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Back to square one: the bodily roots of conscious experiences in early life

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Abstract

Most theoretical and empirical discussions about the nature of consciousness are typically couched in a way that endorses a tacit adult-centric and vision-based perspective. This paper defends the idea that consciousness science may be put on a fruitful track for its next phase by examining the nature of subjective experiences through a bottom-up developmental lens. We draw attention to the intrinsic link between consciousness, experiences and experiencing subjects, which are first and foremost embodied and situated organisms essentially concerned with self-preservation within a precarious environment. Our paper suggests that in order to understand what consciousness 'is', one should first tackle the fundamental question: how do embodied experiences 'arise' from square one? We then highlight one key yet overlooked aspect of human consciousness studies, namely that the earliest and closest environment of an embodied experiencing subject is the body of another human experiencing subject. We present evidence speaking in favour of fairly sophisticated forms of early sensorimotor integration of bodily signals and self-generated actions already being established *in utero*. We conclude that these primitive and fundamentally relational and co-embodied roots of our early experiences may have a crucial impact on the way human beings consciously experience the self, body and the world across their lifespan.

Keywords: self; consciousness; embodiment; predictive processing; *in utero* perception

Introduction

In the past decades, significant theoretical and empirical efforts from philosophy, neuroscience, psychology, psychiatry and the computational sciences have worked to unravel the psychological and neurobiological nature of human consciousness. The so-called 'hard problem' (Chalmers 1995)—how and why do certain physical structures and functions of the brain and body relate and give rise to conscious subjective experiences (Nagel 1974; Block 2008)—continues to fuel current debates. Most theorists address this question by exploring the relationship between 'conscious experiences' and the 'brain' (Dennett 1992; Dehaene 2014), in the search for neural correlates of consciousness. An exhaustive discussion of these theories and their metaphysical assumptions would lead to a substantial digression and cannot be addressed here in detail. (See Table 1 for an overview of the most recent and seminal accounts and (Safron 2020a,b) for a recent discussion.)

In this paper, we propose to zoom out from the classical conundrum of the relationship between consciousness and its neural correlates. Instead, we go back to 'square one' in order to examine the nature of experiences as they arise in early human life, *in utero*. The underlying assumption is that by endorsing a bottom-up and developmental perspective in exploring how conscious experiences dynamically arise and develop in concert with the developing organism, we may reveal important insights into what consciousness 'is' and its basic organic structure (Lyon *et al.* 2021).

We build upon the idea that consciousness is intrinsically linked to 'experiences'. Experiences are particular spatiotemporal events that consist in the instantiation of experiential properties by experiencing subjects (i.e. particular spatiotemporal individuals) (Nida-Rümelin 2017). This means that experiences do not occur in a vacuum, but they are intrinsically linked to an experiencing subject or to 'someone' as their ontological 'bearer' (Sartre

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Table 1. Overview of theories of consciousness and implications of endorsing a developmental lens

	Global Neuronal Workspace Theory (GNWT)	Integrated Information Theory (IIT)	Higher-Order Thought (HOT)	Predictive Processing Theories (PPT)	Integrated World Modelling Theory (IWMT)
Necessary (and potentially sufficient) conditions for consciousness	Large-scale workspaces for integrating and broadcasting information from otherwise segregated specialist processes	Complexes of irreducible self-cause–effect power	Meta-representation of knowledge	Invertible generative world models	Generative world modelling with coherence with respect to space, time, and cause for system and world
Emphasizes phenomenal, access, or autonoetic self-consciousness (P-C, A-C and S-C, respectively)	A-C; Questions distinction with P-C	P-C	A-C (as being equivalent to P-C) and S-C; some versions reject the existence of P-C	All forms of consciousness to varying degrees depending on particular theories	Primarily P-C but also A-C and S-C
Minimal conscious system	Anything possessing a workspace architecture	An elementary particle	Variable, depending on the specific theory being considered	Variable, depending on the specific theory being considered	Any nested generative process capable of generating an integrated world model such that entities can be coherently put in relation to each other with specific properties in space and time
Potential positions on the development of different forms of consciousness	Birth	Independent gametes, and then a new consciousness at fertilization and then eventually a shift to the nervous system	Postnatally	Variable, depending on the specific theory being considered	Unclear for P-C; postnatally for A-C, and multiple years for developing/learning different forms of S-C
Potential positions on the evolution of different forms of consciousness	Unclear, but possibly not until the evolution of a thalamocortical system and avian homologues	Creation of universe (to the extent there was a beginning)	Variable, depending on the specific theory being considered	Variable, depending on the specific theory being considered	Unclear for P-C; expansion of deep hierarchies to include stimulus-decoupled dynamics for A-C (and possibly also P-C), and with the advent of language for S-C
Considerations of embodiment	Minimal	Minimal	Minimal	Variable, depending on the specific theory being considered	Extensive
Implications of adopting the foetus/infant-eye view	When do workspace architectures of which kinds/capacities first get established?	When do complexes of what degrees of integrated information with which internal repertories first form?	When are learners capable of abstracting meta-representations of what degrees of complexity?	What are the initial priors, and subsequent posteriors, functioning as empirical priors for further inference?	What kinds of coherence get established to what degrees at which points in development, and what levels of coherence are required for the emergence of different forms of consciousness?
Implications of drawing attention to non-visual modalities	Workspace architectures could be used for any kind of information	Many, e.g., potentially stronger connections between consciousness and volition in terms of degrees of integrated information associated with body maps	Some modalities may better lend themselves to explicit re-representation relative to others; e.g. interoceptive modalities are difficult to precisely localize/temporalize	PP can be applied to any kind of sense data, albeit with different degrees of tractability with respect to predictive modelling	IWMT suggests that all modalities are enfolded into visuospatial and somatospatial awareness, which should be able to support a touch/smell/sound-first perspective, and which may also alter estimates of when different forms of consciousness first develop

