Memory in utero?

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For thousands of years[1,2] there has been speculation regarding the abilities of the human fetus. In the absence of scientific evidence, views have ranged from the belief that the human fetus was possessed of all the abilities of an adult, to the other extreme – that the fetus was only a conglomeration of cells. Recent years have seen the debate regarding the status of the fetus moving into the social and political arena. Discussions about abortion, embryo research, in-vitro fertilisation have drawn on studies of fetal behaviour to support a particular viewpoint. Such debate has further tended to polarise views on the status of the fetus. Any scientific evidence has either been ignored or used uncritically and inappropriately to support a particular stance. Scientific study of the fetus, its behaviour and abilities, has flourished in recent years.[3,4] One area that has come under increasing scrutiny is that of fetal memory. Questions of the presence and nature of fetal memory have attracted interest for scientific and sociopolitical reasons. The following paper examines the question of memory in utero.

The first issue that needs to be addressed is whether there is any indication of a functioning memory in utero. Evidence may be obtained from two general sources: clinical practice and experimental studies. Both are considered below.

The practice of certain psychotherapists, psychologists and psychiatrists suggests that individuals are able to remember events before and during their birth.[5] It has been claimed that techniques such as LSD experience[6], regression hypnosis[7], primal therapy[8] reveal memories of the pre- and perinatal periods.[5] These prebirth memories are unconsciously stored and may affect adult behaviour directly[9] or indirectly through influencing the individual's affective state.[10] Negative prebirth experiences may result in subsequent psychological or psychiatric problems which may be helped by appropriate therapy.[10] Despite many clinical reports[5,7,10–14] the scientific credibility of these accounts must be questioned. Often evidence of the retention of prebirth experiences is based on interpretation by the therapist. For example, a desire for the sexual practice of bondage in adulthood may be attributed to entanglement in the umbilical cord during birth, or the fear of being crushed attributed to a prolonged birth caused by the narrowness of the mother's pelvis.[10] These interpretations seem ambiguous and obscure and should be treated with scepticism. Whether there is any real evidence contained in these recollections to indicate memories of before or during birth is questionable. Moreover there is little control over the accuracy of recall. It is possible that knowledge of prenatal events was acquired after birth. Given these problems evidence from such clinical studies must be treated with caution. As yet these studies do not provide definitive evidence of memory in utero.

A second source of evidence of fetal memory is that of experimental studies of fetal learning. Implicit in the concept of learning is the ability to memorise stimuli.[15] Three paradigms have been employed to examine learning: habituation, classical conditioning, and exposure learning.

Habituation

Habituation can be defined as the decrement in response following repeated presentation of the same stimulus.[16] Habituation has been argued to be essential for survival and to underlie many other abilities[17] and is predictive of later educational performance.[18] While there have been a number of reports on response decrement[19–23], beginning with Peiper in 1925[24], few studies have followed the guidelines established by Thompson and Spencer[16] to confirm the cessation of response is due to habituation as opposed to response or sensory fatigue. Hence in many studies it is difficult to say whether the observed decrement in response is due to true habituation (where memory may be involved) or motor fatigue and/or sensory adaptation (where memory is not involved). One study which did evaluate whether the fetus exhibited true habituation was that of Hepper and Shahidullah.[25] In this study fetuses at 36 weeks of gestation initially moved when a 250 Hz pure tone sine wave was played via a loudspeaker placed on the mother's abdomen. After 10 to 15 stimulus presentations fetuses stopped moving. When a new sound, a 500 Hz tone, was presented, the fetus began to respond again. With repeated presentation of this stimulus the fetus ceased to move. Finally the original 250 Hz tone was presented again. The fetus initially responded to the tone but rapidly ceased responding, after fewer instances than when the tone was originally presented. This result satisfies important criteria for establishing true habituation as opposed to response decrement and indicates some form of functioning memory in the fetus.

Classical conditioning

There have been few reported studies of classical conditioning in the fetus. Classical conditioning involves the pairing of two stimuli, the conditioned stimulus (CS) and unconditioned stimulus (UCS). The unconditioned stimulus elicits a response (the unconditioned response, UCR) when presented alone. The conditioned stimulus elicits no reaction when presented alone. However, following a number of pairings with the UCS (i.e. CS followed by UCS), the CS elicits a response, the conditioned response (CR). In Pavlov's 1906 original demonstration of classical conditioning[26] a dog was presented with food (the UCS) which resulted in the dog salivating (the UCR). In this

case the CS (a buzzer) elicited no reaction when presented alone. However after pairing the buzzer with the food, presentation of the buzzer alone came to elicit salivation.

