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Manual cyclical activity as an exploratory tool in neonates

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Abstract

Haptic texture perception was investigated in 3-day-old infants. Following a habituation sequence with a smooth or granular object, babies received a haptic test during which they held either the familiar or a new textured object. Two dependent measures were recorded: (1) Holding time was used to assess habituation as well as reaction to novelty and (2) hand pressure frequency exerted on the object was used to investigate neonates' capacity to adjust their manipulation to the texture of objects. Both measures revealed neonates' capacity to haptically perceive the texture of objects. From the results, it can be concluded that neonate's manual cyclical activity recorded by HPF is a primary exploratory tool that is both necessary and sufficient to obtain knowledge about texture.

Keywords: Neonate; Cyclical manual activity; Haptic perception; Texture

Over the last few years, Bushnell and Boudreau (1991, 1993, 1998) have proposed a general model to account for the development of haptic perception in infants. This model relies heavily on the empirical work of Klatzky and Lederman and their coworkers on adult haptic perception (Klatsky & Lederman, 1993; Klatsky, Lederman, & Metzger, 1985; Klatsky, Lederman, & Reed, 1987; Lederman & Klatzky, 1987, 1990). Klatzky and Lederman have provided substantial evidence that, in adults, the haptic perception of object properties depends on the execution of specific "Exploratory Procedures." An "EP" is a stereotyped pattern of hand movements which is induced by the object properties that the haptic system chooses to process. According to Lederman and Klatsky, some EPs are "optimal": they are the most efficient to perceive a property. Others are "sufficient": they perform the task at above chance level. For example, in adults and for texture perception, the EP labeled "Lateral Motion" is optimal, and the EPs

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"Pressure," "Static Contact," "Enclosure," and "Contour Following" are all "sufficient" to provide gross information about this property. Bushnell and Boudreau have suggested that this adult haptic functioning, i.e., the link between particular hand movements and specific object properties, could also be successfully applied to an understanding of the rules of infant haptic development. The logic of their model is based on the idea that during the first year of life haptic perception is impaired in infants: Until the babies are able to execute the most efficient hand movement, i.e., the optimal EP, for assessing a certain object property, they are unable to accurately perceive that object property. In other words, the development of haptic perception is constrained by developmental changes in motor control. Bushnell and Boudreau suggest that there are three phases through which infants' manual motor abilities with objects progress during the first year. For each phase, Bushnell and Boudreau predict the types of object properties that infants should be able to perceive haptically.

From birth until approximately 3 or 4 months of age, infants are expected to simply clutch objects tightly in one or both fists. This clutch pattern reflects the execution of a palmar grasp reflex, i.e., an automatic closing of the fingers when the palm of the newborn's hand is stimulated. In this situation, babies are thought capable only of opening their hand and synergistically closing their fingers in a "kitten-like kneading pattern." This kind of hand motion gives access to the haptic perception of temperature, size and perhaps compliance. However, the perception of texture, weight and shape would be excluded because the babies do not execute the hand movements that yield accurate information about these properties. At about 4 months, babies enter the second phase. Hand movements with objects are now characterized by repetition, involving cyclical activities that allow the perception of texture, hardness and weight in addition to the perception of temperature and size. However, exact shape of an object would not be possible until the third phase of manual behavior with objects, which occurs at about 9 or 10 months. This phase is characterized by complementary bimanual activities and by the emergence of functional hand movements.

