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Exploring Environmental Influences on Infant Development and Their Potential Role in Processes of Cultural Transmission and Long-Term Technological Change

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ABSTRACT

Emerging understanding of the extent to which the childhood environment can influence long-term neural and cognitive development may justify greater attention to its role in prehistory. In this review, we attempt to identify a range of ways in which changes to the rearing environment might impact on cognitive function with the potential to modify processes of cultural transmission. We focus on the types of change to the infant environment that may arise when moving from mobile hunter-gather to more settled agrarian lifeways. We consider the evidence for such early environmental factors bringing about enduring effects on perceptual tuning, shared attention, behavioural regulation and observational learning, and how these might contribute to differences in processes of cultural transmission across lifeways. We conclude that the potential developmental significance of cultural changes to the infant environment suggests more attention should be paid by archaeologists to lines of evidence related to early childhood environments in prehistory.

KEYWORDS
Childhood; prehistory; hunter-gatherer; farmer; cognitive development; cultural transmission; learning

Introduction

In the prehistoric archaeological record, long periods of little change are often separated by brief periods of rapid cultural turnover: ‘cultural explosions’ or ‘revolutions’. These have often been attributed straightforwardly to external events, such as environmental changes, or the evolution of new cognitive capacities (Klein 2002; Ziegler et al. 2013). More recently, however, archaeology has moved away from such over-simplistic models of causation to consider cultural change instead as the outcome of complex interactions between social, cultural and environmental processes. For example, these might arise not just from environmental change necessitating the invention of new technologies (Stiner and Kuhn 2006), but also from changes in population density (Powell, Shennan, and Thomas 2009), and increased interaction and competition between local populations (Mellars 2005), etc. While the dynamics of cultural and physical environmental change

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(e.g. changes in habitat) are intertwined, modelling of cultural evolution also suggests the importance of primarily socio-cultural factors, such as the spread of a culturally powerful innovation (Kolodny, Creanza, and Feldman 2016). Such 'game-changing' innovations might include specific tools that improve foraging returns and thus the biological carrying capacity of the habitat and hence population size; they might also be broader cultural innovations such as writing (which increases the efficacy of cultural transmission, so reducing the rate of cultural loss (Kolodny, Creanza, and Feldman 2016)), or the adoption of new socio-economic strategies such as agriculture or sedentism (with broad-ranging impacts on many other aspects of human life from health and reproductive strategies to ideologies to regional and indeed global ecosystems).

Here, we consider the significance of changes in the environments (social, cultural and physical) in which infants develop. We argue such changes might also serve as a 'game-changing' factors influencing cultural steady state, therefore warranting closer attention in archaeological inquiry. Infancy (used here in the broad sense of the word to denote a child of up to around five years of age), is a special period in human development. This is the period for which we have the most compelling evidence of environmental factors (in the form of social and cultural changes as well as the physical ones more often foregrounded anthropologically) having lifelong cognitive and neural consequences (Howard-Jones, Washbrook, and Meadows 2012). Therefore, we suggest that societal differences in child-rearing impact on development and learning, and so on the form of cultural transmission and hence technological (in its broadest sense) repertoires within that cultural context. In particular, we focus on the differences in learning environment between mobile hunter-gather and more settled agrarian lifeways since, although we acknowledge the enormous variability within each of these stereotyped and oversimplified categories, the shift from mobile foraging to settled agriculture has been associated in prehistory with many technological innovations and a dramatic accumulation of material cultures more generally (Renfrew 2008).

Several clarifications are required here. Firstly, in comparing infant rearing environments of those pursuing hunter-gather and agrarian lifestyles, our intention here is emphatically *not* to argue that one of these lifeways produces *better* outcomes. Instead, we simply argue that there are strong grounds to suggest that differences in economic, social and cultural strategies may be associated with different – *but equally valid* – styles of cognitive development and cultural transmission that are currently overlooked both in cross-cultural studies of modern-day peoples, and in archaeological approaches to past populations.

Secondly, our use of the term 'environment' in the developmental sense is broader than its typical usage in the anthropological literature, explicitly including everything an individual experiences that is beyond the individual themselves, and therefore including local social and cultural environments and stimuli.

Finally, although we are discussing neurobiological changes, it should be emphasized that the processes we consider here are not evolutionary (i.e. not intergenerational adaptation underpinned by genotypic change) but relate to learning and development: phenotypic cognitive changes occurring within the lifetime of an individual, which can nevertheless be culturally transmitted to subsequent generations as they arise from and influence social and cultural environments. Developmental plasticity is, of course, itself the result of genotypic variation and this evolutionary process, and the factors that made it adaptive, remain a key area of research for palaeoanthropologists. However, once selected for in a lineage/species, as in *Homo sapiens*, the two processes of evolution and development can, to a certain extent, be seen as distinct.

We first examine why infancy is considered as a 'special' time in terms of the potential for environment to impact on cognitive development. We will consider the typical experiences of infants within a small-scale foraging and then a small-scale agrarian society, focusing particularly on factors that may have developmental implications. Finally, we will consider how comparing differences in respect of infant environment may shed light on cultural carrying capacity in relation to technology and its innovation, before reflecting on the implications for efforts to understand accumulative technological innovation across prehistory.