The first report of classical conditioning in the human fetus was by Ray[27] in 1932. Here, using a single subject, a vibration (the CS) was paired with a loud noise (the UCS). Interestingly no results are reported for the study other than the comment the subject suffered 'no ill effects from her prenatal education' (p. 177). Spelt[28] similarly paired a vibration (the CS) with a loud noise (the UCS) and reported that after 15 to 20 pairings some fetuses responded to the vibration (CS) alone. (It is interesting to note in both these studies that a vibration was used as the CS due to the fact it initially elicited no response from the fetus. Today vibroacoustic stimuli are widely used clinically to assess fetal condition[29] because of the very fact that they reliably elicit a response.)

More recently Feijoo[30,31] paired maternal relaxation (the UCS) with music (the CS) and found that after 24 pairings of the stimuli, fetuses on hearing the music (the CS) began moving and after birth newborn infants on hearing the music stopped crying, opened their eyes and exhibited fewer clonic movements.

In a recent replication of Spelt's study[28], using a pure tone as the CS and a vibroacoustic stimulus as the UCS, I found similar evidence of conditioning in fetuses ranging from 32 to 39 weeks' gestation (unpubl. obs.). Most interesting is the fact that I was able to demonstrate classical conditioning in anencephalic fetuses – a point I shall return to later.

'Exposure' learning

The final paradigm to provide evidence of fetal memory is that of 'exposure' learning. The general procedure adopted by such studies is to 'expose' the fetus to a stimulus (most often sound) and then observe its response after a number of exposures. The individual's response to the familiar stimulus is compared either in the same individual to a comparable but unfamiliar stimulus, or to the response of individuals who have not previously been exposed to the stimulus. Evidence of a differential response to the familiar and unfamiliar stimuli, or between individuals previously exposed or unexposed to the stimulus is taken as evidence of learning and memory.

One of the first studies in this area was performed by DeCasper and Fifer[32] who found that newborn infants, soon after birth, preferred their mother's voice to that of an unfamiliar female. Although possible that this preference was acquired in the intervening period between birth and the time of testing, it was more likely that it was acquired before birth. Confirmation of this came with a study by Fifer and Moon[33] who presented babies with a choice between their mother's voice as it sounded within the womb and as it sounded outside of the womb. If the newborn infant's preference for their mother's voice was acquired postnatally the baby should prefer the latter stimulus as this would only be heard after birth. However if their preference was acquired before birth, they should prefer their mother's voice as it sounded in the womb. The babies showed a preference for their mother's voice as it sounded in the womb. This, and other studies[34,35], have confirmed the view that the fetus can learn its mother's voice before birth.

Other studies have found that fetuses will readily learn any familiar and repeated auditory stimulus presented to the baby while in the womb. For example I found that babies, if their mothers had watched the TV soap 'Neighbours' when pregnant, preferred this tune after birth to other unfamiliar tunes.[36,37] As exposure was under the control of the experimenter, thus preventing exposure to the tune between birth and the time of testing, the resulting preference can be attributed to experience of the tune before birth. Similar results have been obtained using other tunes or sounds.[38,39,40]

Other sensory modalities

Evidence drawn from studies using three different learning paradigms provides evidence of a functioning fetal 'memory'. However a number of important questions remain.

All of the above examples have used auditory stimuli. It is important to determine whether learning and memory can occur in other sensory modalities or whether it is restricted solely to auditory stimuli. Recently evidence has started to accumulate that the human fetus is capable of learning and remembering olfactory stimuli.

Early indications of prenatal olfactory abilities were presented by studies demonstrating that newborn infants were capable of recognising their mother's smell soon after birth.[41] However postnatal exposure cannot be totally ruled out in these cases. In a preliminary study, Schaal and Orgeur[42] gave a pregnant women cumin to eat during the last 12 days of her pregnancy. After birth, her infant was exposed to the smell of cumin and citral, an aldehyde present in lemon oil, or air. Only the odour of cumin resulted in the newborn infant exhibiting a change in heart rate.

More recently I examined the ability of fetuses to learn an odour, garlic, experienced only prenatally, via the mother's diet.[43] When tested 20 hours after birth, infants exposed to garlic during pregnancy showed a different response to garlic when compared to individuals not prenatally exposed. Individuals not prenatally exposed to garlic avoided the smell whereas those prenatally exposed via the mother's diet showed no aversion.

These studies indicate that learning and memory is not specific to sound stimuli but also occurs in other sensory modalities.

