the disk were positioned in the frontal plane and were centred on the midline of the infant’s body. The height of the disk was adjusted so that the center of the rod was at the level of the infant’s right shoulder, at a 52 cm height.

![Fig. I: The experimental display used for haptic discrimination of rod orientations (here in vertical position).](image)

**Experimental conditions and procedure**

Each infant was placed in a small experimental room, in front of an 80 x 80 cm white wooden screen, at a distance of 50 cm. Large white wooden cloth was used to minimize the vertical and the horizontal cues. Infants were seated in a vertical, width-adjustable car seat.
The seat was tilted back slightly (less than 5°) to maintain infants in a seated position. We put a cushion on both sides of the infant to avoid tilting of the infant’s body.

A large white cloth bib was attached around the baby's neck at one side and to the screen at the other. The bib prevented infants from seeing their shoulder-hand systems, even laterally, but left them free to move. It also allowed the infant's right hand to be recorded by means of a video-camera situated under the bib level.

During this procedure, the first experimenter, located behind the screen, controlled the video-recording. The second experimenter sat under the bib and to the right of the infant. Her tasks included putting the rod in the infant's hand and recording holding times. The infant's right hand was used in all experimental conditions as previous studies have provided evidence that the right hand is preferentially used for moving objects in space as compared to the left hand (e.g., Streri & Gouarir, 1996). The experiment included a familiarisation phase and a test phase.

a) Familiarisation phase

In the familiarisation phase, a fixed-duration procedure was adopted in which the stimulus was presented until each infant accumulated a 90 second duration of holding time. The infant's right hand was put on the rod fixed upon the apparatus. When the infant let go of the rod for more than 2 seconds and did not re-grasp the rod by himself or herself, the experimenter reinstalled the infant’s hand on the rod again until she/he accumulated a 90 second duration of familiarisation. The familiarised orientation was either the 10°-left oblique orientation (defined gravitationally) or the vertical orientation. The parents could see their children on a television screen during the experiment.
b) Test phase

The test phase began immediately after the familiarisation phase. For each trial, an infant-controlled procedure was used: the trial began when infants held the rod in their right hand and finished when they released their hold. During this phase, two orientations were presented successively: the familiar orientation (previously used in the familiarisation: 10° or 0°) and the novel orientation (differing from the familiar orientation by 10° on the infant's right side: 0°, or on the infant's left side: 10°). The 10° difference choice between the familiar and the novel orientations allowed us to make comparisons with Gentaz & Streri's results (2004) and Kerzerho, Streri & Gentaz results (2005). The two orientations were presented alternately during four trials (two test trial pairs) in a counterbalanced order between subjects. For the 10°-oblique familiarisation group: 10°/ 0°/ 10°/ 0° (order 1) or 0°/ 10°/ 0°/ 10° (order 2), and for the vertical familiarisation group: 0°/ 10°/ 0°/ 10° (order 1) or 10°/ 0°/ 10°/ 0° (order 2).

RESULTS AND DISCUSSION

Familiarisation phase

Data analyses were carried out on the number of times that the infant let go of the rod during the 90 second familiarisation phases for each orientation, in order to judge whether the results observed in the test phase could be due to the biomechanical constraints of the task during the familiarisation phase. The two types of numbers were verified a posteriori from the video-recordings by the two experimenter (the inter-observer reliability was very high (Pearson correlation; r = 0.98). A t-test compared the mean number of times that infants let go of the rod in each familiarisation condition. The difference between the number of times that infants let go of the rod during the vertical familiarisation (M = 2.08; SD = 2.7)
and the number of times that infants let go of the rod during the oblique familiarisation (M = 2.67; SD = 2.3) was not significant (p>.25).

**Test phase**

We analysed the holding times (in seconds) of the rod during the test phase for each experimental condition. Holding times were verified *a posteriori* from the video-recordings by the two experimenters. The inter-observer reliability in all sessions was very high (Pearson correlation; r = .90). The means and standard deviations of the holding times in the test phase for each experimental condition are shown in Table 1.

Table 1: Mean holding time (M) in seconds and standard deviations (SD) in the test phase as a function of test trial pair, test stimulus and familiarised orientation.