The early years as formative for cognitive function

In mammals, developmental brain processes involving the specification of cell types and their guidance into appropriate locations are complete by mid-gestation. However, a number of developmental neuronal processes continue postnatally, including the growth of branches (dendrites) from the neuronal cell, the formation of connections (synapses) between neurons and the unique structuring of the cortex in relation to function. The rate of this development varies in relation to different regions of the brain but even the prefrontal cortex, whose development continues into adolescence, may be particularly susceptible to environmental differences during infancy (Hodel 2018). In humans, the density of synapses (the connections between neurons that 'code' for information) peaks at around 3–4 months in the primary auditory and visual cortices and at about three and a half years of age in the prefrontal cortex (Huttenlocher and Dabholkar 1997). Associations between some age-specific behaviours and measures of cortical thickness (Landing et al. 2002) suggest that synaptic proliferation (which likely contributes to the physical thickness of cortex) is an important development process; experience, in the sense of stimuli provided by the external environment, is essential for the normally occurring regulation of the molecular basis for this synapse formation, suggesting this process constitutes a physiological basis for those 'sensitive periods' of development during which the brain is tuning itself to the individual's environment (Fox, Levitt, and Nelson 2010). Synaptic pruning, which follows proliferation, is thought to involve loss of 'untuned' connections, so increasing the signal-to-noise ratio and efficiency of information processing (Blakemore 2008; Neville and Bavelier 2001); non-human studies have demonstrated that experience has a major role in the selection of axons, dendrites, synapses and neurons that form functional sensory neural circuits (Hubel and Wiesel 1977; Rakic 1976; Sur, Pallas, and Roe 1990).

Human behavioural evidence supports the notion that these biological changes relate to sensitive periods in development, particularly in 'tuning' perception to stimuli salient in the environment. For example, infants can discriminate among virtually all the phonetic units used in all languages at around 7 months but this ability disappears by around 11 months (Kuhl 2004), as their auditory system becomes tuned to only the tones they hear around them. Similar processes have been reported for vision: the domain-general ability of visual acuity, measured by being able to discriminate between black stripes on white compared with plain grey, is thought to have a sensitive period extending over the first 10 years of life (Maurer 2017). Early visual input is considered necessary for the normal development of the neural substrate on which more sophisticated visual pattern processing will build and early visual neuronal circuits are modified by experience, with greater populations of cells being assigned to more frequent features of the environment (Girshick et al., 2011). These developmental processes have been argued to explain a range of cultural phenomena, including cultural differences in visual search strategies (Ueda et al. 2018) and similar line distributions between writing systems and natural scenes (Changizi et al. 2006). The recognition of faces is the type of visual pattern processing most studied in terms of the likelihood of early visual perceptual tuning. Three-month-old infants with more experience with their own-ethnicity than other-ethnicity faces look more at own-ethnicity over other-ethnicity faces, which is interpreted as reduced ability to discriminate between other-ethnicity faces (Kelly et al. 2007; Kelly et al. 2005; Marquis and Sugden 2019). This effect can be prevented and even undone if infants experience other-race faces via picture books or videos by 6 or 9 months of age while associated brain circuits are still at their most malleable (Anzures et al. 2012; Heron-Delaney et al. 2011). While review supports the notion of sensitive periods in visual development that impact on face recognition (Pascalis, Fort, and Quinn 2020), the extent to which these derive from sensitive periods in domain-general visual processing (and therefore might relate to objects other than faces) remains a matter of research.

A range of other environmental influences on developing cognitive function have been observed with the potential for lifelong consequences. Well before a child can understand speech, he/she will begin to attend to the world in ways that are guided by the interests and values of those around them. The ability to follow eye-gaze at 6 months is correlated with later executive function at 18 months, with the relationship depending on the quality of parent-infant interaction over the preceding months (Marciszko et al. 2020). Specifically, parent interaction that uses the Western, educated, industrialized, rich and democratic (WEIRD) pedagogical approach of 'scaffolding', i.e. that supports a child's rehearsal of an ability until they can perform it independently, predicts a profile of executive function that is considered favourable within WEIRD societies (Marciszko et al. 2020), and which predicts higher achievement within a WEIRD formal schooling system (Clair-Thompson and Gathercole 2006). Following the eye-gaze of adults is also thought to contribute to the cultural transmission of visual attentional style, which has been used to explain cultural differences in judgment and memory (Chua, Boland, and Nisbett 2005). For example, infant eye movements show divergence in patterns of visual attention according to culture as early as 24 months, with US children attending more to the objects and Japanese children attending more to the actions with which they were engaged (Waxman et al. 2016). By around 16 months, infants appear able to learn to use specific tools that are in their immediate environment by observing an adult's use (Fagard et al. 2016). As speech develops, WEIRD studies show early engagement with adult talk can impact on cognitive function (e.g. Rowe, Leech, and Cabrera (2017)) and, in Western societies, the imposition of behavioural expectations in the pre-school years have been shown to impact on self-regulation in later childhood (Morawska, Dittman, and Rusby 2019) – which is another significant predictor of lifelong success within WEIRD societies (Robson, Allen, and Howard 2020).

The potential of the early years environment to 'mould' longer-term outcomes has not been lost on educators, and many pre-school educational interventions have been shown to have measurable effects in later life (Vandell et al., 2010; Chetty et al., 2011; Schweinhart et al., 2005). Such evidence, supported by understanding of the increased plasticity of a young child's brain as outlined above, has prompted scientists to consider early development as foundational for supporting later learning. Economic models of the economic returns of education (fitted to behavioural data) suggest it is an educational investment in the early years that is most likely to yield the greatest overall return for the broader community (Cunha, Heckman, and Schennach 2010). The accumulative nature of effects in early development suggests an upward spiral of causality (Mol and Bus 2011) – or a 'Matthew effect' in which 'learning begets learning' or, perhaps more accurately, 'learning and development in a particular direction begets learning and development in a particular direction'.