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1943; Zahavi 2005; Legrand 2006; Ciaunica 2016, 2017). As Nida-Rümelin points out: 'we cannot even think the occurrence of an experience without thereby thinking it as involving an experiencing subject' (2017, 56). Hence, the notion of an experiencing subject is conceptually prior to the notion of an experience, and the notion of an experience is conceptually prior to the notion of consciousness.

If this is so, then before any attempt to understand consciousness, we must address the nature of 'experiencing subjects'. As we will see shortly, this emphasis is far from being trivial. This is because, as it happens, this 'someone', or the 'bearer' of experiences is not an abstract entity floating in an abstract space. Rather, humans—the experiencing subjects at stake here—are 'embodied' living organisms actively engaging with a wider physical and social environment in order to secure survival, self-preservation and potential reproduction (Gibson 1977; Varela *et al.* 1991; Aitken and Trevarthen 1997; Gallagher 2000; de Jaegher and Di Paolo 2007; Thompson 2007). Indeed, recent years have seen an 'embodied turn' in addressing the nature of conscious experiences. There is a growing consensus in philosophy, psychology and cognitive neuroscience that multisensory and sensorimotor information about the 'body' plays a central role in structuring our basic sense of self and subjective conscious experiences (Reed 1996; Gallagher 2000; Blanke and Metzinger 2009; Trevarthen and Delafield-Butt 2017; Trevarthen *et al.* 2006).

However, as we will see shortly, if we understand consciousness as necessarily related to experiences and from there to embodied experiencers (i.e. human embodied individuals actively engaging with an environment in order to maintain self-preservation), then it becomes clear that consciousness cannot be addressed in isolation from 'bodily self-consciousness'. Recent work in mind and brain research stipulates that our perceptions, cognitions and actions are fundamentally geared towards self-preservation,[1] i.e. the need to maintain and regulate the psychological and physiological needs for the integrity of the living organism (the human body or individual) within a wider and highly volatile social and physical environment (Varela *et al.* 1991; Northoff and Panksepp 2008; Clark 2013; Hohwy 2013; Ciaunica 2019; Limanowski and Friston 2018; Seth and Tsakiris 2018; Seth 2021). In order to fulfil the fundamental conditions for self-preservation, humans need to constantly move, act and interact with the physical and social environment. Multisensory integration of sensory signals arising from both inside and outside our bodies is fundamental to building a cohesive model of our body, self and the world (Park and Blanke 2019). It scaffolds not only our subjective experience of being present, in the here and now, but most importantly, it ensures successful navigation in a complex and ever-changing physical and social world.

Now, one way the human organism may complete this task is described by the influential 'Predictive Processing' framework (Friston 2010; Clark 2013; Hohwy 2013). This theory proposes that the brain maintains conditions for self-preservation by extracting patterns of information from its embodied, worldly interactions in order to generate self- and world models of the environment (Conant and Ashby 1970). These models form the basis of the so-called 'expectations' of the agent about the causal structure of its internal and external worlds (Rao and Ballard 1999). The human brain actively predicts or anticipates causes of incoming sensory inputs via Bayesian 'prior' beliefs,[2] allowing the modelling of possible 'hidden' causes of the sensory information.