<table>
<thead>
<tr>
<th>Test trial pair X Test stimulus</th>
<th>Test trial pair 1</th>
<th>Test trial pair 2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10°</td>
<td>0°</td>
<td>10°</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>(SD)</td>
<td>(SD)</td>
<td>(SD)</td>
</tr>
<tr>
<td><strong>Familiarised orientation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical (0°)</td>
<td>7.45</td>
<td>18.20</td>
<td>8.65</td>
</tr>
<tr>
<td></td>
<td>(5.4)</td>
<td>(14.22)</td>
<td>(7.45)</td>
</tr>
<tr>
<td>Oblique (-10°)</td>
<td>18.76</td>
<td>23.78</td>
<td>7.62</td>
</tr>
<tr>
<td></td>
<td>(17.6)</td>
<td>(13.67)</td>
<td>(4.23)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>13.10</td>
<td>20.99</td>
<td>8.13</td>
</tr>
<tr>
<td></td>
<td>(14)</td>
<td>(13.95)</td>
<td>(5.97)</td>
</tr>
</tbody>
</table>
A preliminary ANOVA on the holding times in seconds showed that the factor "order of test trial" had no effect. A 2 (familiarised stimulus) x 2 (test trial pair) x 2 (test stimulus) ANOVA (with repeated measures on the last two factors) on the holding times in seconds revealed a main effect of the test stimulus (F(1,22)= 20.13, p <.0002; η² = 0.48), with longer holding time for the vertical orientation (M = 18.11) than for the 10°-left oblique orientation (M = 10.62).

The main effect of the test trial pair was significant also (F(1,22)= 5.1, p <.035; η² = 0.18), with longer holding time in the first test trial pair (M = 17.05) than in the second one (M = 11.68). The main effect of the familiarised stimulus was not significant (F(1,22)= .88 p >.25). The familiarised stimulus and test trial pair interaction was significant (F(1,22)= 4.6, p <.044; η² = 0.17). This means that after a familiarisation with the 10°-left oblique orientation, the holding time was longer in the first test trial pair (M = 21.27) than in the second test trial pair (M = 10.8), whereas after a familiarisation with the vertical orientation there was no significant difference between the first test trial pair (M = 12.82) and the second one (M = 12.55). No other interactions were significant (all p>.25).

In sum, the results of Experiment 1 showed that 5-month-old infants preferred the vertical orientation in the test phase over the 10°-left oblique orientation whatever the familiarisation condition (10°-left oblique orientation or a vertical orientation). These results support the hypothesis that an intrinsic preference for vertical orientation exists in these conditions, at least when the angular difference between the two orientations tested in the test phase is 10°. In Experiment 2, we explored a new angular value (20°) in order to better understand the switch of the direction of preference (from the vertical preference to the novel orientation preference).
EXPERIMENT 2

METHOD

Participants

Sixteen infants aged from 4 months 20 days to 5 months 10 days (8 males and 8 females; mean age: 155.5 days) participated in this experiment. All infants came from middle socio-economic backgrounds, and were observed at our laboratory. Additional infants were eliminated from the study because of fussiness (N=2) during the experiment.

Apparatus

The haptic apparatus was exactly the same as in the first experiment.

Experimental conditions and procedure

The same experimental conditions and procedure as in Experiment 1 were used in Experiment 2.

a) Familiarisation phase

In the familiarisation phase, a fixed-duration procedure was adopted in which the stimulus was presented until each infant accumulated a 90 second duration of holding time. One of the experimenters brought the infant’s right hand to the rod fixed to the apparatus and made sure that the infant’s hand held on to the rod. When the infant let go of the rod for more than 2 seconds and did not spontaneously re-new her or his grasp on the rod, the experimenter brought the infant’s hand back on the rod again until she/he had accumulated a 90 second duration of familiarisation. The familiarised orientation was the vertical orientation (defined gravitationally). The parents could see their child on a television screen during the experiment.
b) Test phase

The test phase began immediately after the familiarisation phase. For each trial, an infant-controlled procedure was used: the trial began when infants held the rod in their right hand and finished when they let it go. During this phase, two orientations were presented successively: the familiar orientation (previously used in the familiarisation phase: 0°) and the novel orientation (differing from the familiar orientation by 20° on infant's left side). Those two orientations were presented alternately during 4 trials (two test trial pairs) in a counterbalanced order between subjects: 0°/ 20°/ 0°/ 20° (order 1) or 20°/ 0°/ 20°/ 0° (order 2).

RESULTS AND DISCUSSION

The means and standard deviations of the holding times in the test phase for each experimental condition are shown in Table 2. Holding times were verified \textit{a posteriori} from the video-recordings by the two experimenters. The inter-observer reliability in all sessions was very high (Pearson correlation; $r = .99$).

A preliminary ANOVA on the holding times in seconds showed that the factor "order of test trial" had no effect. A 2 (test trial pair) x 2 (test stimulus) ANOVA (with repeated measures on the two factors) on the holding times in seconds revealed a main effect of the test stimulus ($F(1,15)= 9$, $p < .01$; $\eta^2 = 0.37$), with longer holding time for the 20°-left oblique orientation ($M = 18.78$) than for the vertical orientation ($M = 11.79$). The main effect of the test trial pair and the interaction between the test trial pair and the test stimulus were not significant (both $p > .25$). These results indicate that 5-month-old infants preferred the novel (20° oblique) orientation in the test phase over the familiar (vertical) orientation.
Table 2: Mean holding time (M) in seconds and standard deviations (SD) in the test phase as a function of test trial pair and test stimulus.