Our increased appreciation of the significance of early childhood experience makes it timely to appraise its role in cross-cultural consideration of development, learning and longer-term technological innovation. While both present day and past cultures vary along many axes simultaneously, one major structuring principle of human behavioural ecology centres around socio-economic organization, with subsistence strategies being strongly associated with a range of other aspects of lifeways. We will thus consider here the potential impact of different environmental stimuli associated with hunter-gatherer vs. farming societies on infant development, specifically relating to cultural transmission of technology. Did the shift from mobile hunting and gathering lifeways which commenced among some prehistoric groups after around 10,000BCE change the environments of infant development, and how might this be addressed in future work?

Early childhood within a foraging society

Child-rearing among foragers is generally characterized as relatively relaxed. Parenting is typically proximal, i.e. close-contact, and highly responsive, with children kept in close proximity to – often carried in slings, etc. by – parents, especially mothers, who are often still breastfeeding them on demand as they go about their daily activities (Fouts, Neitzel, and Bader 2016; Keith 2005). This co-location of primary carers and children tends to continue until children are too heavy to carry (typically between 2 and 3 years old but often longer) and/or weaned, and has some important implications. Firstly, the relative positioning of infants and carriers may shape the kinds of interactions and modes of cultural transmission that are possible – for example, being carried may limit infants' ability to follow the direction of the caregivers' gaze. This is discussed in more detail below. Secondly, such close proximity to caregivers also means infants' exposure to different activities associated with technologies varies cross-culturally, depending to a significant extent on the kinds of activities engaged in by their mothers.

As Keith notes,

> being carried by their mothers … exposes young children of both sexes to the kinds of tasks associated with women. It allows them to closely observe the work their mothers do and to hear groups of women working together as they discuss and solve the problems encountered in their daily activities. (Keith 2005, 30)

While there is obviously some variability and the rigidity of gendering of roles differs between societies, typically women's activities relate to the domestic sphere and to gathering activities (Keith 2005) rather than to big-game hunting, an activity from which women are often (though not always) excluded in forager societies (though they may engage in trapping, net hunting, etc. e.g. among the Aka; Keith 2005). For example, among many traditional Inuit groups, women's activities are domestic in nature and generally keep them close to home when not foraging for plant foods, firewood or water (Keith 2005), while hunting is a male preserve. As Keith notes, the status of *umialik* refers to someone who organizes and leads a hunt, but is in fact 'based primarily on an individual's wealth (in the form of boats and equipment)', i.e. on technology (Keith 2005); thus hunting, male state and technology are virtually synonymous. Keith notes in some Inuit groups tool-making was not a gendered activity, but in others repairs and manufacture of experiment and discussion around technology and hunting strategy were largely restricted to the *kashim*, the men's house; while women and children were not barred from this space they typically lived in separate homes, and children were not exposed to gender-specific activities until around 10 years old (Keith 2005). Some ! Kung groups, in fact, effectively ban women from handling hunting implements (Shostak 2009), though admittedly among other foragers, e.g. the Aka, the association of tools and indeed roles was much less gendered (Keith 2005).

Plant foraging, historically, has not involved much interaction with technology beyond a simple digging stick (e.g. Oswalt 1976). Instead, hunter-gather infants encounter a natural environment involving a rich variety of plant foods, and observation of adults applying a broad and deep knowledge base of how to forage effectively in the natural world (among the !Kung more than 100 plant species are considered edible; Keith 2005). Whether or not their attention is deliberately focused by their mother on aspects of these activities, children can learn from where an adult is looking (e.g. learning associations and about the adults' goals). WEIRD studies demonstrate that children begin associating their parent's gaze direction and the locations of interesting sights at around 1 year old (Deak et al. 2014; Paulus 2011). Depending, as noted, on the mode of child-carrying, children observing adults foraging will be observing the use of visual search strategies that reflect the need to alternate between exploration of the environment and the exploitation of foods found within it (Ramos Gameiro et al. 2017). This contrasts with the visual demands of manufacturing and using technology, which might reasonably benefit from more consistently focused gaze behaviour and a more object-focused attentional style.

With language still in the early stages of development, observational learning has been identified as prominent in the earliest years of a child's development. WEIRD research demonstrates, for example, that infants of less than 2 years old can learn from watching complete strangers who are ignoring them (Shimpi, Akhtar, and Moore 2013). Lew-Levy et al. (2017, 379) consider that 'Observation appears to be central to how forager children establish competency' but, as noted by Gaskins and Paradise (2010), observational learning is most powerful when children are involved and *belong* to the world in which they make the observation. Thus, the food and foraging they observe may be more impactful on their learning than incidental observation of hunting and its associated technologies, if they are unlikely to have become involved with these. Lew-Levy et al. (2017) suggest that their meta-ethnography of hunter-gatherer societies shows again and again the prominence of what Gaskins and Paradise (2010) call 'open attention', a form of learning found in small-scale societies where children are in such constant contact with adults and older children, that learning occurs without the child or the 'teacher' specifically intending it. Western society places great value on literacy and oracy, but formal schooling, in fact, diminishes children's attention to what is going on around them (Silva, Shimpi, and Rogoff 2015). Therefore, cultural perspective and attentional experiences within modern Western culture may contribute to under-estimating the potential of independent infant learning in other cultures, including those found in prehistory.