If this is so, then two key observations arise for consciousness studies. First, in order to understand the nature of conscious experience in the here and now of adult life, it is essential to look at how these experiences get off the ground from the outset, in early life. This is because adult conscious experiences cannot be addressed in isolation of prior (early life) perceptual experiences. Regardless of when various forms of consciousness first emerge, there is an experiential continuum between early and later experiences.

Second, if consciousness cannot be addressed in isolation from experiences, then the latter cannot be isolated from experiencing subjects, which in turn cannot be isolated from their bodies and their closest environment. Or the most primitive and closest 'environment' of the developing human body is another human body. Hence, the most basic perceptual experiences—the 'first priors' (Ciaunica *et al.* 2021b)—may arise already in the womb, that is, when humans share bodily and organismic resources with another human being. Indeed, one essential yet overlooked aspect of current discussions on consciousness is that experiencing subjects first develop 'within' another human body. These primitive and fundamentally relational co-embodied roots of our experiences may have crucial impacts on the way human beings start consciously experiencing the self, body and the world.

We unpack these ideas below as follows. In second section, we start with the observation that consciousness studies typically endorse an adult-centric, vision-biased perspective. Cashing out conscious perception in terms of visual processing may be misleading because it overlooks the fundamental multisensory, relational and dynamic nature of our perceptual experiences from the outset, in early life. We suggest that we need a more dynamic and inclusive approach in order to include subjective experiences that are potentially felt, experienced, and yet unreported and/or verbally unreportable. We then introduce the phenomenological notion of pre-reflective self-consciousness that lies at the core of all our conscious experiences and outline its embodied sensorimotor roots. Third section looks at evidence pointing to the sensorimotor roots of embodied experiences *in utero*. Indeed, while it is widely acknowledged that the integration of 'bodily sensory' inputs is fundamental for human perceptual experiences, less attention has been paid to the idea that human bodies necessarily emerge within another human body (co-embodiment). We describe how the preconditions for pre-reflective self-consciousness are established *in utero* in terms of basic forms of self-awareness. Fourth section builds upon the robust evidence speaking in favour of self- and environment exploratory movements and actions in foetuses in order to argue that the latter may be regarded as experiencing subjects in a basic sense, i.e. they perceive and explore themselves, the world and their relation to the world via repeated trials, learning and observation, mainly through proximal senses such touch and olfaction. We suggest that these embodied experiences—regardless of whether they are or are not associated with phenomenal consciousness—come first and constitute the roots of all conscious experiences, even though we do not explicitly or verbally recollect them as adults, nor we always pay attention to them later in life.

[1] Note that this is not to say that agents are limited to perceiving events/objects that are directly related to their survival. Rather, it is to say that perception functions first and foremost a manner of contributing to self-maintenance. We are grateful to one anonymous reviewer for pressing clarification on this point.

[2] 'Belief' here is defined as a probabilistic representation encoded by neuronal activity in a hierarchical Bayesian network.

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Consciousness is not all about seeing a ripe tomato (and reporting it)

Consciousness studies typically endorse an adult-centric, vision-biased perspective in both theoretical and experimental frameworks, predicated mostly on verbal reports (Faivre *et al.* 2017). As Graziano notes, many scientists who study consciousness focus on 'a microcosmic problem: a person looking at a small round spot on a screen' (Graziano 2018) and subjectively reporting that visual conscious perception. Being able to report a given perception counts as an indicator of the fact that *that* perception is conscious. For example, two key features of conscious sensory states, namely 'qualitative character' and 'subjectivity' (Nagel 1974; Kriegel 2009), are usually and famously exemplified with the case of 'seeing a ripe tomato' (Jackson 1986; Levine 2006).

This bias runs deep in current consciousness studies, characterizing even the distinction between conscious versus unconscious perception. For example, subliminal perception is 'inferred when a stimulus is demonstrated to be *invisible* while still influencing thoughts, feelings, actions, learning or memory' (Kouider and Dehaene 2007, 857, our italics). It is 'primarily via the demonstration of *semantic* activation from *invisible* stimuli that researchers tried to define the limits of non-conscious perception' (Kouider and Dehaene 2007, 858, our italics) (see also Marcel 1974). There is some early work tackling tactile detection and auditory modality (Stroh *et al.* 1908). However, vision-based studies became the predominant research paradigm of conscious perception in the past century (but see Arzi *et al.* 2020 for a recent experimental approach; see Barwitch 2020; Millar 2021 on recent theoretical accounts of olfactory perception).

