The haptic processing of texture and shape by 7- to 9-month-old infants

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This study was designed to assess whether infants can encode both the texture and shape of the same haptic stimulus or alternatively are confined to encoding only one feature or the other. A sample of 24 infants (mean age 31.8 weeks) was familiarized to one stimulus and then presented with this familiar stimulus and two other stimuli, one being novel either in texture or shape and the other novel in both these features. Only haptic contact with the stimuli was permitted. The pattern of responses to the three stimuli confirmed that the infants encoded both texture and shape.

It is clear that 'haptic' (Gibson, 1966) processing provides an important source of information about the physical world for young infants. Studies employing an habituation procedure have demonstrated that infants are capable of discerning or discriminating key properties of stimuli such as shape (Gottfried & Rose, 1980; Mackay-Soroka, Corter & Abramovitch, 1979) and rigidity (Streri & Spelke, 1988) solely on the basis of haptic exploration (i.e. without attendant visual fixation). However, there are important aspects of haptic response in infants that have yet to be investigated.

Firstly, the capacity of infants to process other stimulus features in haptic terms has yet to be established. In particular, there is a need for further information on infant haptic response to texture. There is evidence for haptic sensitivity to texture when visual processing is also involved. For example, infants who were permitted to view and manipulate a stimulus subsequently showed different types of haptic response to a range of different stimulus textures (Ruff, 1984). Furthermore, infants have also displayed the capacity to detect a mismatch between visual and haptic information about texture (Bushnell & Weinberger, 1987). It remains to be ascertained whether infants demonstrate such responsiveness to texture solely in terms of haptic processing without visual involvement.

To achieve a relatively 'pure' estimate of haptic capacities, it is important that this assessment precludes any visual contact with the stimulus since visual input could conceivably contaminate the outcome-either because visual cues may facilitate haptic response or alternatively because visual cues could compete with and perhaps diminish haptic performance. In the framework of an habituation or familiarization procedure, this would mean haptically familiarizing infants to one texture and subsequently testing haptic response (without visual input) to a novel texture. This is one of the concerns of the current study.

Secondly, in addition to investigating haptic response to individual features such as texture, there is also a need to determine infant capacity to process more than one feature for the same stimulus. In terms of infant exploration of objects in the natural environment, it would seem necessary that if haptic information is to result in accurate or useful knowledge about objects, then infants should be able to encode more than a single haptic feature for any one stimulus. It has been well established that infants are capable of this with respect to visual stimuli (e.g. studies showing infant encoding of both the colour and shape of a stimulus, such as: Bushnell & Roder, 1985). However, it has yet to be determined whether this capacity generalizes to infant haptic processing as well.

The limiting factor in this regard may be the capacity of infant short-term memory to carry information about more than one feature simultaneously. If haptic features make large demands on memory, then only one feature may be successfully encoded- either because it has a serial advantage (i.e. is processed ahead of other features) and/or a temporal advantage (i.e. is processed at a more rapid rate than for other features). There are some indications that for infant visual processing, memory constraints may result in a tendency to focus or fix on some features to the neglect of others. For example, for very brief stimulus exposure intervals, infants may tend to process colour rather than shape for some stimuli (Rose & Slater, 1983) or infants may process colour and shape for stationary stimuli but when the stimuli are in motion, only colour and not shape may be encoded (Burnham, Vignes & Ihsen, 1988).

Such issues have not yet been explored for stimuli encoded by infants solely in haptic terms. The present study offers a preliminary assessment of these questions by determining the baseline issue of whether infants are capable of encoding two haptic features of the same stimulus within a relatively brief (30 s) exposure or whether they tend to focus on one feature alone.

There are numerous haptic features that could be investigated in regard to this question, but initially it would seem valuable to assess the relative salience of shape versus texture for infants. There is some evidence for differential encoding of these haptic features for older (preschool-aged) children who may favour texture over shape under some conditions (e.g. particularly for larger, two-dimensional stimuli) (Warren, 1982). The current study will examine whether infants also have a tendency to 'fix' on either texture or shape, or alternatively are able to encode both features to some degree for the same haptic stimulus.

Method

Subjects

There were 24 infants accepted for final analysis (mean age: 31.8 weeks; SD 3.0; range: 28-38 weeks).[1] A further seven infants were not included in the final analysis-five because of fretful behaviour du ring testing, one because of parental intervention and one other because of an aberration in the videotape record. The infants were randomly assigned to two experimental groups (details below) and to one of the four possible stimulus combinations (see Table 1) within each of these groups (equal numbers of infants for each stimulus combination).

