Tactile Sensory Capacity of the Preterm Infant: Manual Perception of Shape From 28 Gestational Weeks

WHAT’S KNOWN ON THIS SUBJECT: Preterm infants from 33 gestational weeks can detect specific shape features (prism and cylinder) by touch (without visual control), and remember them; however, nothing is known about such abilities earlier in development.

WHAT THIS STUDY ADDS: The preterm infant, even when very immature (from 28 gestational weeks), is endowed with tactile sensory abilities: the exploration and memorization of an object by touch, the discrimination of a novel object, and the recognition of a familiar object after interference.

abstract

OBJECTIVE: Recent studies have shown that from the postconceptional age of 33 weeks, preterm infants are able to memorize tactile information about the shape of an object by using their hands, and can detect differences with another shape. This study aimed to investigate tactile abilities earlier on in development, in very preterm and mildly preterm human infants.

METHODS: Infants were assigned to 2 groups according to postconceptional age: very preterm (before 32 weeks) and mildly preterm (from 32 to 33+6 weeks). The test consisted of the repeated presentation of an object (prism or cylinder) in the left hand. The experiment was conducted in 3 phases: habituation (repeated presentation of the same object), discrimination (presentation of a novel object), followed by recognition (presentation of the familiar object).

RESULTS: Forty-eight newborns were recruited (24 very preterm; 24 mildly preterm). During habituation, each infant showed a decrease in the holding time of the object. Then, when a novel shape was put into the preterm newborn’s hand, holding time increased. Finally, when the familiar shape was presented again, the holding time decreased. Preterm infants can memorize by touch specific features that differentiate prism and cylinder shapes, discriminate between them, and recognize them after interference.

CONCLUSIONS: From 28 weeks, and from the first days of life, the preterm newborn is endowed with tactile sensory capacities. The tactile stimulations that are presented to preterm infants during their hospitalization should be adapted while respecting their sleep-wake rhythms. Pediatrics 2012;130:e88–e94

AUTHORS: Leïla Marcus, MD,a Fleur Lejeune, PhD,b Frédérique Berne-Audéoud, MD,a Edouard Gentaz, PhD,b and Thierry Debillon, PhD,a

aService de médecine et de réanimation néonatale, Hôpital Couple Enfant, Grenoble, France; and bLaboratoire Psychologie et NeuroCognition (CNRS), Université Pierre Mendès-France, Bâtiment des Sciences de L’homme et des Mathématiques, Grenoble, France

KEY WORDS
preterm infants, neonatal period, tactile modality, haptic perception, shape

ABBREVIATIONS
GW—gestational weeks
PCA—postconceptional age

All authors made substantive intellectual contributions to this study by making substantive input to its conception and design, to the acquisition of data, and its analysis and interpretation. All authors contributed to the drafting of the article or revising it critically for important intellectual content and interpretation of data, and gave final approval of the version to be published.

www.pediatrics.org/cgi/doi/10.1542/peds.2011-3357
doi:10.1542/peds.2011-3357

Accepted for publication Mar 1, 2012

Address correspondence to Leïla Marcus, MD, Service de médecine et de réanimation néonatale, Hôpital Couple Enfant, CHU Grenoble - BP 217, 38043 Grenoble Cedex 09, France. E-mail: lmarcus@chu-grenoble.fr

PEDIATRICS (ISSN Numbers: Print, 0031-4005; Online, 1098-4275). Copyright © 2012 by the American Academy of Pediatrics

FINANCIAL DISCLOSURE: The authors have indicated they have no financial relationships relevant to this article to disclose.

FUNDED: Dr Gentaz received funds from Region Rhone-Alpes of France (Number: CIBLE 2007 - 07 016861 01-TZ 016).
In recent years, there has been increased interest in the manual perception of objects in full-term and preterm human newborns.\(^1\)\(^{-3}\) Besides possessing manual reflexes, newborns are also able to handle small objects and to perceive their properties. Thus, by using a classic habituation and dishabituation procedure, a recent study\(^4\) showed that 2-day-old full-term newborns were able to detect differences in the contours of 2 different-shaped objects. After habituation with 1 object placed in either the right or the left hand ("objectivized" by a progressive decrease in the holding time of the object, in successive trials), a novelty reaction ("objectivized" by an increase in the holding time for the novel object) was observed when a different object was put into the same newborn's hand. This was the first evidence of habituation and reaction to novelty observed with both the left and right hands in human newborns.