This tacit bias can be straightforwardly accounted for in terms of the facility of the experimental designs and reportability. After all, it is easier to ask adult participants 'what it is like' to see a ripe tomato or whether they have spotted a word on a screen. It is less evident to ask infants whether there is something 'what it is like' for them to listen a lullaby or to detect a tactile experience on their skin, because infants do not yet have language with which to report their experiences. But can we safely infer from lack of potential reportability abilities to lack of conscious awareness? Here, we suggest that we need a more inclusive approach in order to include under the umbrella of consciousness science those subjective experiences that are potentially felt, experienced, and yet unreported and/or verbally unreportable.

The focus on visual conscious perception may be seen as an intellectual inheritance from the historical development of philosophy and neuropsychology that approached vision as the most accessible, 'lowest hanging fruit' in the dissection of subjective experience and its neural underpinning. However, as we will examine throughout this paper, our daily experiences involve more proximal and rich multisensory inputs such as tactile, proprioceptive, visceral, as well as olfactory and auditory signals (Noë 2004; Faivre *et al.* 2017; Ciaunica 2017; Barwitch 2020). All these multisensory dynamic perceptions are blended to form an 'invisible' or 'transparent' experiential background that consciousness studies typically take for granted (Ciaunica *et al.* 2021).

This idea has been long advocated by theorists from the phenomenological tradition (Sartre 1943; Merleau-Ponty 1945/1962) and more recently by Zahavi (2005); Fuchs (2005); Legrand (2006); Nida-Rümelin (2017); Ciaunica (2016); Ciaunica (2017). According to these theorists, the awareness involved in 'my' experiences is not an awareness of it as an 'object', in the sense that I cannot endorse the perspective of an external observer or spectator on it.[3] Rather, any experience directed towards an object in the world (e.g. seeing a ripe tomato or my face in a mirror) implies a 'pre-reflective self-consciousness' that makes my experiences immediately and tacitly given as mine (Zahavi 2005).

As Sartre famously put the point, this fundamental form of pre-reflective self-consciousness should not be regarded as an extra layer added to the on-going experience. Rather, it essentially constitutes the very mode of being of 'any' conscious experience: 'This self-consciousness we ought to consider not as a new consciousness, but as the only mode of existence which is possible for a consciousness of something' (Sartre 1943, 20 [1956, liv]). In Sartre's view, necessarily, any conscious experience is a pre-reflective self-conscious experience (Legrand 2006): 'a consciousness has no need at all of a reflecting [higher-order] consciousness in order to be conscious of itself. It simply does not posit itself as an *object*' (Sartre 1936, 29 [1957, 45], our italics). Pre-reflective self-consciousness is intrinsically a non-objectifying form of self-awareness. This form of self-awareness is thought to pervade and constitute every conscious experience without requiring introspection or reflection (Zahavi 2005).

Importantly for our discussion here, those theorists[4] claiming that one attains self-consciousness only if one has the ability to use the first-person pronoun 'I' to refer to oneself are also committed to the idea that infants are not conscious beings capable of exhibiting pre-reflective self-awareness (Carruthers 1996). By contrast, those theorists who claim that pre-reflective consciousness is an intrinsic feature of our primary experiences and does not stand in a transitive relation to the state of which it is aware allow for infants to be self-aware in this basic sense (Rochat and Striano 2000; Ciaunica 2016).

Interestingly, the phenomenological view—according to which every experience has necessarily and tacitly an experience of bodily selfhood underwriting it (Merleau-Ponty 1945/1962)—echoes recent influential work in mind and brain research stipulating that self-preservation, i.e. the maintenance of one's vital integrity, is at the core of all perceptual events (Northoff and Panksepp 2008; Ciaunica 2017; Rudrauf *et al.* 2017; Seth and Tsakiris 2018; Limanowski and Friston 2020). In this view, the self is not only embodied, but also perceptual experiences are imperatively driven by basic constraints of physiological regulation that subserve self-preservation of the embodied human individual.[5] Whenever we perceive something, self-related interests (information relevant to self-preservation) necessarily guide both our perception and actions (Ciaunica and Crucianelli 2019).

In what follows, we propose that examining the nature of our basic pre-reflective embodied experiences may help us shed light on the nature of conscious experiences *tout court*. Specifically, we suggest that the preconditions for basic and embodied forms

[3] This is not to deny the existence and importance of the fact that I can endorse a third-person objectifying view on myself and take myself as an object of experience (e.g. self-introspection or self-recognition). Rather, it is just that this observational stance should be regarded as emerging late in phylogeny and ontogeny, being dependent on a more primary form of self-consciousness. For example, for some authors, the child's ability to recognize herself in the mirror via the famous rouge test (Lewis and Ramsey 2004), i.e. ∼18 months of age, constitutes the hallmark of self-consciousness. This point however is controversial (see Rochat and Striano 2000; Ciaunica 2016).