However, empirical data reported in the literature on neonate's haptic perception do not support the predictions of the Bushnell and Boudreau's model. Studies using the habituation paradigm have clearly shown that although neonates are not able to execute the specific hand movements necessary for the perception of shape and weight, they are nonetheless able to react to a change in shape property (Streri, Lhote, & Dutilleul, 2000) as well as to a change in weight property (Hernandez-Reif, Field, Diego, & Largie, 2001). These two studies give important insights into neonates' haptic competences: They allow us to know the haptic properties to which neonates can react. Unfortunately, because these studies are principally based on holding time analyses, they do not allow us to understand how neonates process these properties. Actually, holding time is a good descriptor of the attention-orientation toward a stimulus presented during habituation and test sequences but it fails to give any information about the characteristics of the haptic exploratory activity infants employ to pick up information about the physical properties of an object. Consequently, the above-mentioned studies leave open the question of how babies haptically process object properties that are supposed to remain inaccessible because of their hands' motoric limitations. Part of the answer to this question can be gleaned from studies of neonatal haptic perception that have used the hand pressure frequency (HPF) exerted on an object as the dependent variable. HPF involves the recording of the successive contacts between the skin and an object while the object is being explored by the hand. HPF recording has been successfully used in a series of studies conducted with neonates to assess the haptic perception of object substance (Rochat, 1983, 1987), and texture (Jouen & Molina, 2000; Molina & Jouen, 1998, 2001, 2003). Results of these studies provide clear evidence that neonatal manual activity cannot be characterized as a rigid archaic reflex activity nor simply as a clutch pattern. On the contrary, neonate's palmar grasp activity appears to be a cyclical activity that newborns modulate according to object properties such as rigidity and texture. In the rigidity study (Rochat, 1983, 1987), 2–4-day-old newborns squeezed more on hard than soft objects. This result is congruent with the prediction of Bushnell and Boudreau's model since clutch activity allows access to substance. In the texture study (Jouen & Molina, 2000; Molina & Jouen, 1998, 2001, 2003), 3-day-old newborns exerted greater HPF on a smooth versus a granular object. This interesting result suggests that contrary to Busnhell and Boudreau's proposal, neonate's cyclical manual activity may also be sufficient to obtain information about texture. Although neonates cannot evidently execute the optimal Lateral Motion Procedure to perceive texture, they could nevertheless make use of some broad procedures resembling the sufficient EPs defined by Lederman and Klatzky. Taken together, these results lead to the conclusion that contrary to Bushnell and Boudreau's model, motoric constraints do not constitute an obstacle to haptic perception in neonates. Instead, we suggest that the neonate's palmar grasp activity is a cyclical activity that babies use as a primary exploratory tool to acquire knowledge about object properties. Consequently, the neonate's manual activity is expected to be a dynamical process that takes place over time to permit the discovery of specific object properties (Gibson, 1988; von Hofsten & Lee, 1982). The present study was aimed at evaluating this hypothesis. To assess this goal, HPF exerted on objects of varying texture was analyzed during a habituation sequence followed by a test period. It was expected that during the habituation period, babies would obtain information about texture properties by means of exploratory hand activity: this would lead to different patterns of HPF according to objects' properties. Because exploratory hand activity is hypothesized to be devoted to the encoding of object properties, it was expected that once babies reached a habituation criterion, the presentation of a familiar object during a subsequent test period would lead to a decrease in exploratory behavior. On the contrary, it was expected that the presentation of a novel object would induce greater exploratory hand movement. Consequently, HPF was expected to be higher for a novel than for a familiar object.

1. Method

1.1. Participants

Thirty-two (16 males and 16 females) White Caucasian, middle class, newborn infants ranging in age from 3 to 5 days ($M = 4.12$ S.D. $= 0.78$) participated in the study. These infants were recruited directly through the maternity ward of Belvédère hospital in the Rouen community. All subjects had birth APGAR Scores of at least 8, had normal deliveries, and were not on medication. The mean gestation age was 40.0 weeks (S.D. $= 1.5$). The mean birth weight was 3355.4 g (S.D. $= 379$).

Haptic habituation with an infant controlled procedure was used. Half of the 32 babies received haptic habituation with a smooth object and the other half with a granular object. Infants were then randomly assigned to an experimental (novel object) or a control condition (familiar object). Table 1 summarizes the experimental design.