By age 3-5, children are becoming too heavy to be carried, though they are still typically too young to keep up with adults in their daily activities. After this, children in these societies are provided with a great deal of autonomy and are not expected to be 'productive' until relatively old – while still making themselves useful by providing care for younger infants and performing other chores such as collecting water or firewood (Blurton-Jones 1993; Fouts, Neitzel, and Bader 2016; Melvin Konner 2017). However, these chores are generally not demanding and children are not expected to provide for themselves by foraging (Melvin Konner 2017, Table 6.1). Therefore, despite the maternal tie and proximal parenting style associated with late weaning, young children in foraging societies can spend considerable amounts of time in the company/care of other children of usually different ages, freely exploring the 'non-technological' world beyond the settlement.

In hunter-gather societies, practical experience of hunting (generally only or primarily by boys) does not normally occur until children are older e.g. around the age of 12 years old (among the !Kung; Keith 2005; cf MacDonald 2007). However, younger children may encounter knowledge of hunting and associated technologies via stories and recountings of hunting; as MacDonald notes (2007, 392), children in forager groups frequently listen to men's stories about hunting, including descriptions of past hunts, associated folklore and information about animal behaviour and hunting strategies. Although young infants may hear hunting talk, their lack of exposure to the concrete use and manufacturing of the associated technologies may be a significant constraint on developing the best cognitive foundation for later understanding them. The manufacturing of technologies differs from other types of knowledge (e.g. ecological knowledge for foraging) in its potential for being learnt more through observation than through storytelling (Garfield, Garfield, and Hewlett 2016). Even when speech is involved, WEIRD studies suggest interactions with infants that have a demonstrable impact on technological skills tend to refer to what is concretely present. This has been shown for children learning their first words (Baldwin 2000) and for infants of 14–30 months learning number (Gunderson and Levine 2011). In the latter study, number talk in relation to present objects e.g. 'One, two bees. [pointing to pictures in a book]' was a significant predictor of children's later number knowledge at 46 months, while talk without the involvement of present objects was not (e.g. 'One, two, three, whoo! [mother picks up child]').

Alongside the development of speech arises the possibility of being instructed. Although foragers may sometimes engage in teaching, it is clear that independent observation and practise is favoured over more structured teaching/learning pedagogy (e.g. Boyette and Hewlett 2018; Hewlett and Roulette 2016). A meta-ethnographic review has highlighted 'the importance placed on children's autonomy in their own learning process' by forager groups, with children allowed 'to observe and experiment with minimal interference' (Lew-Levy et al. 2018, 375–376). For example, among the Inuit (in fact, a highly specialized forager group with complex technology who might be presumed to show more similarities to some small-scale farming societies) there is 'remarkably little meddling by older people in this learning process. Parents do not presume to teach their children what they can as easily learn on their own' (Guemple 1979, 50; in Gaskins and Paradise 2010).

Early childhood within a small-scale agrarian society

More permanent settlement is associated with a greater amount and a broader range of material culture (Hodder 2018; Sahlins 1972; Shott 1986; Testart et al. 1982) with housing particularly well-elaborated in settled and farming communities (Kent 1990). A shift to more permanent living structures (including the mobile structures of many pastoralists (e.g. Prussin 1989)) is one that has been highlighted by a number of authors, who emphasize the key role of houses as 'structuring structures', not only reflecting but materializing/reifying and imposing/enforcing in a very physical manner social expectations with regard to expected forms of attention, interaction and behaviour (Donley-Reid 1990; Hillier and Hanson 1984; Whitelaw 1991; Wilson 1991). While, of course, children in these societies continue to encounter more expansive natural environments, as we note below, child-rearing practices in settled/agrarian communities are typically more focused on these domestic environments, with less activity occurring outside structures in communal areas (Wilson 1991). Such changes can thus provide a rather different form of experience for infants, not only socially but also in terms of perceptual stimuli, with more permanent structures also curtailing visual horizons.

Thus, for infants developing within an agrarian society, compared with a hunter-gatherer society, early perceptual tuning might be expected to occur in relation to rather different visual scenes. Children reared in more permanent dwellings spend more time processing visual features typical of human technology (corners, straight lines, symmetry, etc.). As discussed above, within the first few months of birth, the visual stimuli encountered by infants impact on the early tuning of their perceptual processing. Early visual neuronal circuits are modified by features in the visual environment, including those arising from technological innovation such as house construction, potentially introducing a developmental bias that favours discrimination of visual features associated with that environment.

In agrarian societies, infants and young children are typically less physically close to their mothers, weaned earlier, required to engage in practical labour, albeit light, and exposed to more formal teaching. A common reason presented for early cessation of breastfeeding in agricultural societies is the need for parental labour (Keller and Kärtner 2013). For example, among the subsistence farming Makassar of Indonesia, mothers return to working in the fields after 4–6 weeks, relying on extended family for childcare; likewise, among the Bara pastoralists of Madagascar, mothers share care of their children with others and by the child's second year they will be spending most of their time with peers; similar patterns are seen among the Lese of the Democratic Republic of Congo (Morelli, Henry, and Spielvogel 2019). While the reasons are open to argument (e.g. see Hewlett et al. 1998), and the variability is considerable, breastfeeding ceases earlier among agricultural and industrialized societies compared to mobile foragers (M. Konner 2005; Sellen and Smay 2001). For example, among the Bofi, forager groups weaned their children between 36 and 53 months of age, whereas the agrarian group weaned between 18 and 27 months of age (Fouts, Hewlett, and Lamb 2005). As might be expected, weaning is clearly associated with a difference in parenting styles, with forager societies best characterized as 'proximal' parents with infants kept in close physical proximity to and often carried by, caregivers, especially the mother (providing on-demand breastfeeding) until they are physically too heavy to carry. In contrast, farming societies are more 'distal' in their parenting, with children less often in direct physical proximity to caregivers (Hewlett et al. 1998).