Human full-term newborns have, therefore, a certain number of elaborate sensory and cognitive abilities (tactile exploration of their environment). Preterm birth implies a brutal change in the sensory environment of newborns, while all their senses are still developing. How, then, can an immature newborn explore his or her environment? Moreover, because being born prematurely can hinder long-term cognitive development, better knowledge of the sensory capacities of a premature newborn child could allow adaptation of both the sensory environment and of stimulations during the neonatal period, with a view to improving cognitive development.

The development of sensoriality in utero follows a precise and identical chronology in all mammals: first touch, then olfaction, taste, hearing, and, finally, vision.\(^5\) The cutaneous receptors are present early during embryogenesis; they appear from the seventh week of gestation around the mouth, and subsequently extend throughout the whole body (20 gestational weeks [GW]) by way of cephalo-caudal maturation.\(^6\)\(^{-8}\) Touch is the first sense to develop in utero. The preterm infant, even when very immature, has a number of functional tactile abilities. Tactile experiences in utero are specific. In the case of a preterm birth, the newborn evolves in a different sensory environment, which can potentially modify his or her abilities. The sensory stimulations to which preterm newborns are exposed during their hospitalization may influence the structure and the functioning of the central nervous system as well as their behavior. Knowing more about their tactile abilities would allow us to provide them with more adapted stimulations during their hospitalization.

Recently, Lejeune and her collaborators\(^9\) investigated the ability of preterm infants' hands to perceive and discriminate between various shapes. Twenty-four preterm infants of a postconceptional age (PCA) of 33 to 34+6 weeks were tested; the results showed that they were able to detect by touch the specific features that differentiate prism and cylinder shapes, and remember them. In using a similar experimental paradigm, the aim of the present behavioral study was to further investigate these tactile abilities in very preterm (<32 GW) and mildly preterm (between 32 and 33+6 GW) human infants.

**METHODS**

This study was prospective, observational, and carried out between April 2009 and July 2010.

**Participants**

Participants were selected from NICUs in the hospital of Grenoble, France, and were assessed before the PCA of 34 weeks. Two groups were made up according to PCA: very preterm (<32 GW) and mildly preterm (between 32 and 33+6 GW). We excluded from the study preterm infants with a polymalformative syndrome, those with cystic periventricular leukomalacia, grade III or IV intraventricular hemorrhage based on their cranial ultrasound, and those who received sedative or anticonvulsive treatment during the experiment.

**Procedure**

Parents gave written consent for infants to participate in the experiment. Each infant was assessed only once during the first 10 days of life to minimize postnatal experience. The hand tested was the left one, as it was mostly free of any prosthesis. This experiment was run without visual control; the experimenter positioned the infant’s head in the opposite side of the tested hand and if the infant turned his or her head during the experiment, the experimenter placed her hand between the infant’s eyes and the object. Certain conditions had to be respected during the experiment, each infant was swaddled and assessed in an arousing state of 4 on the Brazelton scale,\(^10\) just before, or more than 1 hour after, being fed. Other environmental stimuli were limited as far as possible. The whole experiment was videotaped for subsequent analysis. The experiment was conducted in 2 phases: the habituation phase, then the test phase for the habituated infants.

The habituation phase consisted of the repeated presentation, in successive trials, of a wooden object (prism or cylinder). Two groups were made up according to the shape of object used; half of the infants received the prism and the other half the cylinder (randomized repartition). Holding time was recorded for each trial. The experimenter put an object in the infant’s left hand and the first trial started. Once the preterm infant released the object after having held it for at least 1 second, the experimenter stopped the recording and ended the trial. If the preterm infant held the object for 60 seconds, the experimenter gently opened the infant’s
hand and removed the object, ending the trial. After an intertrial interval of ~5 seconds, the experimenter presented the object again, beginning another trial. The criteria for habituation were obtained when the holding time of 2 consecutive trials totaled a third or less of the total holding time of the first 2 trials. If the criterion of habituation had not been met by the 12th trial, the infant was excluded from the experiment. Immediately after habituation, the test phase began; 4 test trials were conducted in the same experimental conditions. Half of the infants (control group) received the familiar object (the object presented during the habituation phase) during all 4 trials, and the other half (experimental group) received the novel object twice, and then the familiar object twice. For the experimental group, we defined discrimination as having occurred when the mean holding time for the novel object (trials 1 and 2) was significantly greater than the mean holding time displayed in the last 2 habituation trials. If the preterm infants in the experimental group were capable of discrimination, we were then interested in their recognition of the familiar object. We defined recognition as having occurred when the mean holding time for the familiar object presented in test phase (trials 3 and 4) was significantly lower than the mean holding time for the novel object (trials 1 and 2). For the control group, we expected that the mean holding time for the familiar object presented during the test phase and the mean holding time displayed in the last 2 habituation trials would not differ significantly.