[4] For example, some theorists account for the intransitive use of the term 'conscious' by means of some kind of higher-order theory (Carruthers 1996). For these authors, the presence/absence of a relevant meta-mental state was supposed to serve as a criterion in distinguishing conscious/unconscious mental states.

[5] We are grateful to one anonymous reviewer for pressing clarification on this point.

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of pre-reflective self-consciousness are already becoming established *in utero*. That is, prenatal organisms possess a basic form of self-awareness (Ciaunica 2016), which constitutes the fundamental basis or roots for all conscious experiences. As we will see shortly, there is growing empirical evidence suggesting that the most basic experiences are already present *in utero* (Zoia *et al.* 2007; Castiello *et al.* 2010; Piontelli 2010; Delafield-Butt and Gangopadhyay 2013; Ciaunica 2017; Ciaunica and Crucianelli 2019; Quintero and de Jaegher 2020; Ciaunica *et al.* 2021).

A metaphorical way of putting the point is to say that in order to understand the nature of a tree, it is not enough to measure its observable 'reflective' branches. Rather, one must also take into account its less accessible, implicit 'pre-reflective' roots, which are, as we will see shortly, fundamental to understand how humans consciously experience themselves, their bodies and their relation to the environment. This is because perceptual experiences develop and unfold gradually on a continuum, spanning from pre-reflective bodily forms towards more sophisticated and reflective forms. The latter are grounded on the former, the same way the directly perceivable branches of a tree both spring forth from, and are also supported by its underground roots. Attention only to the visible branches may produce a superficial account; yet, the tree has deep roots fundamental to its entire form and function. In the next section, we present evidence describing how the preconditions for pre-reflective self-consciousness are established *in utero* in terms of basic forms of self-awareness.

The sensorimotor roots of embodied experiences *in utero*

A significant body of work in philosophy, psychology and neuroscience proposed that at the heart of human perceptual experience of all kinds lies the integration of 'bodily sensory' inputs (Varela *et al.* 1991; Gallagher 2000; Legrand 2006; Seth *et al.* 2011; Apps and Tsakiris 2013). The embodied aspects of self-related experiences have been extensively investigated in the literature from various theoretical perspectives (Berlucchi and Aglioti 1997; Damasio 2000; Downing *et al.* 2001; Critchley *et al.* 2004; Panksepp 2005; Trevarthen and Delafield-Butt 2017; Allen and Tsakiris 2019; Free 2020; Jékely *et al.* 2021). Again, a detailed discussion of these accounts would lead to a substantial digression.

Here, we build upon the fairly uncontroversial idea that the multisensory integration of sensory signals must always serve the survival and the maintenance of the body within a wider physical and social environment. Crucially, to achieve this vital goal, the organism needs to remain active. Rather, it needs to actively coordinate the movements of its skeletomusculature to achieve in action the goals that sustain its vitality. All animals share this common foundation of sensory-motor integrative activity, mediated by a highly evolved cell system to serve this purpose rapidly, and with efficient effect—the nervous system (Sherrington 1947).

It has been proposed that a potentially reliable marker of an organism's emergence of perceptual experiences is the identification of anticipatory, goal-directed sensory-motor actions (Merker 2005; Panksepp 2011). The development of prospective, anticipatory awareness in motor control emerges at the beginning of foetal life at the end of the first and beginning of the second trimester (Delafield-Butt and Gangopadhyay 2013). This is an emerging hub of endogenously generated actions with outcomes contingent on proprioceptive, tactile and distance receptors to sense the effect of one's own self-generated action on the external or intra-personal world. In human development, the first signs of the self-generated actions are at exactly 7 weeks and 2 days of gestational age (Lüchinger *et al.* 2008). This is a composition of whole-body, writhing worm-like movements with a patterned oscillatory cascade that travels limbs and trunk as one integrated system. These very first movements lack the discrete, isolate control of a part of the body (an arm, a finger) commonly associated with voluntary, intentional control. Rather, they reflect a whole-organismic motility within uterine fluid dynamics and the gelatinous structure of a late-stage embryo. The latter has limited affordances for action. At this point the nervous system is very immature. Indeed, cervical spinal cord nuclei are rapidly forming axodendritic synapses, initially between interneurons and motor neurons, and then between afferent fibres and interneurons. It begins to function now as an integrated system. Moreover, the 'special visceral nuclei' of the brain are formed and they are becoming innervated via integrative affective systems (Trevarthen 1985).