<table>
<thead>
<tr>
<th>Familiarised orientation</th>
<th>Test trial pair 1</th>
<th>Test trial pair 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical (0°)</td>
<td>12.59</td>
<td>18.06</td>
</tr>
<tr>
<td></td>
<td>(9.13)</td>
<td>(14.51)</td>
</tr>
<tr>
<td></td>
<td>10.99</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td>(8.38)</td>
<td>(15.28)</td>
</tr>
</tbody>
</table>

GENERAL DISCUSSION

We explored two factors affecting the manual discrimination of spatial orientations and the orientation preferences in 5-month-old infants by using a familiarisation (with a 90 second fixed-duration)/reaction to novelty procedure.

Whatever the familiarisation condition, 5-month-old infants preferred the vertical orientation in the test phase. This main result of Experiment 1 supports the hypothesis that an intrinsic preference for vertical orientation exits when the angular difference between the two orientations tested in the test phase was 10°. It should be noted that this angle discrimination is really acute. 5-month-old infants are able to precisely perceive orientation differences by their hand in relation to the vertical axis defined gravitationally. These results confirm the idea that the vertical orientation is used as an important axis to define spatial orientations haptically when the shoulder-arm-hand system is unrestrained to hold the
oriented rod. Gravitational cue is provided by the shoulder-arm-hand system during the exploration of the rod (Gentaz & Streri, 2004).

In experiment 2, we examined the directional preference in infants with an intermediate orientation between the vertical and the 45°-oblique orientation. The results of the test phase showed that 5-month-old infants, after a vertical rod familiarisation, clearly preferred the novel 20° oblique orientation, as it was the case with the 45°-oblique orientation. This result elucidated the boundary of the change of orientation preference. It seems to indicate that this limit is located between the 10° oblique orientation and the 20° oblique orientation.

How can the fact that the infants changed their preference between these 10°-oblique and 20°-oblique orientations be explained? This phenomenon could not result from the familiarisation/reaction to novelty procedure, and the vertical orientation was not always favoured when oblique orientations were far from it. We suggest that the modification of orientation preference in the manual discrimination of orientation by 5-month-old infants can be explained in terms of the magnitude of the angular deviation to vertical (gravitational vertical and body axis aligned). When infants were tested with orientations which were close to both the gravitational vertical and their body axis, these reference cues may have acted as “attractors” and thus, reinforced the “vertical preference”. Thus, the reference cues available in each condition may determine the orientation preference. Furthermore, infants compete with gravity to develop and maintain vertical postures during the first year of life, progressing sequentially from head control, trunk control to erect position. Therefore we do not know how exactly the development of gravity is related to vertical preference. By contrast, when infants were tested with orientations which were further away from the gravitational vertical, like the 20°-oblique and the 45°-oblique, the weak availability of these
reference cues would not reinforce the vertical preference and thus a novelty preference would be possible.

We propose that different preferences are intrinsically mediated by perceptual mechanisms. However, biomechanical constraints might also play a role. Two arguments allow ruling out the second interpretation. First, the number of times that infants released their grip of the rod during the familiarisation phase for the vertically and the obliquely oriented rod were similar in the first experiment. Secondly, a similar analysis was not possible in the second experiment because the infants were only familiarised with the vertical rod and not with the 20°-left oblique, but in Gentaz and Streri’s study (2002), the difference between the number of times that infants let go of the rod during the vertical familiarisation \( (m = 17/8 = 2.12) \) and the number of times that infants let go of the rod during the 45°-left oblique familiarisation \( (m = 20/8 = 2.5) \) was not significant \( (p > .25) \). As a consequence, it seems less plausible that the amounts of withdrawals for 20° are more frequent than those for 45°.

As indicated by previous research, 5-month-old infants (in an upright body position) preferred the novel orientation in the test phase (45° or 0°) whatever the orientation (0° or 45°-left oblique) presented in the familiarisation phase (Gentaz & Streri, 2002). Thus, we can speculate that infants prefer the novel vertical orientation over the 20°-left oblique familiar orientation after a 20°-left oblique familiarisation. A way to test this interpretation would be to examine this ability in older infants. Rochat (1992) reported that when infant at about 9 month-old infants attain a self-sitting posture they shift toward reaching more often with one hand so that the other can be used to maintain balance (see also, Rochat & Goubet, 1995). Thus, we can assume that the preference for vertical orientation would disappear in older infants when they easily offset gravitational forces acting on the body. This hypothesis will be explored in future studies.
REFERENCES


Howard, I. P. *Human visual orientation*. Londres: Wiley and Sons; 1982