Data Collection
We recorded gestational age, gender, birth weight, antenatal steroid treatment, growth restriction, mode of delivery, Apgar scores at 5 and 10 minutes, necessity for endotracheal intubation, a nasal continuous positive airway pressure, a nasal cannula for oxygen therapy, and percutaneous intravenous catheter. On the test day, we recorded postnatal age, PCA, weight, and the presence or absence of a percutaneous intravenous catheter on the tested arm.

Statistical Analysis
All statistical analyses were conducted using SPSS 15.0 (SPSS Inc, Chicago, IL). Fisher’s exact test was used for the comparison of qualitative variables. A Student’s t test was used for mean comparisons during the habituation phase. The statistical test used to determine the phenomena of discrimination and recognition in both groups was an analysis of variance. The significance threshold was .05.

RESULTS
Characteristics of the Population
Fifty-three preterm infants were first included in the study; however, 5 preterm infants were initially wrongly considered as not being habituated while they were not in an arousal state 4 on the Brazelton scale (based on video analyses), so they were excluded from the experiment. Finally, 48 preterm infants were included in the study, and divided into 2 groups based on PCA at the time of testing: 24 very preterm (<32 GW) and 24 mildly preterm (between 32 and 33+6 GW). Information regarding gestational age at birth, postnatal age, PCA, birth weight, and weight at test can be seen in Table 1. All the preterm infants’ medical characteristics for both age ranges are reported in Table 2. There was no significant difference between the 2 groups in gender, antenatal steroid treatment, growth restriction, mode of delivery, or Apgar scores at 5 and 10 minutes.

Habitation Phase
The criteria for habituation were obtained for the 48 preterm infants (gradual reduction of holding time). No infant failed to habituate; each infant in a quiet wakeful state met the criterion of habituation before the 12th trial. The holding times for each trial and each age range are presented in Fig 1.

Three parameters of habituation were measured: mean total holding times occurring until the habituation criterion was reached, mean holding times for the first 2 trials, and mean number of trials conducted. We compared these parameters of habituation according to the object (prism or cylinder) and the age ranges (very preterm and mildly preterm). The results are presented in Table 3. For the very preterm group, a significant effect of the shape factor was found for the total holding time; preterm infants held the cylinder significantly longer than the prism (142 seconds vs 77.5 seconds) during habituation ($P = .043$). There were no other significant effects for either age range; moreover, parameters of habituation did not differ significantly between the 2 age ranges (all $P > .05$).

Test Phase
Comparisons were made between the medical characteristics of preterm infants in the control group and in the experimental group. The results are presented in Table 4. No significant differences were found.

The results of the test phase (Fig 2) were based on 2 phenomena: discrimination between a novel object and a familiar one, followed by recognition of the familiar object. The comparison of the quantitative parameters recorded during discrimination and recognition revealed no significant differences between the 2 age ranges (all $P > .05$).

Discrimination
For each age range, the results (Table 5) revealed that the experimental group held the novel object significantly longer than during the last 2 habituation trials; however, in the control group, the mean holding time for the familiar object
object and the mean holding time displayed in the last 2 habituation trials did not differ. These results revealed discrimination for each age range.

**Recognition**

For each age range, the results (Table 6) revealed that the experimental group held the familiar object presented during the test phase for a significantly shorter time than the novel object. Nevertheless, in the control group, the mean holding time for the familiar object presented during the test phase did not differ significantly between trials 1 and 2 and trials 3 and 4. These results revealed recognition for both age ranges.

**Clinical Description of Manual Exploration**

Video observations showed different patterns of behaviors during an object’s exploration: fixed states, little finger movements, wrist movements, and forearm movements. Either different patterns of behaviors could be observed for 1 infant during the experiment, or only 1 pattern could be observed for 1 infant. Patterns of behaviors were varied for each participant, suggesting that there was not a particular behavior of exploration for detecting discrepancies between objects.

**DISCUSSION**

The previous study published in February 2010 by Lejeune and her collaborators showed that from 33 to 34+6 GW, preterm infants were capable of manual habituation to, and discrimination of shapes. The current study, carried out in the same experimental conditions, revealed that the more immature preterm infants, from 28 GW, were able to remember through touch the specific features that differentiate prism and cylinder shapes, discriminate between them, and then recognize them after interference (presentation of a novel object).

