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Fragility of haptic memory in human full-term newborns

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ABSTRACT

Background: Numerous studies have established that newborns can memorize tactile information about the specific features of an object with their hands and detect differences with another object. However, the robustness of haptic memory abilities has already been examined in preterm newborns and in full-term infants, but not yet in full-term newborns. This research is aimed to better understand the robustness of haptic memory abilities at birth by examining the effects of a change in the objects' temperature and haptic interference.
Methods: Sixty-eight full-term newborns (mean postnatal age: 2.5 days) were included. The two experiments were conducted in three phases: habituation (repeated presentation of the same object, a prism or cylinder in the newborn's hand), discrimination (presentation of a novel object), and recognition (presentation of the familiar object). In Experiment 1, the change in the objects' temperature was controlled during the three phases.
Results and conclusion: Results reveal that newborns can memorize specific features that differentiate prism and cylinder shapes by touch, and discriminate between them, but surprisingly they did not show evidence of recognizing them after interference. As no significant effect of the temperature condition was observed in habituation, discrimination and recognition abilities, these findings suggest that discrimination abilities in newborns may be determined by the detection of shape differences. Overall, it seems that the ontogenesis of haptic recognition memory is not linear. The developmental schedule is likely crucial for haptic development between 34 and 40 GW.

1. Introduction

Touch is the first sense to develop in utero. Regarding its primacy during prenatal development, one can assume that tactile perception is very important to the developing organism (Bremner & Spence, 2017; Heller & Gentaz, 2013). At birth, pressure exerted by an object placed in the palm of the newborn's hand triggers the closing of their fingers around the object: this is the well-known grasping reflex. However, this is not only a pure reflex. This tactile manual exploration of objects is an active haptic process allowing newborns to gather information about their environment (Streri, de, Hevia, Izard, & Coubart, 2013). Indeed, studies have revealed that full-term newborns are able to discriminate, without visual control, different properties of objects with their hands, like weights (Hernandez-, Reif, Field, Diego, & Largie, 2001; Molina, Guimpel, & Jouen, 2006), textures (Molina & Jouen, 2004), substances (Rochat, 1987), temperatures (Hernandez-, Reif, Field, Diego, & Largie, 2003), and shapes (Streri, Lhote, & Dutilleul, 2000). This research is aimed to further examine these haptic abilities.

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The procedure commonly used for studying haptic abilities in newborns is a habituation/discrimination procedure (without visual control). Habituation is defined as a progressive disinterest in a stimulus and consists in the repeated presentation of an object in the newborn's hand in successive trials. The newborn is considered habituated to an object when the holding time of this object decreases until it attains a criterion. This criterion in the tactile modality is classically defined for studies in newborns as follow: holding time in any two consecutive trials, from the third trial onward, totaled a third or less of the total holding time in the first two trials (Lejeune et al., 2010; Sann & Streri, 2007; Streri & Gentaz, 2003; Streri & Gentaz, 2004; Streri et al., 2000). Immediately after habituation, a different object (for example, a different shape) is presented in the newborn's hand. Discrimination corresponds to the renewed interest towards the novel object and reveals the ability of the newborns to memorize tactile information about the specific features of an object and detect differences with another object (discrimination). This procedure provides evidence of haptic memory abilities in newborns.

During the habituation/discrimination procedure, holding the same object in the hand trial after trial could have led to an increase in its temperature. Indeed, the hand should be at body temperature (37 °C) and the object, at room temperature (25 °C). The physical phenomenon of thermal conduction stipulates that the system is no longer in equilibrium when two surfaces of two different temperatures are in contact. A transfer of heat is thus necessary from the hottest surface to the coolest one to recover a state of equilibrium characterized by a uniform temperature (Jones & Ho, 2008). Furthermore, newborns are able to discriminate cold from warm objects with their hands, varying only of few degrees (4.4 °C; Hernandez-Reif et al., 2003), it is possible that the difference of temperature between the habituated object and the novel one at least partially explains the discrimination abilities in newborns. In other words, the early haptic abilities could not only concern the discrimination of a single property (shape, texture, or weight), but also its combination with the perception of the temperature change.