1.2. Stimuli

Two haptic objects were used in this experiment. Both objects (8 cm in length and 2.5 cm in diameter) were conic regular nipples used for lamb feeding. Each object weighed 20 Gs. The two objects varied

Table 1
Experimental design

Condition	Habituation phase	Test phase	Female (*N*)	Male (*N*)	Age in days	Range in days
SG	Smooth	Granular	4	4	4.13 (0.90)	3–5
SS	Smooth	Smooth	5	3	4.38 (0.52)	4–5
GS	Granular	Smooth	3	5	4.20 (0.83)	3–5
GG	Granular	Granular	4	4	3.88 (0.82)	3–5

only according to their texture density: Either smooth ("smooth" object) or granular ("granular" object). The smooth object consisted of the uncovered rubber uniform surface texture of the nipple. The granular object consisted of the same rubber surface on which thin plastic pearls were added and maintained by a nylon wire. Thirty pearls were attached in a repetitive configuration. Each pearl measured 2 mm in diameter. The total surface covered by the pearls was equal to 94.2 mm^2 in reference to the total surface of the fabric (1884 mm^2). By definition, the texture density ratio of the smooth object was equal to 0 and the texture density ratio of the granular object was equal to 0.05 (92.4/1884). Prior to any experiment, we verified that the presence of pearls did not affect the rigidity of the object: for an equal pressure exerted on each object, a signal of the same magnitude was obtained. The nipples were connected to a piezo resistive pressure sensor (ALCATEL Model DS1) which allowed recording of a differential positive pressure for up to 1.7 MPa. Right hand pressure exerted on the pipette was continuously sampled by a 12-bit A/D converter at a rate of 20 Hz and stored on a PC compatible computer for further analysis. In order to limit the aliasing effects of high frequency components, the signal was submitted to a filter involving FFT smoothing over a 5 measure mobile window and eliminating all frequencies equal to or above 4 Hz. The smoothing is accomplished by removing Fourier components with frequencies higher than $1/(n^* \Delta t)$ where n is the number of data points considered at a time (5), and Δt is the time spacing between two adjacent data points (0.05 s). Constant component and linear trend of the sample signal were also removed numerically. Each acquisition file contained N samples (20 Hz $\times$ n s), which therefore corresponds to the time series of the hand pressure.

1.3. Procedure

All the infants were observed in the morning after bathing and less than 1 h after the last feeding. The babies were placed in the mother's arm, in a semi-reclined position, facing the experimenter. They were free to move their arms. For habituation and test periods, one experimenter introduced the haptic object into the right hand of the infant by holding the object at its junction with the air pressure tubing. As soon as the infant grasped the object, the first experimenter signaled to a second experimenter the beginning of a trial. A trial ended when the baby released the object or after 60 s of continuous holding; in this latter case, Experimenter 1 gently opened the baby's hand and removed the object. Before testing, infants' arousal was manipulated according to Grenier's (1981) method to ensure that the newborn was in a state of alert inactivity at the start of the experiment. Behavioral state was then evaluated for each successive trial: newborns were tested in state 4 according to the NBAS. Data sampling was programmed to stop whenever the baby began to fuss or held the object for less than one second. However, because of the strict criteria we used (babies tested less than 1 h after the last feeding, babies wearing a clean diaper and

Table 2
Holding time-dependent variables

	Holding time throughout the habituation period (s)	Holding time during the two first trials (s)	Number of trials to reach criterion of habituation
Smooth	103.69 (74.35)	38.37 (31.69)	0.65 (1.97)
Granular	89.75 (69.19)	49.75 (44.71)	5.56 (1.67)
Both	96.72 (71.00)	44.06 (38.56)	6.03 (1.86)

babies observed in state 4), we never observed fussing in the neonates. During the habituation period, testing continued until nine trials had been presented or until a criterion of habituation had been met, whichever came first. The criterion for habituation was the same as that used by Streri et al. (2000). The criterion for habituation was reached when the duration of holding on any two consecutive trials, from the third trial onwards, totaled a third or less of the total of the first two. Each infant therefore received between four and nine habituation trials. Only one baby failed to reach the criterion of habituation. The mean number of trials to reach the habituation criterion was 6 (S.D. 1.81). As soon as the habituation period ended, the test period began. Each baby received two test trials, with each trial following the same procedure as the habituation trials.

During each trial of the habituation and test period, HPF was continuously sampled from each infant. As soon as the baby held the object in its hand, the first experimenter signaled to the second experimenter the beginning of the data sampling. As soon as the infant opened the hand and released the object, the first experimenter signaled to the second experimenter the end of the data sampling. One data sample was recorded for each trial of the habituation and test periods.