During habituation, the 48 preterm infants showed a decrease in the holding time of the object in successive trials. The comparison of the quantitative parameters of habituation revealed no significant differences between the 2 age

---

**TABLE 1 Preterm Infants’ General Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Mean (SD), [range]</th>
<th>Very Preterm &lt;32GW</th>
<th>Mildly Preterm 32–33+6GW</th>
</tr>
</thead>
<tbody>
<tr>
<td>At birth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age, GW</td>
<td>29±2 (±1.2), [26+6–31+1]</td>
<td>32 (±0.6), [30+6–33+3]</td>
<td></td>
</tr>
<tr>
<td>Weight, g</td>
<td>1285 (±287), [830–1895]</td>
<td>1635 (±323), [1040–2240]</td>
<td></td>
</tr>
<tr>
<td>Time of testing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postnatal age, d</td>
<td>7 (2–4), [2–10]</td>
<td>6 (2.8), [1–10]</td>
<td></td>
</tr>
<tr>
<td>PCA, GW</td>
<td>30±2 (±1), [28–31+5]</td>
<td>33 (±5.0), [32–33+6]</td>
<td></td>
</tr>
<tr>
<td>Weight, g</td>
<td>1230 (±267), [825–1740]</td>
<td>1585 (±296), [1020–2240]</td>
<td></td>
</tr>
</tbody>
</table>

**TABLE 2 Preterm Infants’ Medical Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Very Preterm</th>
<th>Mildly Preterm</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boy</td>
<td>30</td>
<td>16 (66.5)</td>
<td>14 (58.3)</td>
</tr>
<tr>
<td>Girl</td>
<td>18</td>
<td>8 (33.5)</td>
<td>10 (41.7)</td>
</tr>
<tr>
<td>Antenatal steroids</td>
<td>38</td>
<td>20 (83.5)</td>
<td>18 (75)</td>
</tr>
<tr>
<td>Hypotrophy</td>
<td>4</td>
<td>2 (8.3)</td>
<td>2 (8.3)</td>
</tr>
<tr>
<td>Caesarean delivery</td>
<td>30</td>
<td>15 (62.5)</td>
<td>15 (62.5)</td>
</tr>
<tr>
<td>Apgar score &lt;7 at 5 min</td>
<td>2</td>
<td>2 (8.3)</td>
<td>0</td>
</tr>
<tr>
<td>Apgar score &lt;7 at 10 min</td>
<td>1</td>
<td>1 (4.2)</td>
<td>0</td>
</tr>
<tr>
<td>Intubation</td>
<td>26</td>
<td>18 (75)</td>
<td>8 (33.3)</td>
</tr>
<tr>
<td>nCPAP</td>
<td>33</td>
<td>20 (83.5)</td>
<td>13 (54)</td>
</tr>
<tr>
<td>Nasal cannula</td>
<td>18</td>
<td>13 (54)</td>
<td>5 (21)</td>
</tr>
<tr>
<td>Catheter</td>
<td>33</td>
<td>22 (69.7)</td>
<td>11 (45.8)</td>
</tr>
</tbody>
</table>

nCPAP, nasal continuous positive airway pressure; NS, no significant difference.
ranges. The degree of immaturity does not appear to influence the habituation process. In the group of very preterm infants, however, exploration of the cylinder was significantly longer than for the prism (142 seconds vs 77.5 seconds; $P = .045$), whereas in the older group, the holding time was similar for both shapes. This result is worth investigating in follow-up studies to look for medical and environmental factors that could provide an explanation.

After habituation, when an object with a novel shape was put in the preterm newborn’s hand, the holding time increased. This result reveals the presence, from 28 GW, of manual discrimination between a prism and a cylinder. Moreover, after interference (presentation of a novel object), recognition of the familiar object was obtained, as could be seen from the significant decrease in holding time. These results were objectified by the control group, who were presented with the same object throughout the entire experiment. Consequently, the grasping observed in infants from 28 GW cannot be attributed to reflex, because preterm infants were able to memorize tactile information about specific shape features, to detect the differences of shape when a novel stimulus was presented, and to recognize a familiar shape after interference. This notion of short-term memory in the preterm newborn is fairly new in the literature. Similar to the habituation phase, the comparison of the quantitative parameters recorded during discrimination and recognition revealed no significant differences between the 2 age ranges. Thereby, the degree of immaturity did not seem to influence the discrimination and recognition processes.

Finally, regarding the methodology of our study, the essential condition, and the 1 that was most difficult to obtain, was the correct estimation of the arousal state of the newborn. As a result, some preterm infants were initially wrongly considered as not being habituated while they were not in an arousal state 4 while they were not in an arousal state 4.

