

The Prenatal Concept of Number: Evidence of Visual Processing Information before Birth

1. Introduction

- Interventions supporting children's educational attainment often target early years education and schooling. Yet, it is becoming increasingly clear that this appears too late (Bolden & Tymms, 2020) and the early years healthy educational review recognised that 'the building blocks begin at conception'.
- The association between early numeracy skills and later mathematical ability are increasingly found (e.g. Watts et al., 2013). Number sense even within the first 6 months has been found to uniquely contribute to later maths scores (Starr et al., 2013).
- The discrimination of small number sets have been found from birth (Antell & Keating, 1983; Coubart et al., 2013; Spelke et al., 2009; Turati et al., 2013), yet how and when this develops before this period is unknown.
- Recent work suggests that there is substantially more luminance within the uterus than previously expected (Del Giudice, 2011) and that early behavioural response to visual stimuli can be found before birth (Reid et al., 2017).
- Using shapes presented through light, Reid and colleagues (2017) have shown that, like newborn infants (Morton & Johnson, 1991), fetuses have a looking preference for upright in comparison to inverted face-like shapes.

2. Research Questions

- **Can we apply this novel methodology to the study of numeracy perception before birth?**
- **Do we visually discriminate small number sets before birth?**

3. Methodology

- Participants were recruited from the north-west area of the UK. All had singleton pregnancies with no complications and a BMI of approximately 30 or lower at the time of booking.
- Behavioural responses were assessed utilising 4D ultrasound ($N = 63$). Fetuses were excluded due to error (2), poor image resolutions (12) or behavioural state deep sleep (15, Nijhuis et al., 1982). The final sample ($N = 29$) had gestational ages between 224 and 252 days ($M = 241.03$ days).
- **Data acquisition.** Fetal behaviour was recorded using a GE Healthcare Voluson E8 Expert BT13 advanced 4D HD live ultrasound scanner and 4D probe, model RM66. Recordings were saved to DVD for offline coding.
- **Light Sources.** Light sources were custom made devices with diodes emitting (650nm 6mm 3V 5mW Laser Dot Diode Module Head With Red Dot R1B0). For perceptual control, the light source was calibrated so that the light strength could be continually varied throughout trials using a dial feature. In addition, the overall surface area was controlled across the two conditions by the removal of the centre dot from the 3-dot condition in the 2-dot number set.
- **Procedure.** Light presenting two or three dots (order counterbalanced) of light was delivered to the maternal abdomen for 45 seconds to the side of the fetal face, such that the stimuli were presented to peripheral visual areas (left, $N = 14$, right, $N = 15$). The counter number of dots was then presented for 45 seconds. The process was then repeated for a total of 3 minutes.
- **Measures.** Looking time to the stimuli was measured from recordings of the 4D scan using Observer XT (Tracksys Ltd.)

