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Intermodal matching by human neonates

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Normal human adults judge two identical objects to have the same shape even when they are perceived through different modalities, such as touch and vision. The ontogenesis of man's capacity to recognise such intermodal matches has long been debated. One hypothesis is that humans begin life with independent sense modalities and that simultaneous tactual and visual exploration of shapes is needed to learn to correlate the separate tactual and visual sense impressions of them[1-3]. A second hypothesis is that the detection of shape invariants across different modalities is a fundamental characteristic of man's perceptual–cognitive system, available without the need for learned correlations[4-7]. Recent research has shown that 6–12-month-old infants can recognise certain tactual–visual matches[8-11]. However, such data cannot help resolve the classic theoretical debate. Infants of this age repeatedly reach out and touch objects they see, and such simultaneous bimodal exploration presumably offers ample opportunity for learning to correlate tactual and visual sense impressions. The experiments reported here show that humans can recognise intermodal matches without the benefit of months of experience in simultaneous tactual–visual exploration. We demonstrate that 29-day-old infants can recognise which of two visually perceived shapes matches one they previously explored tactually, thus supporting the second hypothesis listed above.

For our assessment of intermodal matching, we adapted a paradigm used to test infant memory[12]. We began with a brief familiarisation period during which the infant tactually explored an object. Next, the infant was shown a pair of visual shapes, only one of which matched the tactual stimulus. Visual fixation to the matching versus non-matching shape was then recorded. Three experimenters were used to ensure objectivity of the results. One experimenter selected the tactual shape and the left–right positioning of the visual shapes. This experimenter was not involved with testing the infant. A second experimenter administered the tactual stimulus. He was not informed about the left–right positioning of the visual shapes. A third experimenter observed the infant's visual fixations through a 0.64-cm peephole in the centre of the rear wall of the testing chamber. He was unaware of both the tactual shape used and the left–right positioning of the visual shapes. Corneal reflections of the test objects were visible to this scorer, but the shapes of the objects were not resolvable. He scored the infant as fixating the left object when the left reflection was visible in either of the infant's pupils, and as fixating the right object when the right reflection was visible[13]. These fixations were recorded on a Rustrack event recorder. Inter-observer agreement was high when assessed in both experiments (0.93, experiment 1; 0.98, experiment 2).

Thirty-two full-term infants ranging from 26 to 33 days old (mean 29.4 d) served as subjects in experiment 1. As infants of this age will not explore objects manually, the tactual stimuli were constructed by modifying pacifiers so that small, hard-rubber shapes could be mounted on them (Fig. 1). The matching shapes used for the visual test were constructed from dense Styrofoam and painted bright orange (diameter 6.4 cm). The experiment started with a 90-s tactual familiarisation period during which infants orally explored one of the tactual stimuli. This stimulus was then removed and the infant presented with both visual shapes for a 20-s visual test. Care was taken to ensure that the tactual stimulus was administered and removed without the infant seeing it. The shape used for tactual familiarisation, the left–right positioning of the visual objects, and the sex of the infants were counterbalanced. Thus, half the infants were tactually familiarised with the sphere and half with the sphere-with-nubs; half the infants in each of these groups were shown the familiar shape on the left and half on the right; half the infants within each of these subgroups were male and half female.

The results clearly demonstrate that infants under 1 month of age are capable of intermodal matching (Table 1). Of the 32 infants, 24 fixated the shape matching the tactual stimulus longer than the non-matching shape. These results were significantly different from chance ($P<0.01$; binomial test). The mean per cent of total fixation time directed to the matching shape was 71.8%, as compared with the chance level of 50% ($t=3.07$; $P<0.01$). There were no significant differences due to sex of the infant, familiarisation object or method of feeding (breast or bottle), nor were there significant preferences for fixating the right versus left side or for fixating the sphere versus sphere-with-nubs.