FIGURE 2
Discrimination and recognition according to the age ranges (very preterm <32 GW and mild preterm 32–35+6 GW) and the group (control versus experimental). *Significant difference.
in the attentive observation of the newborn is important; stimulation should be offered only to preterm infants who are in a quiet wakeful state, to respect their sleep-wake rhythms.

Our study reveals that preterm infants from 28 GW in a quiet wakeful state are capable of exploring their environment with their hands. During a preterm birth, the infant has to adapt quickly to modifications of the sensory environment. Moreover, the infant is exposed to unpleasant and inappropriate sensory stimulations. Our results show that the infant is endowed with tactile abilities, so certain applications can be proposed, especially in the context of developmental care: favoring tactile exploration while respecting sleep-wake rhythms. The tactile stimulations regularly proposed to the preterm infant during hospitalization should be adapted, must not be painful (grasping a blanket or a parent’s finger), and must respect the infant’s sleep-wake rhythm. In short, encouraging freedom of movement seems essential, to allow the infant to explore his or her environment. Because both the deep and light sleep states are indispensable to the infant’s development, it is therefore necessary to foster these priorities. It is also important for the medical team and the parents to be able to recognize a quiet wakeful state during which the infant is ready to communicate and to receive stimulation (hence the necessity of training in the attentive observation of the newborn). The purpose is neither to overstimulate the infant nor to impose tactile learning, but to offer the infant well-adapted tactile stimulations.

**CONCLUSIONS**

Preterm infants, even when very immature (from 28 GW), are endowed with tactile sensory abilities: the exploration and memorization of an object by touch, the discrimination of a novel object, and the recognition of a familiar object after interference. Several other experiments on tactile sensibility were conducted in the NICU. Our last study revealed that, in spite of the immaturity of the corpus callosum in preterm infants, its development seems to be sufficient to allow some transfer of information between both hands from 33 GW.

The purpose of these experiments on sensibility was to obtain a better understanding of the sensory abilities of preterm infants, to provide them with better care, and to improve their development.

**ACKNOWLEDGMENTS**

We thank the infants and their parents who participated in the experiment, and the staff members working in the Centre Hospitalier Universitaire (CHU) of Grenoble, the Centre National de la Recherche Scientifique (CNRS), and the Rhône-Alpes region.

**REFERENCES**

1. Lejeune F, Gentaz E. To perceive by the touch, an early capacity [in French]. Biofutur. 2011; 328(Nov):35–37


Tactile Sensory Capacity of the Preterm Infant: Manual Perception of Shape From 28 Gestational Weeks
Leïla Marcus, Fleur Lejeune, Frédérique Berne-Audéoud, Edouard Gentaz and Thierry Debillon

Pediatrics 2012;130;e88; originally published online June 25, 2012; DOI: 10.1542/peds.2011-3357

Updated Information & Services
including high resolution figures, can be found at:
/content/130/1/e88.full.html

References
This article cites 19 articles, 2 of which can be accessed free at:
/content/130/1/e88.full.html#ref-list-1

Citations
This article has been cited by 3 HighWire-hosted articles:
/content/130/1/e88.full.html#related-urls

Subspecialty Collections
This article, along with others on similar topics, appears in the following collection(s):
Developmental/Behavioral Pediatrics
/cgi/collection/development:behavioral_issues_sub
Fetus/Newborn Infant
/cgi/collection/fetus:newborn_infant_sub

Permissions & Licensing
Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at:
/site/misc/Permissions.xhtml

Reprints
Information about ordering reprints can be found online:
/site/misc/reprints.xhtml

PEDIATRICS is the official journal of the American Academy of Pediatrics. A monthly publication, it has been published continuously since 1948. PEDIATRICS is owned, published, and trademarked by the American Academy of Pediatrics, 141 Northwest Point Boulevard, Elk Grove Village, Illinois, 60007. Copyright © 2012 by the American Academy of Pediatrics. All rights reserved. Print ISSN: 0031-4005. Online ISSN: 1098-4275.
Tactile Sensory Capacity of the Preterm Infant: Manual Perception of Shape From 28 Gestational Weeks
Leïla Marcus, Fleur Lejeune, Frédérique Berne-Audéoud, Edouard Gentaz and Thierry Debillon
Pediatrics 2012;130;e88; originally published online June 25, 2012;
DOI: 10.1542/peds.2011-3357

The online version of this article, along with updated information and services, is located on the World Wide Web at:
/content/130/1/e88.full.html