4. Results

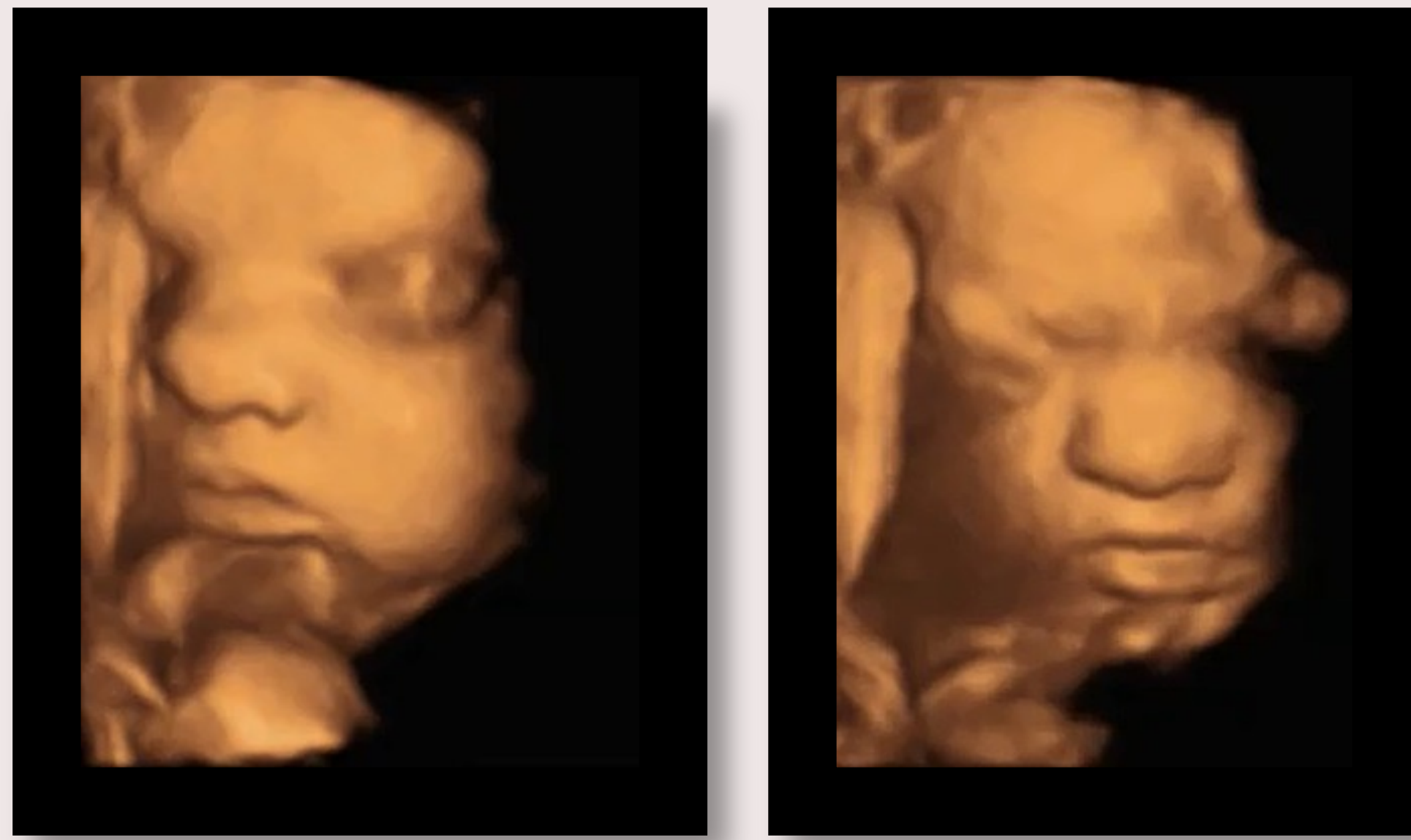


Fig. 1. An illustration of a typical head movement towards visual stimuli in utero.