Design and rationale

To reiterate, the aims of the study were to evaluate the capacity of infants to process the texture or shape of a stimulus solely on the basis of haptic exploration and to determine whether infants can encode both of these features for the one stimulus or alternatively will favour one over the other.

These abilities were evaluated by means of a familiarization procedure in which infants were accustomed to one stimulus and subsequently presented with three 'test' stimuli in successive, random order: the familiar stimulus and two novel stimuli, one differing from the familiar only in texture *or* shape (the 'novel 1 stimulus') and the other differing in both these features (the 'novel 2 stimulus'). Infants were randomly assigned to either the 'new-texture' or 'new-shape' novel 1 conditions. Only haptic contact with the stimuli was permitted throughout the task (see Table 1 for summary of design).

Table 1. Design and stimulus combinations

	Stimuli		
Novel 1 condition[a]	Familiar	Novel 1	Novel 2
(a) New-shape			
(i)	rough sphere	rough cube	smooth cube
(ii)	smooth sphere	smooth cube	rough cube
(iii)	rough cube	rough sphere	smooth sphere
(iv)	smooth cube	smooth sphere	rough sphere
(b) New-texture			
(i)	rough sphere	smooth sphere	smooth cube
(ii)	smooth sphere	rough sphere	rough cube
(iii)	rough cube	smooth cube	smooth sphere
(iv)	smooth cube	rough cube	rough sphere

• Novel 1 condition is a between-subject factor and stimuli is a within-subject factor.

[1] The age range for the study was selected partly on the basis of the range of ages tested in past studies of haptic abilities-most have ranged from 5 months (Streri & Pecheux, 1986) to 12 months (Gibson & Walker, 1984)-and partly on the basis of pilot testing with the current apparatus and procedure which indicated maximum cooperation was likely with infants of this age range. Older infants tended to make vigorous, and often successful, efforts to remove the bib in order to view the stimulus, while it was difficult to induce younger infants to maintain the posture needed to effectively manipulate the stimuli. However, the selected age range satisfactorily fulfils the requirement to employ a group of 'pre-verbal' infants who would be unlikely to encode the stimulus parameters in verbal terms.

If infants are able to encode both the shape and texture of the familiar stimulus, then this should produce the following pattern of responses to the test stimuli in each novel 1 condition: novel 2 > novel 1 > familiar stimulus, since both novel features would be detected for novel 2 as would the respective single novel feature for each novel 1 stimulus.

Stimuli

The stimuli consisted of four rigid plastic shapes (two identical cubes and two identical spheres) (approx. 3.5 cm in diameter) of similar weight and density. One cube and one sphere were covered in a knitted fabric, which provided a rough surface texture and the other cube and sphere were left bare, which provided a smooth, slippery surface texture. The stimuli were mounted at the base on wooden paddles (1 cm thick) to facilitate presentation and withdrawal during testing (details below) but otherwise virtually the whole surface area of the shapes was free-standing and could be explored by the infant.

Testing area and apparatus

The infant was seated on the parent's lap before a table. The experimenter sat at the opposite end of the table but was hidden from the infant's view by an upright wooden partition mounted midway across the table, about 40 cm from the infant. The partition had two apertures- one at the base which permitted the stimulus paddles to be inserted and moved towards the infant and another immediately above for a video camera which was mounted on the experimenter's side of the partition. At the infant's end, the table edge was cut into a concave shape enabling the parent to sit so that the infant's chest was virtually flush with the table and his/her arms and hands were resting on the table surface. Cushions were used to adjust seating height. The table area on which the infant's hands rested was screened from the infant's view by a rectangular fabric cover which was suspended 10 cm above the table surface and attached at each of the shorter ends to two wooden barriers (approx. 40 x 10 cm) mounted on the table surface to the left and right of the infant.

The cover screened an area on the table surface from the infant's end to the upright wooden partition and was approximately shoulder height on the infants. At the infant's end, a bib was attached at one end to this cover (after Streri & Pecheux, 1986) and at the other to the infant, giving the infant some freedom of movement but preventing the infant from viewing under the cover. The entire testing area was screened and most surfaces (including the table, partition, cover, etc.) were white or cream so that there was little alternative visual stimulation apart from the immediate testing apparatus. The testing area was dimly illuminated by a shielded fluorescent lamp above and behind the infant.

Procedure

Infants were seated in the testing area for several minutes prior to testing to accustom them to the surroundings. The parent then took the infant's hands, placed them on the table surface and played with them to accustom the infant to tactual stimulation under the cover.