Length of memory

When 'memory' begins is unknown. There has been much debate in the psychological literature over the types and forms of memory processes and it is not intended to rehearse these issues again here.[44–47] However a very broad categorisation divides memory into short-term and long-term; short-term or working memory being a memory which only lasts for about 15 minutes, and long-term memory, which may last a lifetime.[48] Habituation may provide evidence of short-term memory whereas both classical conditioning and exposure learning provide evidence of long-term memory.

Studies of habituation have found the fetus can habituate from as early as 22 weeks of gestation.[49] Classical conditioning studies have taken place over the last 10 weeks of pregnancy and have reported some, but not completely conclusive, evidence of learning during this period.[28,30,31] Experimental studies of exposure learning offer perhaps the greatest opportunity for assessing when 'memory' begins since it is possible to expose individuals to stimuli at specific times during gestation. Few studies have yet attempted this. I demonstrated that fetuses at 37 weeks' gestation would respond differently to familiar and unfamiliar stimuli but exhibited no differential response at 30 weeks of gestation.[37] These few studies suggest

that short-term memory processes are functional some weeks before more long-term memory processes are present.

A separate issue is the duration of memory for events acquired prenatally. Whilst some claim events experienced in the womb may persist for the remainder of life[5,14], scientific evidence to assess these claims accurately does not yet exist. One study did assess the duration of memory for stimulus acquired prenatally.[37] In this study, babies in the first week after birth responded differentially to a familiar (experienced prenatally) and unfamiliar tune but this differential response was not apparent 3 weeks after birth. This suggests that the memory for prenatally experienced stimulus is short-lived in the absence of any postnatal exposure.

Conclusion

The evidence for memory in utero presented above relies on observations of a behavioural response which is influenced by previous events. Care needs to be taken in how one interprets this, especially in attributing adult-like memory qualities to the fetus[1]. In particular, while behaviourally similar observations of memory are found in the fetus and adult, the underlying mediation of memory in both may be very different. For example, my observations of classical conditioning in anencephalic fetuses, whose CNS is very different from that of unaffected adults where there are identical observations of classical conditioning, may suggest that the parts of the central nervous system underlying this process in fetuses may be different from that of adults.

Similar (identical?) evidence of prenatal learning and memory abilities can be found throughout the animal kingdom. Rat fetuses are capable of habituation[50], classical conditioning[51,52,53], and exposure learning.[54,55] Embryos of birds whilst in the egg are capable of learning the calls of their parents (exposure learning).[56,57] Rousseau asserted that the human fetus could be considered as a 'witless tadpole'. Interestingly tadpoles are capable of learning about odours present in their pre-hatch environment, showing a greater preference for familiar odours as tadpoles and even after metamorphosis as frogs.[58] Even invertebrates have been shown to be capable of learning and remembering stimuli in their environment prior to their emergence from the pupae.[59,60] In all cases, identical demonstrations of learning and memory are evidenced. The CNS of the invertebrate pupae and human fetus are undoubtedly anatomically different, but the behavioural response exhibited by each is identical. Therefore great care must be exercised when extrapolating from observations of memory in the fetus to their underlying mediation or similarity to memory processes evidenced after birth. Despite appearances of continuity of memory function before and after birth there is little evidence at present to assess fully the similarity of memory in utero with that observed after birth.

There is evidence of memory in utero. Scientifically reliable studies have clearly demonstrated that human fetuses are able to learn and memorise stimuli. However this memory must be considered rudimentary and of very limited duration. It is unknown at present what these studies indicate about the functioning of the CNS and the continuity, or relationship, between the memory abilities evidenced before birth and those evidenced after birth and later in life. It would be very easy to simply assume the observed fetal memory abilities equate directly to those of the adult but further study is necessary before any such conclusions can be drawn.