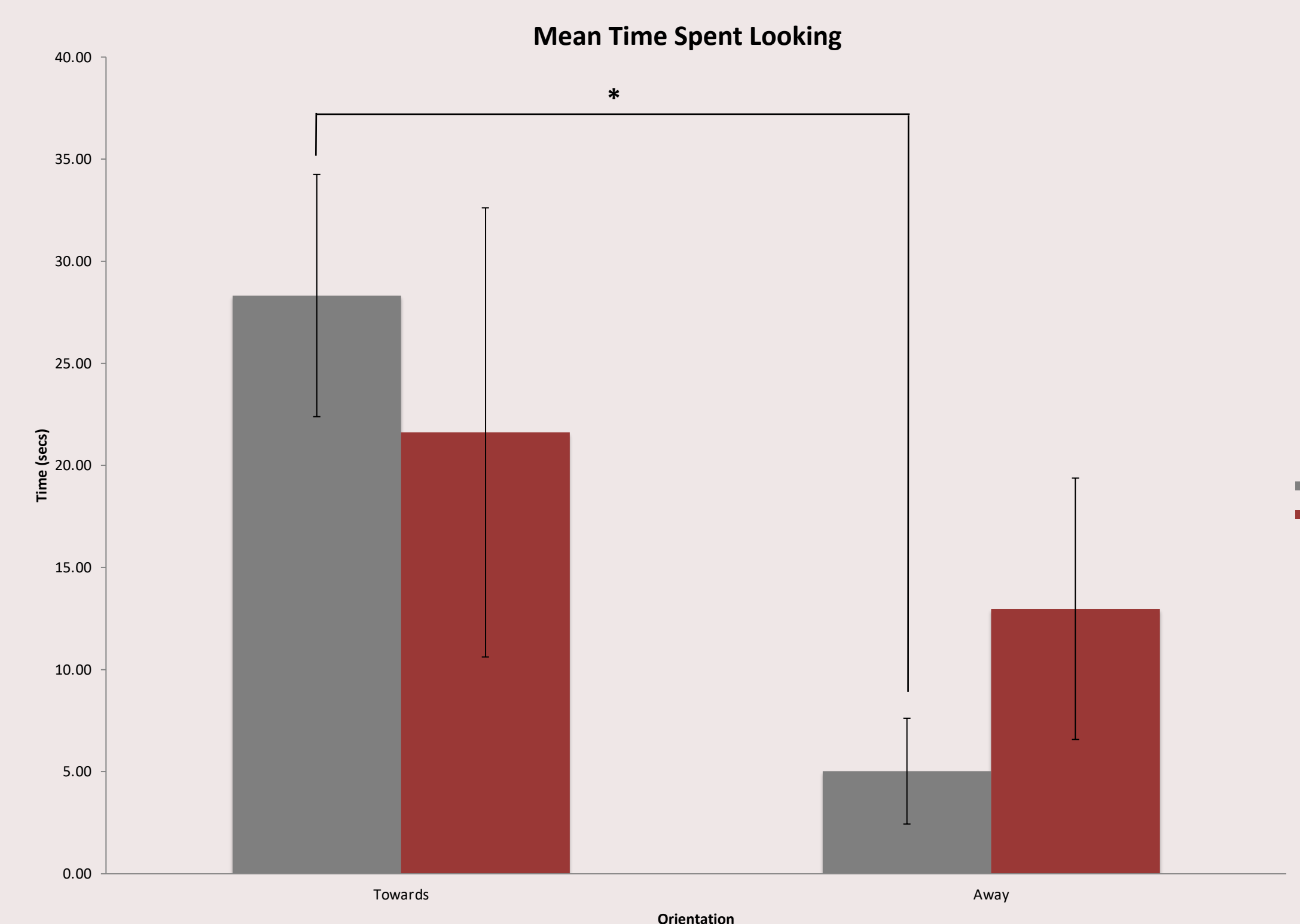


Fig. 2. The time spent looking towards and away from 2- and 3- dot configurations. Error bars represent standard errors.

- The mean looking time towards stimuli were measured using recordings of the 4D scan. On average, Figure 1 shows that fetuses spent more time looking in the direction of 2 dots ($M = 28.32$, $SD = 5.93$) than in the direction of three dots ($M = 21.62$, $SD = 11.00$). More time was spent looking away from three dots ($M = 12.98$, $SD = 6.4$) than two dots ($M = 5.03$, $SD = 2.59$).
- A Wilcoxon Signed-Ranks test indicated fetuses spent significantly more time looking towards than away from 2 dots only ($Z = 2.293$, $p = 0.022$).

5. Discussion and Future research

- These data indicate that the late term fetus is likely to engage with number sets of two only and a less developed, yet not no, number sense than at birth (Antell & Keating, 1983; Coubart et al., 2013). *Comparison of fetal response to 1 vs 2 dots is currently under analysis.*
- A developing number sense at this stage indicates that genetic number sense interpretations of early infant responses should be taken with caution (e.g. Wynn., 1992).
- Good mathematical ability is associated with not only educational outcomes, but later employment success and national economic growth and educational attainment has a significant impact on a child's perception of personal control and self-esteem (Ross & Broh, 2000).
- Acknowledging prenatal and neonatal development of mathematical ability allows for the possibility of earlier environmental intervention on developmental outcomes.
- Dunn et al. have established a new research group (Prenatal Effects on Postnatal Outcomes, PEEPO), funded by the Nuffield Foundation, aiming to understand more about how variations in the in-utero environment (e.g. maternal stress, nutrition, metabolic disorders, and maternal sleep) link to variations in later child educational outcomes.
- Now that 4D ultrasound scanning produces such high-quality images, it is possible for this technique to be utilised such that fetal research can employ similar methodologies and control procedures as those seen in the infancy domain.
- This will provide more information about the nature of development in the transition from fetus to infant.

7. References

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