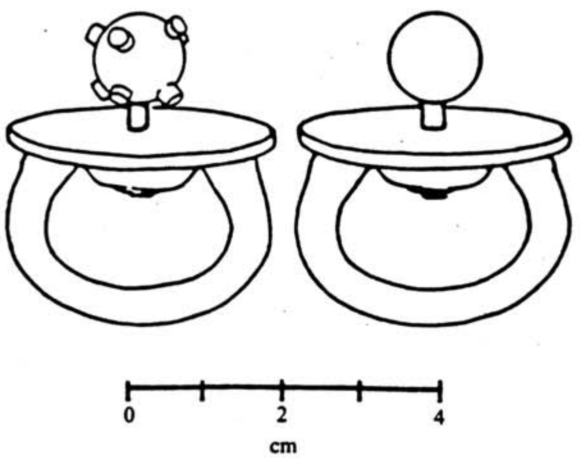

Fig. 1 The tactual objects. The tactual shapes were 1.2 cm in diameter. They were moulded from G.E. RTV-630A silicone rubber and fixed to a threaded nylon rod (6–32) that was bolted to the pacifier backing. The sphere-with-nubs was administered so that four of the nubs were orientated towards the base of the infant's mouth and four towards the roof. The nubs on the sphere were 2 mm high × 3 mm wide. The tactual stimuli were administered while the infant sat in an infant chair with his back to the visual objects. They were administered without the infant seeing them by having the experimenter hide them in his cupped hand while he was bringing the objects to and from the infant's mouth. The tactual familiarisation period started as soon as the infant began sucking on the tactual shape. Ten seconds before the end of the familiarisation period, the room lights were extinguished and the infant's seat was swivelled around so that he faced the visual objects. When the familiarisation period ended, the experimenter removed the tactual object, centred the infant's head midway between the visual objects, and only then switched on the light illuminating the visual objects. As soon as the infant made his first fixation to either object, the visual test period began, and the experimenter removed his hands from the infant. The centres of the visual objects were 28 cm apart and 32 cm from the infant's eyes. They were displayed in a three-sided black cardboard chamber 71 cm high × 112 cm wide × 52 cm deep, and each suspended from the ceiling of this chamber by a thin black rod (diameter 0.64 cm). Illumination for the visual objects was provided by an incandescent bulb directly above and behind the infant's head, yielding a luminance of approximately 0.86 log cd m^{-2} at the objects and −0.14 log cd m^{-2} at the background midway between the objects. The visual sphere-with-nubs was orientated so that four of the nubs directly faced the infant. Each nub on the visual object was 1.1 cm long and 1.2 cm in diameter and fashioned from a section of wooden doweling with the edge rounded.

Table 1 Numbers of infants who looked longer at the object matching one they had explored tactually, compared with those who looked longer at the non-matching object

	n	Looked longer at matching shape	Looked longer at non-matching shape	*P* (binomial test, two-tailed)
Expt 1	32	24	8	0.01
Expt 2	32	22	10	0.05

Studies using paired-comparison paradigms usually report a preference for the novel stimulus. The present findings are not incompatible with this, as there are several important procedural differences between the present experiments and those previously reported. For example, the present experiments (1) used infants younger than typically tested with the paired-comparison technique, (2) assessed tactual–visual rather than visual–visual matching, (3) used three-dimensional forms rather than two-dimensional patterns, (4) used a 90-s tactual familiarisation period. These differences may interact to influence the direction of infant visual preference.

A second experiment checked whether different experimenters using a different sample of infants could replicate the previous effects. A new group of 32 full-term infants 27–31 days old (mean 29.4 d) served as subjects. The procedure was identical to that used in experiment 1 and the effects were replicated (Table 1). Of the 32 infants, 22 fixated the matching shape longer than the non-matching one ($P = 0.05$). The mean per cent of total fixation time directed to the matching shape was 67.1% ($t = 2.14$; $P < 0.05$).

These experiments used a successive, intermodal matching task. The tactual object was no longer in the perceptual world at the time the infants were presented with the visual test. Positive results from such a task indicate that neonates can (1) tactually discriminate between the shapes presented, (2) visually discriminate between them, (3) store some representation of the tactually perceived shape, and (4) relate a subsequent visual perception to the stored representation of the tactually perceived shape. The last point has implications for our current theories of infancy.

A basic assumption of Piagetian theory[3] is that infants begin life with independent sense modalities that gradually become intercoordinated with development. Our findings, however, show that neonates are already able to detect tactual–visual correspondences, thereby demonstrating an impressive degree of intermodal unity. Thus, whatever develops in the first year of life, it is apparently not the *de novo* coordination of functionally independent sense modalities. A more general implication of the present research is that human neonates are not limited to processing bits of sense-specific information such as retinal images or tactual sensations. If neonates were restricted to registering such sensory elements they could not succeed on these intermodal matching tasks. Obviously, these initial experiments do not isolate the exact nature of the information perceived as invariant across the different modalities. However, they suggest that neonates are capable of using and storing surprisingly abstract information about objects in their world. This information must be abstract enough, at least, to allow recognition of objects across changes in size and modality of perception.

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