References

1. Hepper PG (1992) Fetal psychology: an embryonic science. In Nijhuis JG, editor. *Fetal Behaviour: Developmental and Perinatal Aspects*. Oxford: Oxford University Press, p. 129–56.
2. von Raffler-Engel W. (1994) The Perception of the Unborn Across the Cultures of the World. Seattle: Hogrefe & Huber.
3. Nijhuis JG, editor. (1992) *Fetal Behaviour: Developmental and Perinatal Aspects*. Oxford: Oxford University Press.
4. Lecanuet J-P, Fifer WP, Krasnegor NA, Smotherman WP, editors. (1995) *Fetal Development: A Psychobiological Perspective*. Hillsdale, NJ: Lawrence Erlbaum.
5. Chamberlain DB. (1990) *Babies Remember Birth*. New York: Ballantine Books.
6. Grof S. (1983) *Topographie des Unbewußten*. Stuttgart: Klett-Cotta.
7. Cheek DB. (1975) Maladjustment patterns apparently related to imprinting at birth. *American Journal of Clinical Hypnosis* **18:** 75–82.
8. Emerson W. (1989) Psychotherapy with infants. *Pre- and Perinatal Psychology Journal* **3:** 190–217.
9. Chamberlain DB. (1993) Prenatal intelligence. In Blum T, editor. *Prenatal Perception Learning and Bonding*. Berlin: Leonardo. p 9–31.
10. Janus L. (1993) Affective learning processes before and during birth. In Blum T, editor. *Prenatal Perception Learning and Bonding*. Berlin: Leonardo. p 33–60.
11. Waldman M. (1990) Life before birth: the impact of prenatal experience. *Journal of Regression Therapy* **4:** 46–53.
12. Rhodes J. (1991) Report on research project: interviews with 2.5 to 3.5 year old children regarding their memories of birth and the pre-natal period. *Pre- and Peri-natal Psychology Journal* **6:** 97–103.
13. Laibow RE. (1986) Birth recall: a clinical report. *Pre- and Perinatal Psychology Journal* **1:** 78–81.
14. Janov A. (1983) *Imprints: The Lifelong Effects of the Birth Experience*. New York: Coward-McCann.
15. Lipsitt LP. (1990) Learning and memory in infants. *Merrill-Palmer Quarterly* **36:** 53–66.
16. Thompson RF, Spencer WA. (1966) Habituation: A model for the study of neuronal substrates of behavior. *Psychological Review* **73:** 16–43.
17. Bornstein MH. (1989) Stability in early mental development: from attention and information processing in infancy to learning and cognition in childhood. In Bornstein, MH, Krasnegor NA, editors. *Stability and Continuity in Mental Development*. New Jersey: Lawrence Erlbaum. p 147–70.
18. McCall RB, Carriger MS. (1993) A meta-analysis of infant habituation and recognition memory performance as predictors of later IQ. *Child Development* **64:** 57–79.
19. Groome LJ, Bentz LS, Mooney DM, Singh KP, Collins HB. (1994) Early heart rate response of normal human term fetuses to vibroacoustic stimulation. *American Journal of Perinatology* **11:** 273–78.
20. Smith CV, Davis SR, Rayburn WF, Nelson RM. (1991) Fetal habituation to vibroacoustic stimulation in uncomplicated term pregnancies. *American Journal of Perinatology* **8:** 380–2.
21. Shalev E, Weiner E, Serr DM. (1990) Fetal habituation to sound stimulus in various behavioural states. *Gynecologic and Obstetric Investigation* **29:** 115–7.
22. Leader LR, Baille P, Martin B, Vermeulen E. (1982) Foetal habituation in high risk pregnancies. *British Journal of Obstetrics and Gynaecology* **89:** 441–6.
23. Madison LS, Adubato SA, Madison JK, Nelson RM, Anderson JC, Erickson J, Kuss LM, Goodlin RC. (1986) Foetal response decrement: true habituation. *Developmental and Behavioral Pediatrics* **7:** 14–20.
24. Peiper A. (1925) Sinnesempfindungen des Kindes vor seiner geburt. *Monatsschrift für Kinderheilkunde* **29:** 237–41.
25. Hepper PG, Shahidullah S. (1992) Habituation in normal and Down Syndrome fetuses. *Quarterly Journal of Experimental Psychology* **44:** 305–17.
26. Pavlov I. (1906) Scientific study of the so-called psychical processes in the higher animals. *The Lancet* **2:** 911–5.
27. Ray WS. (1932) A preliminary report on a study of foetal conditioning. *Child Development* **3:** 175–7.