This more distal parenting style early in an infant's development has the potential to impact on developmental trajectory, through promoting face-to-face contact. Across cultures, lower amounts of body contact are consistently associated with higher amounts of mutual visual engagement and vice versa (Keller et al. 2004; Keller et al. 2004; LeVine 2004). As pointed out by Keller et al. (2009), physical contact makes it practically impossible for the face-to-face interaction typical of distal parenting to occur simultaneously, and WEIRD data suggests more distal parent-infant positions favour more eye contact in face-to-face play (Lavelli and Fogel 2002). For example, the so-called '2-month shift' involving an increase in waking times, face-to-face interaction and mutual smiling is well-documented in industrialized societies, but may be quite culturally-specific: Keller (2017) notes that it manifests rather differently in small-scale agrarian societies such as the Nso of Cameroon: 'German mother-infant dyads showed the expected increase in face-to-face exchange and smiling, the Nso dyads did not' (835). She ascribes this to a different cultural attitude to child-rearing among the Nso more akin to gerontocracy than neontocracy (Lancy 2014), typically more common among mobile foragers; one might also argue that such differences could relate to the physical interactions between infant and adult occasioned by physical proximity and carrying. An early focus on faces can be significant in developmental terms, given the importance of the following gaze for the sharing of attention to objects, and such considerations help explain culturally specific differences in subsequent development amongst children in contemporary cultures. In a study of Israeli and Palestinian cultures, greater face-to-face exchange, social gaze, object focus, and active touch in infancy and indirect parental assistance to toddlers was found for Israeli families, while interactions amongst Palestinian families consisted of more continuous contact, neutral affect, reduced negative emotionality, and concrete assistance (Feldman, Masalha, and Alony 2006). Social gaze, touch, and indirect teaching at 5 months predicted self-regulation among Israeli toddlers; contact and concrete assistance were predictors among Palestinians. Differences in what is being attended to, which are known to emerge during infancy (Waxman et al. 2016), have also been used to explain cultural differences in what adults remember. Two prototypical attentional styles have been identified by Nisbett and Masuda (2003) that describe the Western analytic style of those more likely to focus on focal objects (i.e. low context-sensitivity), and a holistic style more typical amongst those from East Asian contexts, characterized by a higher sensitivity for the context and the relations between elements in a scene. For example, North Americans of European extraction are more likely to report and memorize a large focal fish swimming in an aquarium, while Japanese participants report and remember more details about the background, such as the plants and smaller animals present (Masuda and Nisbett 2001).

As well as the additional attentional training to faces encouraged by more distal parenting, this style of parenting necessitates childcare arrangements that might also impact on an infant's early attentional tuning. With parents – especially mothers, as fathers have considerably less direct input into care in agricultural and pastoral groups (Hewlett and Macfarlan 2010) – often working out away from the home or indeed village at agricultural tasks, one key task to which older children are put is to look after the infants. For example, among the Gusii of Kenya, young children were left at home in the care of 6–11 year old children for about 4–5 hours a day while they worked in the field (and unlike in hunter-gatherers, the expectation was of 'care' rather than simply companionship (Morelli, Henry, and Spielvogel 2019)). Likewise, Draper and Cashdan (1988) note that among settled !Kung, 'By the age of six to eight months, children are cared for by older children for half or more of each day' (p340). Only some groups of !Kung have adopted settled life-ways; others continue to pursue mobile foraging strategies (albeit while interacting with other settled peoples in the region, as well as with increasing influence from global twenty-first century cultures, as is the case for all contemporary foragers). Since all !Kung peoples share long cultural histories, the significant differences in childhood experience between primarily settled and mobile groups documented by Draper and Cashdan can be more definitively related to their different socio-economic organization and demonstrate a greater emphasis on sibling care of infants during this very early period of infant development: as noted above, among mobile foragers, including mobile groups of !Kung, proximal care by primary caregivers is the norm during early infancy. Only later in childhood were infants cared for by an older sibling or cousin, or perhaps extended family members such as grandparents or elders.

Among mobile groups, children appear to be subjected to much less formal 'care' in general, and large groups of children of varying ages can be free to roam camps and indeed beyond (Draper and Cashdan 1988; Moses 2015). In contrast to the relatively free lifestyle of infants developing within a hunter-gather or foraging society, ethnography suggests that, among settled and agrarian societies, a greater imposition of behavioural regulation by carers and greater encouragement of self-regulation amongst those infants being cared for is more common. This serves to facilitate a greater infant-carer ratio, allowing more adults and older juveniles to work in the fields and so contributing to overall productivity. Discipline, in the form of self-regulation and response inhibition, and a greater reliance on having one's attention controlled and directed by a carer, may thus be stressed earlier and more intensely in farmer societies, and this can be expected to impact on how a child's cognition develops. For example, it can be expected to improve infants' readiness to be taught (as well as helping develop the juvenile carer's informal teaching skills), through developing an infant's executive function (EF). EF refers to a set of cognitive processes necessary for the cognitive control required to attain goals, such as attentional control. In a WEIRD school setting, greater control of attention was demonstrated after a structure was imposed requiring 4–5 year olds to practise equitably sharing attention with each other (Diamond et al. 2007).