2. Results

2.1. Holding time

2.1.1. Habituation period

Infants' holding time during habituation trials was analyzed with a 2×4 mixed-model ANOVA with Habituation condition (Smooth or Granular) as a between subjects factor and with Trials (4) as a within Subjects factor. The main effect of Habituation condition was not significant, nor was the condition $\times$ trial interaction. This suggests that infants in the smooth condition and infants in the granular condition did not differ in their habituation rate. In both conditions, a main effect of the trials was observed, $F_{1\text{–}30} = 32.42$; $P < 0.0001$, revealing that, in each group, babies decreased their holding times as habituation progressed (see Fig. 1). No other significant effects were observed.

In order to quantify the habituation phenomena for texture, different variables were computed (Table 2). Nonparametric analyses were then performed on these variables. Mann–Whitney analyses failed to reveal a significant difference between condition in the number of trials to reach the habituation criterion ($U = 89.5$; $P = 0.147$), nor for holding times during the two first trials ($U = 123$; $P = 0.850$), nor for holding times throughout the habituation period, ($U = 113.5$; $P = 0.584$). These results confirm that infants in the smooth condition and infants in the granular condition did not differ in their habituation rate.

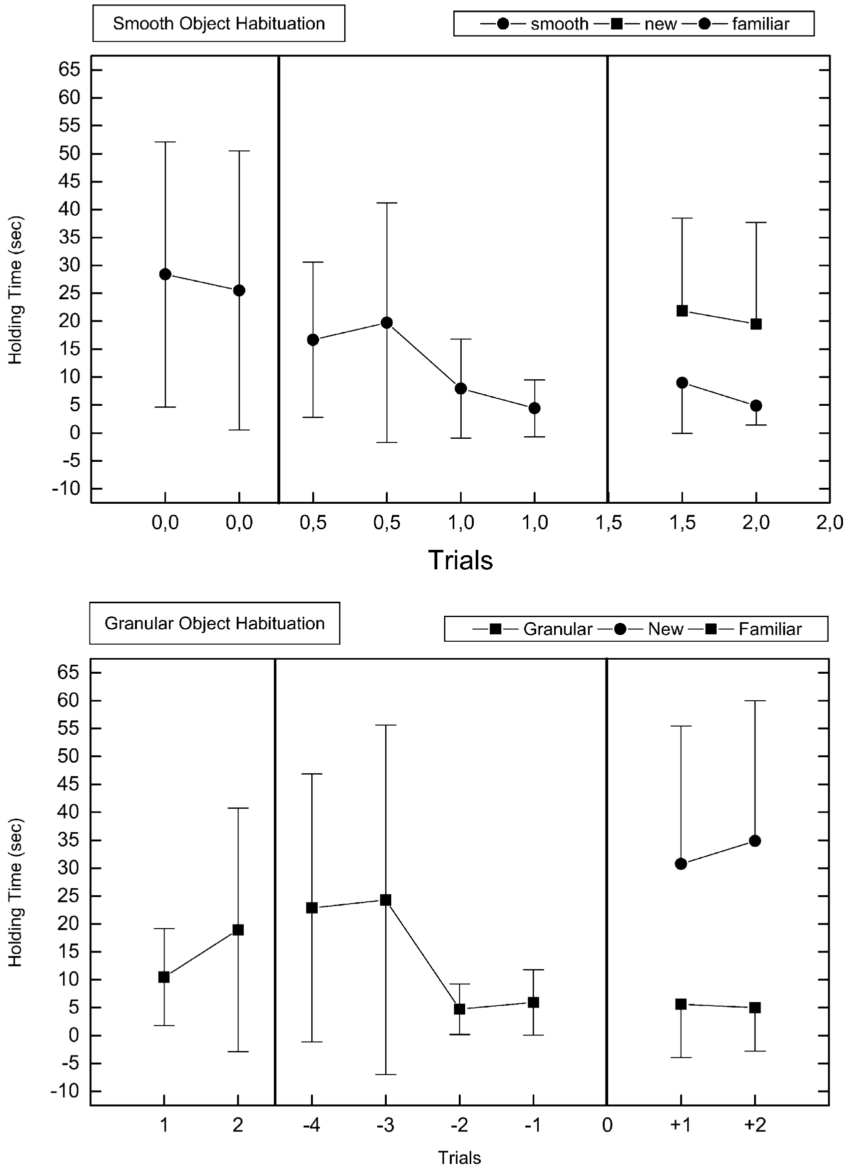

Fig. 1. Mean holding time in seconds and S.D. for the two first and for the last four habituation trials with the smooth and the granular object. Mean holding time in seconds and S.D. for familiar and new objects during the two test trials following habituation with the smooth object (upper panel) and with the granular object (lower panel).

2.1.2. Test period

Holding times during test trials were analyzed with a $2 \times 2 \times 2$ mixed-model ANOVA with Habituation condition (Smooth versus Granular) and Test object (Smooth versus Granular) as between Subject factors and with Trials (2) as a within Subject factor. Analyses revealed a single significant interaction between habituation condition and Test object, $F_{1\text{–}28} = 22.34$; $P < 0.0001$. After habituation to the smooth

Table 3
Holding time: test recovery

Conditions	Test recovery
SG	18.25 (16.23)
SS	3.75 (9.51)
GS	24.00 (24.95)
GG	0.50 (5.60)

object, babies presented with the new granular object held it for longer periods of time compared to babies presented with the familiar smooth object. Similarly, after habituation to the granular object, babies presented with the new smooth object held it for longer periods of time compared to babies presented with the familiar granular object. Planned comparisons were performed to further assess the reported phenomenon. After habituation