Lederman and Klatzky (1993) distinguished two different object dimensions. The geometrical dimension relates to the structure of the object and its spatial characteristics (shape and size). The material dimension refers to a small deviation of the geometry of the surface that does not alter the shape of the object (temperature, weight, texture and substance). Three-month-old infants are able to discriminate objects which differed on their material properties, including texture, temperature, substance, and weight (Striano & Bushnell, 2005). The distinction between the two dimensions is supported by a behavioral study in newborns examining their abilities to transfer shape and texture information from vision to touch and from touch to vision (Sann & Streri, 2007). The results showed that newborns visually recognized a shape previously held but they failed to tactually recognize a shape previously seen. In contrast, a bi-directional cross-modal transfer of texture was observed. It seems that newborns would process material and geometric dimensions differently in the visual and tactile modalities. Moreover, touch is more specialized in the perception of material properties than in the perception of the geometric dimension, an area of excellence of vision (Lederman & Klatzky, 1997). As a material dimension, it is likely that the temperature is preferentially treated by the newborns' hands in comparison to the geometric dimension. This question needs to be investigated in order to disentangle the role of temperature in the haptic memory abilities in newborns.

The habituation/discrimination procedure (comprising two phases: the habituation phase followed by the discrimination phase) provides evidence of haptic memory abilities in newborns but it does not give information about the robustness of this haptic memory. This procedure can thus be completed by a recognition phase. It consists in the presentation of the familiar object following the presentation of the novel shape (considered as interference). This 3rd phase allows one to study the robustness of haptic memory by examining the ability of the newborn to maintain the tactile information of the habituated shape in his/her memory during haptic interference (presentation of another object). We call it the haptic recognition memory.

Lhote and Streri (1998) studied the robustness of haptic memory in 2-month-old infants. They used an infant-controlled criterion to determine a successful habituation which takes into account the important inter-individual variability in infancy as it does not limit the duration of their exploration. In this study, the stimuli were presented in either the infant's right or left hand and they were a pair of flat objects (disk and square) and a pair of volumetric objects (cone and plate). The haptic shape recognition memory following interference was observed in 2-month-old infants only with the left hand. The same authors reproduced this experience in 4-month-old infants and found that they are also able to recognize a familiar shape following interference but only with the left hand (Lhote & Streri, 2003). Catherwood (1993) studied the robustness of haptic memory in 8-month-old infants. The procedure did not used a habituation (infant-controlled criterion) but a 30-second familiarization of the object (cube and sphere). The results revealed that infants at 8 months failed to recognize a familiar shape after interference (Catherwood, 1993). It is possible that the 30-second familiarization of the object was too short for effective haptic recognition memory. Overall, these results in full-term infants indicate that haptic recognition memory after haptic interference seems to be fragile. No study has investigated the haptic recognition memory in full-term newborns.

Interestingly, preterm newborns are also able to discriminate between different objects by their shape (Lejeune et al., 2010; Lejeune et al., 2012; Marcus et al., 2012), and they exhibit haptic shape recognition abilities from 28 GW (mean postnatal age = 7 days; Marcus et al., 2012). However, another study also indicates that at a later post-conceptional age of 34 GW, preterm infants with less postnatal experience (mean postnatal age = 6.2 days) display this ability, while preterm infants with higher postnatal experience do not (mean postnatal age = 31.2 days; Lejeune et al., 2014). These results suggest that it is not the degree of immaturity that would explain this failure of recognition following interference, but rather the length of postnatal experience. A longer postnatal experience in preterm infants implies a greater degree of medical intervention (for example, antenatal steroid treatment, intubation, ventilation, or catheterization), as well as longer exposure to the bright and noisy environment of the neonatal intensive care unit (NICU) - that also involves numerous tactile demands and painful procedures (Koenig-, Zores, & Kuhn, 2016; Lejeune & Gentaz, 2015). However, the authors did not know whether the absence of haptic recognition memory after interference in the higher postnatal age group should be interpreted as a negative consequence of the particular postnatal experience in the NICU, or as a typical stage in the