It is not until 12–14 weeks of gestational age that the organism, now an early-stage foetus entering its second trimester of gestation, makes isolate movements of the limbs or head, indicating differentiated voluntary control of discreet elements of the skeletomusculature. Most profoundly, shortly after this point in gestation, quantified kinematic analyses reveal the foetus has acquired a sensory knowledge of its environment and can plan movements that expect their sensory consequences (Castiello *et al.* 2010). For example, it has been shown that in the case of twin pregnancies, twin foetuses have been observed to make special twin-directed movements that are distinct from movements towards the uterine environment, such as the placenta wall or umbilical cord. These movements can be differentiated by the start of their action, indicating a prospective awareness of the sensory consequences of the self-generated action from the very beginning. The authors of this study note that the action patterns used to touch the twin were the same as those used to touch one's own face but distinctly different from those used to touch the placenta, indicating a very early 'social' awareness of an 'other' agent (Castiello et al. 2010). In singleton pregnancies, motor planning evident in the action pattern of the arms is structured by its final position, or 'goal', by at least 22 weeks of gestational age (Zoia *et al.* 2007).

Foetal awareness of the consequences of a self-generated action is also evident in anticipatory movements of the hands and fingers to a target part of the body during self-directed action. For example, the mouth of the foetus is observed to open during mouth-directed movements of the arm, carrying the finger to it, but before actual contact (Myowa-Yamakoshi and Takeshita 2006; Reissland *et al.* 2014). This indicates an awareness of a self-generated future that manifests in sensory-motor movement and anticipates its sensory consequences. Finally, at birth, the detailed high-precision sub-second kinematic analysis demonstrates new-born arm movements are prospectively organized, with an anticipation of their outcome in body space (Delafield-Butt 2007).

Taken together, these studies demonstrate that a cardinal sign of anticipatory experience, goal-directed motor control, is evident from the start of the second trimester *in utero* and develops in complexity and precision through foetal life as the skeletomusculature and neural connectivity matures (Delafield-Butt and Gangopadhyay 2013). Spinal column, brainstem and midbrain, where connectivity to limb musculature is already established, must be responsible for these first, cardinal signs of agentive control (Delafield-Butt 2007; Delafield-Butt and Gangopadhyay 2013). Notably, however, corticospinal projections do not reach the cervical spinal cord until 24 weeks of gestation (Eyre *et al.* 2000).

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It has been argued that these phylogenetically ancient brain structures, well-known for visceral organ regulation and sensory and motor information transmission, are not simple relays along the corticospinal tract sending sensory information from inferior visceral and somatic receptors to superior cortical areas, where mental operation generates motor commands for transmission back through brainstem for skeletal muscle movement. Theorists draw on clinical and comparative neurology, neuroscience and neuropsychology findings to present a new perspective of brain stem function that recognizes its capacity for these so-called higher cognitive functions and its importance as a core generator of the conditions for conscious agency and which some have suggested may constitute physical substrates of consciousness in their own right (Merker 2007; Northoff and Panksepp 2008; Panksepp and Northoff 2009; Winn 2012).

However, the question whether subcortical or cortical regions are necessary and/or sufficient conditions for constituting the neural systems responsible for intentional control of action and conscious experience continues to be a subject of debate. For example, some scholars have argued for a subcortical basis for affective consciousness (Panksepp 2005; Damasio 2012; Solms and Friston 2018), drawing on evidence from emotional expressions in anencephalic patients and the preservation of feelings with bilateral insula damage (Merker 2007; Damasio *et al.* 2013). By contrast, others suggest that core affects can be described in terms of emotions and feelings without necessarily being conscious (Safron 2021a,b).[6] In what follows we build upon the fairly uncontroversial idea that the neural and sensorimotor basis necessary for the emergence of perceptual experiences and agentive control are in place by the second trimester of gestation. In the remainder of this paper, we motivate the claim that these early perceptual experiences and signs of proto-agentive control constitute the core of what we call pre-reflective self-consciousness, which is in turn the implicit core of all conscious experiences.

The co-embodied roots of early conscious experiences

How do we start perceiving and experiencing ourselves and the world and when? Is it with our first breath after birth, or before, already in the womb, when we breathe throughout the placenta? How exactly can an ensemble of biological cells expand and transform into a human person able to consciously experience herself as distinct from the world and others? These are fascinating questions that remain largely unexplored. The transformation from biological cells into new human life is a complex, precarious and captivating journey[7] (see Young 2005; Trevarthen *et al.* 2006; Piontelli 2010; Ciaunica and Crucianelli 2019; Quintero and de Jaegher 2020; Ciaunica *et al.* 2021 for an extensive discussion).