to the smooth object, holding times during test trials were higher for babies holding the new granular object than for babies holding the familiar smooth object, $F_{1\text{–}28} = 4.964$; $P < 0.03$. After habituation to the granular object, holding times during test trials were higher for babies holding the new smooth object than for babies holding the familiar granular object, $F_{1\text{–}28} = 19.858$; $P < 0.0001$. These results were confirmed by nonparametric analyses. Mann–Whitney U revealed that during the two test trials, the new object was held for longer than the familiar object both after habituation to the smooth object, ($U = 53$; $P < 0.004$) and after habituation to the granular object ($U = 29$; $P < 0.0005$) (Table 3).

A final analysis was conducted to evaluate whether following the habituation period, the presentation of a new object induced a reaction to novelty such that babies in the Smooth Granular and Granular Smooth conditions displayed greater holding times during the test period than during the last habituation trial. A recovery score was calculated by subtracting (for each baby) the holding time during the first test trial from the holding time during the last habituation trial. This index is a measure of the amount of change in holding time from habituation to test period relative to each subject's own habituated holding level. Mann–Whitney U revealed that from the last habituation trial to the first test trial, the new object induced greater holding times than the familiar object both after habituation to the smooth object, ($U = 11$; $P < 0.027$) and after habituation to the granular object ($U = 5$; $P < 0.004$).

The results obtained from the holding time analysis provide clear evidence for the newborn's capacity to habituate to the texture of an object. The holding time analyses revealed that this capacity does not depend on the texture characteristic: regardless of the object's texture, the characteristics of each pattern of habituation were very similar. After a habituation sequence with a smooth object or with a granular object, the presentation of a newly textured object induces higher holding times than a familiar object. This conclusion is sustained by the following two results. First, during the test period, babies held a newly textured object for a longer period of time than an object with a familiar texture. Second, from the last habituation trial to the first test trial, newborn infants reacted to novelty when presented with a new object. No similar effects were observed when babies were presented with a familiar object during the test period. Taken together, this pattern of results provides clear evidence for neonates' capacity to 1° haptically perceive the texture of an object and 2° to react to a change in texture.