The familiarization trial then began with the experimenter inserting the stimulus paddle through the partition towards the infant's hands. The paddle extended from the infant's to the experimenter's side of the table and prevented the infant from removing and hence viewing or dropping the stimulus. The parents were instructed to place both of the infant's hands on the stimulus and then to release them. The parents were only given broad information about the task prior to testing and were naive as to the exact hypothesis. If the infant withdrew his/her hands, then the procedure was repeated until 30 s of manipulation had been accrued. A similar 'familiarization', rather than 'habituation' procedure, has been successfully employed in past studies of infant tactual response (e.g. Gottfried & Rose, 1980) and was used here to ensure that all infants had comparable exposure to the initial stimulus. Moreover, this procedure obviates the need continually to remove and replace the stimulus which may increase infant distress. The familiarization interval of 30 s was selected on the basis of pilot testing with the current apparatus and age group as being optimal for minimizing subject attrition rates. Trial duration was monitored and controlled by the experimenter.[2]

Following the familiarization trial, the three test trials were then administered in random order. A successive rather than simultaneous presentation of the test stimuli was employed on the advice that the former is easier to code (Rolfe-Zikman, 1987). On each of the test trials, the parent was again instructed to replace both of the infant's hands and then to release them immediately. If the infant failed to maintain contact for at least 1 s, the parent was instructed to try again. The trial was timed for 15 s from the point at which the parent released the baby's hands (and contact was maintained). If the infant broke contact after this initial manipulation, the parent was asked to refrain from re-establishing contact.

A video record was maintained of the infant's manipulation of the stimuli and was subsequently scored for total (cumulative) manipulation time on each test trial by a naive observer with a digital stopwatch. The observer was unaware of the aims of the study and was only permitted to view the three test trials and not the familiarization trial in order to prevent the possibility of inferring the hypothesis from the latter information. The observer was instructed to time the infant's contact with the stimulus from the point at which the parent released the infant's hands on each trial. 'Contact' was to be taken as either grasping the stimulus with the whole hand and resting or moving the fingers or hand(s) over the surface of the stimulus. A second observer co-scored a random selection of half the final sample of infants and agreement with the first observer was estimated as $r = .96$. On this basis, only the first observer's scores were used for analysis.

Results

The dependent variable in the main analyses was the total (i.e. cumulative) manipulation time (seconds) for each of the three test stimuli. The response to the test stimuli was first assessed by means of a 2 x 3 ANOVA (novel 1 condition x test stimuli) which compared the response to each of the three stimuli (familiar vs. novel 1 vs. novel 2) for each novel 1 condition (new-shape vs. new-texture).

The only significant effect of the ANOVA was the main effect for test stimuli ($F(2, 44) = 25.62$, $p < .001$) with the respective mean scores for the familiar, novel 1 and 2 stimuli being 4.8, 8.5 and 11.9 s. Further *a priori* (one-tailed) *t* tests confirmed that the novel 1 stimulus was manipulated more than the familiar stimulus for both the new-shape and new-texture conditions ($t(11) = 2.12$, $p < .05$ and $t(11) = 3.10$, $p < .01$, respectively) and that the novel 2 stimulus was manipulated more than the novel 1 stimulus for both of these conditions ($t(11) = 2.66$, $p < .05$ and $t(11) = 2.45$, $p < .05$, for the new-shape and new-texture conditions, respectively) (see Table 2 for mean scores).

This pattern of results suggests that the infants had encoded both the shape and texture of the familiarization stimuli. However, it is feasible that this pattern of results could have arisen if infants had in fact only encoded one or other of these features, with half the infants encoding shape and the other half texture. In this situation, the former infants would have responded as follows: (novel 2 > novel 1 = familiar stimulus) in the texture condition and (novel 2 = novel 1 > familiar stimulus) in the shape condition, with the converse pattern for the texture-bias infants. The overall product would have been an 'averaging' effect resembling the present pattern of results. But since only three infants gave responses consistent with this interpretation, it seems unlikely that this is a viable account of the results.

[2] Infant behaviour varied during the familiarization phase when not directed to the experimental stimulus. Some infants were more haptically active than others at such times, making contact with the bib or the parent, while others simply maintained their hands in passive contact with the table surface or withdrew them to their laps.

Table 2. Mean manipulation times (seconds) on test trials

Novel 1 condition	Familiar	Test stimulus Novel 1	Novel 2
(a) Texture			
$\bar{X}$	4.8	9.0	12.3
SD	3.6	5.0	3.5
(b) Shape			
$\bar{X}$	4.9	8.0	11.6
SD	4.4	4.2	3.9

Finally, two other analyses were performed to check for possible confounds due to experimental procedure.