As we saw earlier, both phenomenological and Predictive Processing (PP) approaches rightly point to the role of an agent's prior experiences in understanding the constitutive relationship between self-organizing systems (such as human bodies) and their physical and social environments (Varela *et al.* 1991; Seth and Tsakiris 2018). Perception and movement are like the two sides of the same coin (Lee *et al.* 1999; Noë 2004; von Hofsten 2007; Lee 2009). Indeed, as we outlined earlier, consciousness does not float in a vacuum but rather is rooted in experiences—particular spatiotemporal events—which are in turn intrinsically linked to experiencing subjects—particular spatiotemporal individuals. Experiencing subjects are not isolated and static islands. Rather as Maurice Merleau-Ponty (1945/1962) noted, the basis of perceptual experiences is rooted in the moving body exploring and exchanging with the environment.

However, less attention has been paid to the idea that human bodies necessarily emerge within another human body (co-embodiment) (Ciaunica *et al.* 2021). For a set time period (typically 9 months), two (or more) human organisms are bound to co-regulate and share bodily and environmental resources in order to survive (co-homeostasis; Ciaunica *et al.* 2021) in what Trevarthen and colleagues call 'amphoteronomic regulation' (Trevarthen *et al.* 2006).

Let us go back to square one and imagine what it might be like to be a foetus at 10 weeks of gestational age, regardless of whether or not such experiences entail consciousness as defined by standard consciousness science. This is an important foundational question because while the experience of being pregnant is given to a certain category of individuals, the experience of being a foetus is universal (Ciaunica *et al.* 2021). We all have been foetuses at some point of our experiential life; hence, we all have been impacted by the experience of co-embodiment. First, it is important to bear in mind that contrary to the common view of the foetus being passively 'contained'[8] and solipsistically 'trapped' in the solitude of the womb, evidence speaks in favour of an active and bidirectional co-regulation between the two living bodies (Quintero and de Jaegher 2020), what it has been termed 'co-embodiment' and 'co-homeostasis' (Ciaunica *et al.* 2021), or 'amphoteronomic' (Trevarthen *et al.* 2006) that draws attention to the mutual regulation of both maternal and foetal autonomic physiologies.

Second, it is crucial to note that in the womb, the most developed sensory systems in foetuses are tactile and olfactory, not visual. Sound, touch and smell are the principal modalities of perception in early life as well as proprioceptive control of movements and body posture (Witherington *et al.* 2002). These inputs may provide the fundamental basis upon which all our perceptual experiences are built later on in adult life (Ciaunica 2017; Ciaunica and Crucianelli 2019). Indeed, it may be the case that visual consciousness fundamentally depends on non-visual modalities in order to overcome otherwise intractable inverse problems (e.g. is an object near and small, or distant and large) and possibly also for realizing phenomenal binding via affordance relations (Safron 2021a).

Intriguingly, in the womb, foetuses spend a significant amount of time in tactile exploration of the boundary between innervated and non-innervated regions (Piontelli 1992, 2010; Mori and Kuniyoshi 2010). Early foetal self-generated action reveals its exploratory, sensation-testing nature. At the start of isolate limb movement at 10 weeks of gestational age, some areas of the body are innervated with sensory nerve fibres, such as the lips, cheeks,

[6] This view suggests that affects might only be made conscious via re-representation by processes capable of coherent world modelling (Safron 2020a,b, Safron 2021a,b). Alternatively, it could be argued that core affects can be described in terms of emotions and feelings without necessarily being conscious (Safron 2021a). From this point of view, these affects might only be made conscious via re-representation by processes capable of coherent world modelling (Safron 2020; Safron 2021a,b), likely depending on either a thalamocortical system or a functionally similar homologue (Dugas-Ford *et al.* 2012; Shanahan 2012).

[7] The fascinating phenomenology of shared embodiment and emerging selfhood during pregnancy has been addressed elsewhere in the literature in more detail (Young 2005; Smith 2016; Lymer 2011; Ciaunica 2017; Ciaunica and Crucianelli 2019; Quintero and de Jaegher 2020).

[8] For example, Kingma (2019) identified two options for conceiving of the relation between foetus and maternal body: (i) the foetus is merely contained within the maternal body and (ii) it is a part of the maternal body.

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ears and parietal bone, and others are not (Piontelli 2010). Those areas that are innervated are frequently touched by the hands of the foetus, the fingers of which are themselves richly innervated. Importantly, touches to sensitive innervated regions create an autostimulatory feedback loop, with sensory signals generated in both the effector (finger) that is moved to touch and the area being touch (such as the lips). Touches to un-innervated regions do not produce this simultaneous autostimulation, but they do produce the feeling of touch in the fingers and commensurate haptic resistive forces sensed proprioceptively.