2.2. Hand pressure frequency analyses

Due to limitations in the period duration, spectral analyses such as the Fast Fourier Transform could not be applied to the data. As such, individual time series of positive hand pressure (expressed in Volts) were analyzed using the technique of peak analysis developed by Molina and Jouen (1998). Since the technique was described in greater detail in the previous study, only general principles of peak picking will be explained here. Prior to any calculation, the mean pressure and S.D. were calculated from the original signal for each time series of the sampled hand pressure. The method for peak picking uses a moving window over successive hand pressures. The height of the moving window was equal to 1 S.D. and its width was equal to 5 points. To be recognized as a peak, values must be found outside this mobile window in the Y range. Only pressures over 1 S.D. were identified as a peak if the duration of the response was equal to or above 250 ms in the X range. This allowed the file by file calculation of the peak number. From these data, the reduction peak frequency was derived. The peak frequency (expressed in Hertz) is the ratio of the peak number divided by the period duration. The following analysis is devoted to the description of the frequency response to smooth and granular objects.

2.2.1. Habituation period

Infants' HPF during habituation trials was analyzed with a 2×4 mixed-model ANOVA with Habituation condition (Smooth or Granular) as a between subjects factor and with Trials (4) as a within Subjects factor. Analysis revealed a significant effect of the Habituation condition, $F_{1\text{–}30} = 26.139$; $P < 0.0001$. As revealed in Fig. 2, during the habituation period, HPF was significantly higher for a smooth object than for a granular object. Analysis also revealed a significant effect of the Trials, $F_{1\text{–}30} = 7.39$; $P < 0.01$. As can be seen in Fig. 2, HPF decreased over the four habituation trials. No significant interaction was found between habituation condition and trials, revealing that the HPF decrease during the four habituation trials was observed equally for the smooth and granular objects.

2.2.2. Test period

HPF during the test trials was analyzed using a $2 \times 2 \times 2$ mixed-model ANOVA with Habituation condition (Smooth or Granular) and Test object (smooth or granular) as between Subjects factors and with Trials (2) as a within Subjects factor. Analysis revealed a significant effect of habituation condition, $F_{1\text{–}28} = 16.48$; $P < 0.001$. As revealed in Fig. 2, babies habituated with a smooth object had higher HPF during the test period than babies habituated with a granular object.

Analysis revealed a significant interaction between Habituation condition and Test object, $F_{1\text{–}28} = 46.40$; $P < 0.0001$. As can be see in Fig. 2, after habituation with a smooth object, babies presented with a new granular object had higher HPF compared to babies presented with a familiar smooth object. Similarly, after habituation with a granular object, babies presented with a new smooth object had higher HPF compared to babies presented with a familiar granular object. No other significant effects were observed.

Planned comparisons were performed to further assess the reported phenomena. After habituation with the smooth object, HPF during the test trials was significantly higher for babies presented with the new granular object than for babies presented with the familiar smooth object, $F_{1\text{–}28} = 18.87$; $P < 0.0001$. After habituation to the granular object, HPF during test trials was significantly higher for babies presented with the new smooth object than for babies presented with the familiar granular object, $F_{1\text{–}28} = 27.97$; $P < 0.00001$. These results were confirmed by nonparametric analysis. Mann–Whitney U revealed that for both smooth and granular habituation conditions, HPF was higher for the new object than it was for the familiar one (smooth condition, $U = 47.5$; $P < 0.0024$; granular condition, $U = 12$; $P < 0.000012$). In conclusion, these analyses confirmed that during the test period, HPF was systematically higher for a new object than for a familiar object.