Firstly, to ensure that no order effects had contaminated the response on the test trials, an analysis of the relationship between test order and test response (total manipulation in seconds on the test trial) was conducted for each novel 1 condition. There was no evidence of any effect of test order on test response: $r_P = -.11$ and $r_P = .06$ for the new-shape and new-texture groups, respectively.

Next, to ensure that the experimenter had not inadvertently biased the results by using different criteria for permitting the parent to restart the test trials, the number of 'false starts' was calculated by a naive observer from the videotape records for a random sample of 12 infants (six from each of the two novel 1 conditions). The main concern in this regard is that the experimenter may have encouraged more restarts for the novel stimuli than for the familiar stimulus on the expectation that the infants' contact with the former should be lengthier than that with the latter. In fact, the results show the opposite trend. There were somewhat more false starts for the familiar stimulus (nine overall) than for the novel 1 or 2 stimuli (five and six, respectively) although these differences were not significant ($X^2(2) = 1.3$). This result is not consistent with bias of the kind described above and on the contrary might be expected if infants recognized the familiar stimulus and were somewhat more reluctant to re-initiate contact with this stimulus than with either of the novel stimuli.

Although the study was not aimed at evaluating the nature of the infants' manipulation of the test stimuli (as in Ruff, 1984), the video records were coded for the general style of contact in terms of whether the stimuli were stroked with the fingers or grasped with the whole hand (or some mixture of these responses). For the two novel stimuli, infants reacted almost uniformly by briefly fingering the stimulus at first and then grasping it with the whole hand or fingers (100 per cent of all contact for novel 1 stimuli and 92 per cent for novel 2). This was also the main kind of response for the familiar stimulus (on test trials) although the incidence was lower (75 per cent) with a somewhat greater occurrence of fingering (non-grasping) responses in this case (25 per cent).

Discussion

The results reaffirm past findings (Gottfried & Rose, 1980) that infants are capable of encoding stimulus shape on the basis of haptic manipulation alone and extend these findings by demonstrating that infants can also process texture in these terms. Moreover, the pattern of results also indicates that within 30 s of exposure, infants are able to encode both the shape and texture of the same haptic stimulus and are not confined to processing only one or the other feature.

More definitive estimates of the relative extent of encoding of shape and texture could be inferred from a comparison of the magnitude of the respective novelty responses for each feature. However, this would presuppose that the features were comparably scaled-that is, that the perceived discrepancy between familiar and novel stimuli was similar for each feature. Given the difficulty of guaranteeing this precondition within current methodological limitations, the present experiment was not intended to offer conclusive quantification of the relative encoding of shape and texture, but rather to confirm the more fundamental question of whether both these features could be encoded at all for the same haptic stimulus. This baseline issue is clearly answered in the affirmative.

It is not feasible to determine from the current experiment the actual pattern of encoding used by the infants- that is, whether shape and texture were processed in parallel (simultaneously) or in series (one at a time). The present pattern of results could have arisen from either scenario, with infants either encoding shape and texture simultaneously at a similar rate, or in series with the rate of processing being sufficiently rapid to permit adequate encoding of both features within the time frame of the experimental procedure. Future studies could possibly examine this question more closely by systematic variation of the time permitted for initial stimulus familiarization.

Some tentative clues in regard to this question may be found in the style of contact with the stimulus that is displayed by infants. For example, in the current study the infants tended briefly to finger the test stimuli and then proceed to full grasping. This *could* suggest that texture was being sampled (via the brief fingering) and then shape (by the grasping). In any event it may also be useful for future studies to examine the concordance between contact style and depth of encoding for particular features in more detail.

Of course the current findings may not generalize to all stimuli or all textures and shapes. As indicated previously, older children are more likely to encode texture than shape for stimuli which are large or two-dimensional (Warren, 1982). If the stimuli in the current study had been larger or two-dimensional, the infants may have responded likewise.

However, even if different stimuli or different exposure times do yield different outcomes, the current findings have clearly established the baseline proposition that infants are *capable* of encoding both the texture and shape of the same stimulus after a relatively brief (30 s) exposure. This capacity would seem to be crucial if infant exploration of objects in the 'real world' is to generate multidimensional (as opposed to unidimensional) representations of object properties or identity.

Accurate or veridical recognition of objects demands such a representation and it is clear that at least in terms of shape and texture, the infant haptic system is an adequate medium for providing such information.

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