28. Spelt DK. (1948) The conditioning of the human foetus in utero. *Journal of Experimental Psychology* **38:** 338–46.
29. Gagnon R. (1989) Stimulation of human fetuses with sound and vibration. *Seminars in Perinatology* **13:** 393–402.
30. Feijoo J. (1975) Ut conscientia Noscatue. **13:** 14–20.
31. Feijoo J. (1981) Le foetus Pierre et le loup ...ou une approche originale de l'audition prenatale humanine. In Herbinet E. Busnel M-C. editors. *L'aube des Sens.* Paris: Stock. p 192–209.
32. DeCasper AJ. Fifer WP. (1980) Of human bonding: Newborns prefer their mothers' voices. *Science* **208:** 1174–6.
33. Fifer WP. Moon C. (1989) Psychobiology of newborn auditory preferences. *Seminars in Perinatology* **13:** 430–3.
34. Hepper PG. Scott D. Shahidullah S. (1993) Newborn and fetal response to maternal voice. *Journal of Reproductive and Infant Psychology* **11:** 147–53.
35. DeCasper AJ. Spence MJ. (1986) Prenatal maternal speech influences newborns' perception of speech sound. *Infant Behavior and Development* **9:** 133–50.
36. Hepper PG. (1988) Foetal 'soap' addiction. *Lancet* 11th June. **i:**1347–8.
37. Hepper PG. (1991) An examination of fetal learning before and after birth. *Irish Journal of Psychology* **12:** 95–107.
38. Shetler DE. (1989) The inquiry into prenatal music experience: a report of the Eastman Project 1980–1987. *Pre- and Peri-natal Psychology Journal* **3:** 171–89.
39. Wilkin PE. (1993) Prenatal and postnatal responses to music and sound stimuli. In Blum T. editor. *Prenatal Perception Learning and Bonding.* Berlin: Leonardo. p 307–29.
40. Damstra-Wijmenga SMI. (1988) Fetal soap addiction. *Lancet* July 23. 223. (Letter).
41. Porter RH. (1991) Mutual mother-infant recognition in humans. In Hepper PG. editor. *Kin Recognition.* Cambridge: Cambridge University Press. p 413–32
42. Schaal B. Orgeur P. (1992) Olfaction in utero: can the rodent model be generalized? *Quarterly Journal of Experimental Psychology* **44B:** 245–78.
43. Hepper PG. (1995) Human fetal 'olfactory' learning. *International Journal of Prenatal and Perinatal Psychology & Medicine* **7:** 147–51.
44. Polster MR. Nadel L. Schacter DL. (1991) Cognitive neuroscience analyses of memory: a historical perspective. *Journal of Cognitive Neuroscience* **3:** 95–116.
45. Schacter DL. Tulving E. editors. (1994) *Memory Systems 1994.* Massachusetts: MIT Press.
46. Roediger III HL. Craik FIM. editors. (1989) *Varieties of Memory and Consciousness.* Hillsdale. NJ: Lawrence Erlbaum.
47. Squire LR. Knowlton B. Musen G. (1993) The structure and organisation of memory. *Annual Review of Psychology* **44:** 453–95.
48. Baddeley A. (1990) *Human Memory. Theory and Practice.* Hove: Lawrence Erlbaum.
49. Leader LR. Baille P. Martin B. Vermeulen E. (1982) The assessment and significance of habituation to a repeated stimulus by the human foetus. *Early Human Development* **7:** 211–9.
50. Smotherman WP. Robinson SR. (1992) Habituation in the rat fetus. *Quarterly Journal of Experimental Psychology* **44B:** 215–30.
51. Hepper PG. (1993) In utero release from a single transient hypoxic episode: a positive reinforcer? *Physiology and Behavior* **53:** 309–11.
52. Smotherman WP. Robinson SR. (1991) Conditioned activation of fetal behavior. *Physiology and Behavior* **50:** 73–7.
53. Smotherman WP. (1982) Odor aversion learning by the rat fetus. *Physiology and Behavior* **29:** 769–71.
54. Smotherman WP. (1982) In utero chemosensory experience alters taste preferences and corticosterone responsiveness. *Behavioral and Neural Biology* **36:** 61–8.
55. Hepper PG. (1988) Adaptive fetal learning: prenatal exposure to garlic affects postnatal preferences. *Animal Behaviour* **36:** 935–6.
56. Shindler KM. (1984) A three year study of fetal auditory imprinting. *Journal of the Washington Academy of Science* **4:** 121–4.
57. Lickliter R. Stoumbos J. (1992) Modification of prenatal auditory experience alters postnatal auditory preferences of bobwhite quail chicks. *Quarterly Journal of Experimental Psychology* **44B:** 199–214.
58. Hepper PG. Waldman B. (1992) Embryonic olfactory learning in frogs. *Quarterly Journal of Experimental Psychology* **44B:** 179–97.
59. Isingrini M. Lenoir A. Jaisson P. (1985) Preimaginal learning as a basis of colony-brood recognition in the ant. Cataglyphis cursor. *Proceedings of the National Academy of Sciences USA* **82:** 8545–7.
60. Caubet Y. Jaisson P. Lenoir A. (1992) Preimaginal induction of adult behaviour in insects. *Quarterly Journal of Experimental Psychology* **44B:** 165–78.