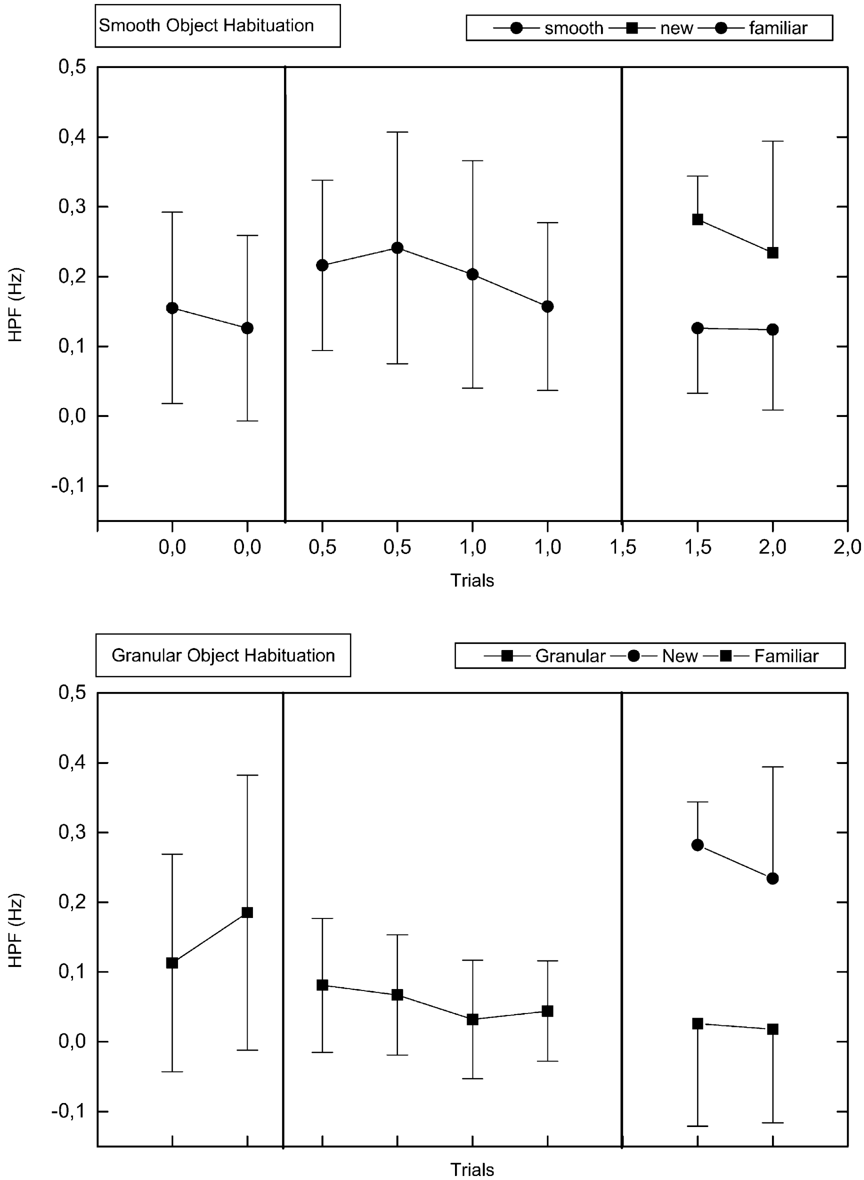

Fig. 2. Hand pressure frequency in Hertz and S.D. for the two first and the last four habituation trials with the smooth and the granular object. Hand pressure frequency in Hertz and S.D. for familiar and new objects during the two test trials following habituation with the smooth object (upper panel) and with the granular object (lower panel).

A final analysis was conducted in order to evaluate whether the two control groups (Smooth Smooth and Granular Granular conditions) and the two experimental groups (Smooth Granular and Granular Smooth conditions) would display greater HPF during the test period than during the last habituation trial. A recovery score was calculated by subtracting each child's HPF during the first test trial from the HPF during the last habituation trial. This index is a measure of the amount of change in HPF from habituation to test period relative to each subject's own habituated HPF level. Mann–Whitney U revealed that from the last habituation trial to the first test trial, the new object induced greater HPF than the familiar object both after habituation to the smooth object ($U = 5$; $P < 0.0045$) and after habituation to the granular object, ($U = 13$; $P < 0.046$).

The HPF analysis reveals two main points. First, during the habituation period, HPF depends on the texture of the object and it evolves as a function of the habituation trials: HPF was higher for a smooth than for a granular object and it decreased as the object became more familiar. Second, during the test period, HPF depends on object familiarity. Regardless of the object to which babies were habituated, presentation of a new object during the test trials induced higher HPF compare to the presentation of a familiar object. From these results, it can be concluded that 1° HPF is a cyclical activity under subject control and 2° HPF is devoted to the exploration of an object's properties.