The spatiality of observational learning may also be impacted by differences in child-care arrangements between small-scale agricultural and hunter-gatherer societies. In both, young children will interact with and often be cared for by other children. In a hunter-gatherer society, however, the scale of play appears to be broader than in a small agricultural society where there can be more community control over play and interactions. In agrarian societies, infant care is facilitated by a smaller number of carers within the more confined area of the village: thus childcare of younger infants seems to be more closely tethered to the home and immediate surroundings, with only older children – especially males – travelling beyond the village to assume labour duties (indeed, arguably further than forager children, at least for the !Kung (Draper and Cashdan 1988)). Therefore, as Moses argues, in farming societies, 'Socialization and traditional teaching would have been strongest at the household level' (Moses 2015, 170). This has implications for the kinds of technologies to which infants in farmer societies are likely to be exposed to, favouring observational learning from events proximal to their home (e.g. Moses 2015; though cf. Draper and Cashdan 1988). As Fouts et al. comment with regard to Bofi farmers,

> weaned farmer children (2–4 year olds) are typically in the village and not in the fields … [they] … observe subsistence work in the village (e.g. processing of food, preparing for work in the fields), have access to subsistence-related objects and tools, and visit the fields periodically. (Fouts, Neitzel, and Bader 2016, 670)

In farming societies, where production and consumption is more likely to be organized at household level (e.g. Byrd 2002; Kuijt et al. 2011) infants' main experience will be of domestic tasks. There may also be more of these in settled villages, whose structures require more maintenance and more cleaning and organizing duties are required (Baird, Fairbairn, and Martin 2017) that may be observed by children.

The material culture present in the domestic environment of an infant can be expected to shift from hunter-gatherer to agrarian lifestyle. For example, Draper and Cashdan (1988) describe the rudimentary physical environment of the bush-living !Kung as including a central yard created by an elliptical arrangement of inward facing dwellings where children, along with the adults, spend the greater proportion of their time in camp, working at food preparation and subsistence tasks. This is an environment well-fitted for learning about the social and ecological worlds as infants first engage with the world attached to their mothers and later in the company of other children. In contrast, the newly settled !Kung described by Draper and Cashdan live in a material environment that 'like the subsistence economy, is more complex and differentiated, mirroring the many necessary activities' (Draper and Cashdan 1988, 344). Here, Draper and Cashdan report physical structures and zones set aside for specialized uses, with family huts further apart. These houses are made using more substantial material and sophisticated building techniques, with separate use areas accumulating outside them, such as stock enclosures, drying racks for processing harvested foods and shade arbours for adults to sit while grinding corn, repairing tools, etc. As already noted, this elaboration of material environments is typical for agrarian (and indeed many pastoralist) societies, in contradistinction to foragers' (see references in Coward and Dunbar 2014). These are environments that would enable a greater diversity of observational learning involving technology. Young children can easily learn through observing adults working with materials about their properties and how to innovate with them: how materials can be bent, broken, treated and joined to create new structures. In addition to learning from observing the production and use of technologies, children's independent learning when exploring and interacting with materials can be boosted simply by seeing how others have *already* used them. That is, they can deduce and creatively exploit the affordances of materials just by seeing outcomes. Neldner, Mushin, and Nielsen (2017) found that 4-year olds, in both a Western urban population and a remote Indigenous community, increased their ability to innovate significantly when the affordances of the materials they were working with were made visible. When 4-year olds saw that a material that had been formed into a shape, they were 9-times more likely to shape it successfully to solve a specific problem. Such evidence suggests the ability of young children to technologically innovate can be increased without the teaching or even observation of processes, but merely through greater exposure to an environment rich in examples of material construction.

We have discussed above how observing the *use* of concrete objects and materials, and the social cues around such usage, should be considered valuable for learning about them – and infants may be closer to the drama of technology use when living within an agrarian settlement than a hunter-gatherer society. The greater technological elaboration of a settled environment, as well as the closer location of the infant within it and their attentional training, are also factors favouring early infant–adult interactions with meaningful reference to technology. Adult–infant verbal interaction in such an environment can arise without any intention to teach but can still benefit from reference to stimuli that are concretely present and, even in early infancy, the benefit can be significant in terms of development. For example, in a WEIRD study, Rowe, Leech, and Cabrera (2017) report that fathers' use of 'wh' questions (who, what, where, why) with infants at 24 months (but not other questions, or quantity of speech generally) was related to both vocabulary and reasoning outcomes 1 year later. In interpreting their results, the authors of the study point to how 'wh' questions encourage children to link referents to objects in their environment.

An infant's social understanding will also be grounded initially in what is concretely present. Time spent away from mothers and with other caregivers, including siblings, may expose infants to a greater number and range of interactants and hence prompt more verbalization and more transferable, abstract forms of cognition. Typically, while still small-scale, settled villages include not only more people, but also (given constraints on the number of individuals one can be intimately acquainted with), a greater proportion of people in one's extended social network with whom one is less familiar, obliging more formalized and abstracted forms of social interaction (e.g. formalized kinship systems with specialized terminologies, etc. (Read 2010)).