3. Discussion

The analysis of holding time clearly demonstrated that neonates are able to haptically process the property of texture. After habituation to a smooth object, the presentation of a new granular object during the test period induced an increase in holding time. Similarly, after habituation to a granular object, the presentation of a new smooth object led to an increase in holding time. No such increase was observed when babies were presented with the familiar object during the test period. These results allow us to add texture to the existing list of properties that neonates can perceive haptically, i.e., shape (Streri et al., 2000) and weight (Hernandez-Reif et al., 2001). However, all of these properties are not supposed to be haptically perceived by neonates according to Bushnell and Boudreau's model (1993, 1998). This renders necessary an investigation of how newborns come to perceive haptic properties that are supposed to remain inaccessible to their hands. Although the habituation paradigm can be used effectively to demonstrate haptic competencies in neonates, holding time unfortunately does not provide any information concerning the way infant's haptic system processes texture. This question was at the heart of the present study, whose main goal was to investigate texture perception in neonates by shifting the focus to the actions young children exhibit while exploring objects of varying textures. Purposive hand movements that were defined in terms of successive pressure on the object were recorded. Hand pressure was then analyzed by studying the evolution of HPF during the habituation and test phases. Results obtained from this analysis point to two conclusions.

First, HPF does not indicate a reflex response triggered by an object's property. Two arguments sustain this conclusion. First, a reflex response is known to present a time-invariance and to remain stable over time: in this sense, a reflex response is not a good candidate for habituation (Bloch, 1985). Results obtained from the HPF analysis clearly showed that HPF evolved over time: HPF recorded for both a smooth object and a granular object decreased during habituation. This clearly means that as the object becomes increasingly familiar, babies decrease HPF exerted on the two types of objects. Second, if HPF was triggered by an object property, then during the test session a higher HPF would have been observed for a smooth object than for a granular object, whatever the object's degree of novelty. The pattern of results obtained does not fit with this reflex-based model. On the contrary, during the test period it was clearly apparent that HPF depended on object novelty rather than object properties: HPF was systematically higher for a new than for a familiar object. Rather than being triggered by an object property, HPF was under subject control.

The latter point leads to a second conclusion. HPF is a measure of palm and digit movements used as an *exploratory tool* to process object properties during manipulation. Following Gibson (1962), Lederman and Klatzky (1987, 1990) pointed out that the purposive hand movements that are necessary to perceive object properties result in successive contacts between the skin and the object. HPF involves the recording of a time series of cyclic contacts between the skin and an object that are performed during purposive exploratory hand movements. The use of such a tool is related to the degree of knowledge about the object. As long as the object is not familiar (e.g., during the habituation phase), the use of this exploratory tool is required and, under such circumstances, HPF depends on the object's texture, with higher frequencies observed for a smooth object and low frequencies recorded for a granular object. Once the object is known (*after* the last habituation trial), this tool becomes unnecessary since exploratory behavior is only required to verify that the object is unchanged. Consequently, HPF is expected to be at a very low level. In contrast, if the object is unknown (*after* the last habituation trial), the use of the exploratory tool is still required to obtain knowledge about the novel object. Once again, HPF is expected to be at a high level under these circumstances. As demonstrated in the results section, this is the pattern of findings that was observed. For babies holding the familiar object during the test session, HPF was lower during the test trial than during the habituation trial. On the contrary, for babies holding the new object during the test session, HPF was higher during the test trials than during habituation trials.

From these results, it can be concluded that the neonate's cyclical manual activity recorded by HPF is primarily an exploratory tool that is both necessary and nonspecific to obtain knowledge about objects. It is necessary because cyclical manual activity is the only tool to be used by neonates to get some knowledge about objects. This tool is also nonspecific since it could allow access to any properties such as shape (Streri et al., 2000), weight (Hernandez-Reif et al., 2001) and texture as reported in the present study. In that way HPF shares similar characteristics with "primary movement repertoire" described by Sporns and Edelman (1993). As any primary movement repertoire, manual cyclical activity would only be constrained by the mechanics of the hand, but would basically be unconstrained by experience. Consequently, the limitations in the neonate's manual motor activity cannot be considered as an obstacle to haptic perception that will be progressively overcome as motor development takes place. The question of interest for future research is to understand how this primary unconstrained movement repertoire will turn out to purposeful exploratory procedures described by Lederman and Klatzky.

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