The factors so far discussed also prepare a child for learning through instruction, a pedagogy that is more common amongst farmer societies (though not, as previously argued, completely absent among foragers). For example, in an investigation of teaching amongst the Aka foragers and Ngandu farmers of the Central African Republic, Boyette and Hewlett (2017) found Ngandu farmers shared with the West a relatively greater use of top-down verbal instruction than the Aka. The emergence of such a pedagogic strategy is aligned with greater emphasis on children's self-discipline and associated with ideologies of deference to elders. For example, Fouts, Neitzel, and Bader (2016, 670) contrast Aka and Bofi foragers, among whom 'children are rarely scolded or directed to behave in particular ways and are afforded much autonomy', with Bofi farmers, whose 'core cultural values emphasize deference and respect for elders … Children … are expected to obey elders'. Punishment per se seems relatively rare across small-scale traditional societies generally (Lew-Levy et al. 2018) but oral censure at least may be more common in farming societies compared to foragers. Among the Rotuma, for example (small-scale horticulturalists), Rogoff et al. (2003) report that children who do not take age-appropriate responsibility or are particularly slow in mastering some task may be criticized. Likewise, Keller observes that among the Nso [small-scale farmers from Cameroon] farmer mothers consider themselves as experts who take the lead in training their babies socially and physically, with interactions framed as lessons between an expert and a novice. As children become physically stronger and potentially more useful, unlike their hunter-gather counterparts who will still be roaming free, children in agrarian societies quickly come to learn through instructed direct experience or, as Lancy refers to it the 'chore curriculum' (Lancy 2014, 235). This emphasis on productivity from an early age probably reflects the extent to which agriculture both rewards additional energetic input (more land can be tilled, more plants sown and harvested, etc. with more people, thus raising carrying capacity, whereas the 'input' of more foragers does not raise carrying capacity and thus simply reduces returns for all), and offers a wider range of simple and physically undemanding tasks suitable for children (e.g. weeding, bird-scaring, livestock-minding, etc. vs. skilled and often dangerous gathering and hunting practices).

Discussion and implications

Prompted by increasing awareness of the impact of early experience on the trajectory of cognitive development, we have considered the early childhood experiences provided by hunter-gatherer and small-scale agrarian lifestyles. Several differences stand out as having the potential to influence the development of cognition. Firstly, a change in the global sensory environment of infants, such as might arise from immersion in a more constructed environment, has the potential to introduce a developmental bias in visual processing that favours discrimination of sensory features associated with the constructed aspects of that environment. Such early perceptual tuning may, therefore, help construct a low-level cognitive foundation for more efficient processing involving technology. However, evidence for infant visual tuning that impacts in later life arises chiefly from the area of face recognition, with no studies yet undertaken to show acquired differences for the visual processing of technology-related objects. We have also noted that the distal parenting style typically emerging from a settled agrarian existence places less emphasis on physical contact. This is also likely to encourage greater training of shared visual attention, including to objects. Adult studies have linked attentional style to performance on a swathe of tasks relying on perceptual, social and reasoning capacities and, since differences begin to emerge early (by 24 months), these might significantly impact on cultural carrying capacity for technology through encouraging a greater focus on focal objects at the expense of context sensitivity. However, although such a finding might be anticipated, no studies have yet addressed whether early differences in visual attentional style exist between hunter-gatherer and agrarian populations.

Early experience contributes to a cognitive platform for instances of learning about the world from adults through observation and through adult–infant interactions (verbal and non-verbal). We would emphasize the role of the infant environment as a constraint/enabler regarding what is likely to be learnt from these early forms of learning. Specifically, we note that the agrarian home environment is characterized by a greater density and a more diverse range of technologies, with more frequent opportunities for informal learning about their manufacture and use. Although infants are typically weaned earlier in agrarian society, related changes in childcare can result in infants spending longer in their domestic environment than similarly aged children in hunter-gatherer societies, providing greater exposure to the paraphernalia and drama of agrarian technology during a foundational stage in their development. Changes in the organization of childcare associated with an agrarian lifestyle may also result in greater demand for behavioural regulation, further contributing to a cognitive platform better fitted to learning through instruction.

Through perceptual tuning to a constructed environment, a training of shared attention, imposed behavioural regulation, observational learning and the contribution of these processes to acquiring a readiness for instruction, the environment of a small-scale agrarian settlement offers a range of paths by which infant development might be impacted with consequences for long-term learning and instruction about technology. Instruction has been shown to be the most efficient means by which to pass information across generations (Morgan et al. 2015). It is most strongly associated with the much longer period of lives when we are able to speak and to listen to others speak, but its foundations are laid much earlier, when perturbations in the environment can have profound effects on later outcomes.

Our observations suggest several potential avenues for investigation. The emergence of agricultural lifeways in a number of independent developments across the Old World after around 10,000 BCE and in the New World slightly later, has been argued to mark one of the most significant developments in prehistory, with enormous implications for subsequent human history. While most attention has focused on the economic aspects of this transition, more recently questions about the social and cultural (see references in Coward and Dunbar 2014) and indeed cognitive (Renfrew 1998) aspects of the shift have been prioritized. In parallel, archaeology has seen increasing interest in revealing more about the presence of children in the archaeological record (e.g. Baxter 2005; Kamp 2001; Sofaer-Derevenski 2000). This has included, for example, evidence of lithic manufacture potentially by children (Grimm 2000; Shea 2006; Sternke and Sorensen 2005) and evidence for more formal 'apprenticeships', where children's experience was directed, or at least facilitated by, an adult in lithic (Coutouly et al. 2021) and pottery (Dorland 2018) production. Such evidence has generated interest in constructing an archaeology of teaching (Tehrani and Riede 2008), linked into a wider literature on cultural transmission in traditional and prehistoric societies that focuses in particular on understanding material culture changes over time (e.g. Walsh, Riede, and O'Neill 2019). Bioarchaeologists and biological anthropologists studying human remains have also touched on this question via their studies of demographic patterns, including child mortality and morbidity, as well as weaning ages, across a range of past cultures (see e.g. Lewis 2007). Notably, such work has identified a phenomenon known as the 'Neolithic Demographic Transition', an apparent increase in fertility rates detectable in skeletal collections from across the world in populations undergoing the shift from mobile foraging to settled agriculture, which arguably presents additional evidence for significant changes in reproductive strategies and the experience of childhood between societies pursuing these socio-economic strategies (Bocquet-Appel 2011).

However, we would advise due consideration to the potentially very significant impact on young children of their environment, prior to being mature enough to respond to intentional teaching from an adult. Specifically, emerging understanding of the lifelong influence of child experience on learning justifies greater emphasis on locating young children's proximity to the drama of technology in prehistory. Certainly, evidence of the presence of children and on their location within physical environments and relative to adult activities is available from the archaeological record. Direct evidence of child-carrying technologies may be limited as most will have been constructed from organic materials; however, possible children's toys have been identified (e.g. Crawford, Hadley, and Shepherd 2018), though their spatiality relative to adult activities remains under-explored. Other evidence includes impressions of fingerprints or teeth. For example, bite marks from milk teeth in a clay ball from the lower levels of the Neolithic site at Çatalhöyük suggest the presence of a young child (2-3) able to observe, explore and interact with the technologies of manufacture (Hodder 2011) - see Fig. 1; likewise, children's prints on objects at Early Bronze Age (Fowler et al. 2020) and Neolithic sites (Bennison-Chapman and Hager 2018) indicate the presence of children experiencing a technologically rich environment (see also Röder (2018) for further examples).

In this paper, we have sought to emphasize the potential significance of early infancy and childhood for cultural transmission. Ethnographic evidence suggests, in particular, a distinction between the social, cultural and physical environments of children raised in small-scale, particularly mobile, cultures, and those in larger scale, settled and agricultural groups. Mobile forager infants are raised in extremely close proximity to caregivers, especially mothers, for longer periods and in environments where material culture may be less diverse and/or less often seen 'in use' (e.g. hunting technology). Once weaned and no longer carried by caregivers, children in

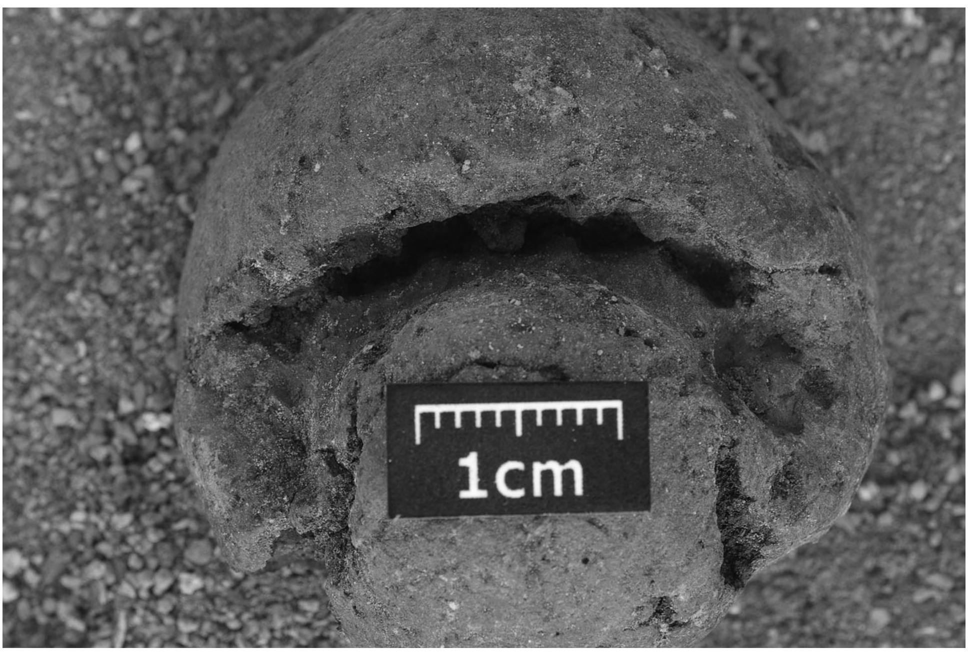

Figure 1. Marks from bite of milk teeth in a clay ball from the lower levels at Catalhoyuk (source: Simon Hillson, reproduced from Hodder (2011)). Such evidence may be helpful in determining whether young children in a settlement were sufficiently proximal to the drama of technology for it to contribute to their longer-term development as individuals and, thereby, to the culture-carrying capacities of their community.

small-scale mobile societies are largely not required to contribute significantly to economic productivity, nor expected to learn in formal, disciplined settings. In contrast, infants in settled, farming societies tend to be weaned earlier and may be rather more spatially distant from parents, left to the care of older siblings or other relatives in household-focused environments which comprise a more diverse range of objects and technologies. They are also more often required and disciplined into formal learning in order to contribute economically to the household. We propose that these differences favour different trajectories of neural and cognitive development, and thus potentially very different forms of learning, cultural transmission and engagement with material culture on the part of children. Hence, we argue that more attention should be paid by archaeologists to lines of evidence with the potential to inform directly on childhood environments in the past.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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