Using real-time ultrasonography, foetuses have been observed exploring the boundary of the innervated and uninnervated regions, particularly at the anterior fontanel of the forehead where innervation ceases (ibid.). The nervous innervation of the forehead migrates during the second trimester. Consequently, the foetus' exploration this innervated and un-innervated body parts migrates as well, demonstrating that the foetus is attracted to the special relationship between differences in self-stimulatory feed-back on either side of the boundary of innervation (Piontelli 2010, 61–67). The foetus is thus exploring the boundaries of his or her self, developing knowledge of the effects of his or her own self-generated action, and its consequences.

The foetus also displays preferential behaviour in olfactory perception. Early work outlined discriminative swallowing response to amniotic fluid after it was flavoured with sweet versus bitter stimuli (Mistretta and Bradley 1986). Another study found that preterm infants 2 months before the gestational term increased their rate of respiration to engage in the pleasant odour of vanilla, while inhibiting their breathing rate to avoid adverse odours (Marlier *et al*. 2001). Moreover, the delivery of odorants or tastants into the amniotic fluid (either through direct infusion or through maternal ingestion) induced subsequent preferences for these chemostimuli when tested between successive foetal stages (see Schaal *et al*. 2000; Lipchock *et al*. 2011). These intentional actions and demonstration of preferences to engage or disengage provide critical evidence that proto-agentic phenomena may be operative as early as the start of the second trimester of foetal life.

Interestingly, this exploration echoes the common etymological understanding of what the term 'experience' designates, namely: (i) the noun 'eks-pē'ri-ens', through trial of, practical acquaintance with any matter gained by trial, repeated trial, long and varied observation, personal or general; and (ii) the verb, to make trial of, or practical acquaintance with, to prove or know by use, to suffer, to undergo. Typically, experiences are regarded by philosophers and scientists as tacitly endowed with phenomenal character (Nagel 1974; Kriegel 2009). This seems to suggest that the subjects undergoing these experiences must be in a position to at least have the ability to detect and access the phenomenal and subjective aspects of these experiences (Block 1997, 2002). However, the question whether experiences necessarily have phenomenal character is debatable in philosophy (see Lee 2016) but leaves open the possibility that observed experiences can be defined as 'practical acquaintance' or 'exploratory observation' of self and world (Delafield-Butt 2007).

Given the extensive evidence in favour of self- and environment exploratory movements in foetuses, one may suggest the latter are experiencing subjects in this basic sense: they perceive and explore themselves, the world and their relation to the world via repeated trials, learning and observation, mainly through proximal senses such as touch and olfaction. Crucially, these embodied experiences come first and constitute the roots of all conscious experiences, even though we do not explicitly recollect them as adults nor we always pay attention to them later in life. Whether or not these primitive experiences have a phenomenal character—namely 'there is something that it is like to be a foetus in someone's else body'—is beyond the scope of the present discussion.

Even though these early experiences remain inaccessible to explicit adult recollection, they may have a powerful impact on the developing mind, especially if the body is found to 'keep the score' (van Der Kolk 2015) of our past experiences (Piontelli 1992, 2002; Delafield-Butt and Trevarthen 2015; Delafield-Butt 2018). Perhaps, our bodies (the pre-reflective bodily self) kept track of these early experiences and use them as the fundamental basis or material for our full-blown consciousness, the one who allows us to successfully report seeing a ripe tomato or a dot on a screen.

One may use the metaphor of a 'growing tree' to better express this idea: that in order to understand the nature of our directly perceivable or accessible conscious experiences (i.e. the contents of conscious experiences that we can explicitly attend to and report), one needs to go back to its pre-reflective, implicit and less accessible, less visible bodily roots. This is because basic pre-reflective bodily forms of conscious experiences may serve as a basis for more sophisticated and meta-cognitive-type consciousness. Examining the early and pre-reflective roots of the 'growing tree' of embodied minds may teach us something essential not only about its accessible aspects but also about the entire structure of minds, understood as a whole.

Conclusion and future directions

This paper advances the idea that consciousness science may be put on a fruitful track for its next stage by examining the nature of subjective experiences through a bottom-up developmental lens. Most theoretical and empirical discussions about the nature of consciousness are typically framed in a way that tacitly endorses an adult-centric and vision-based perspective. Here, we draw attention to the idea that in order to understand what consciousness 'is', one should first tackle the fundamental question: how do embodied experiences 'arise' from square one?

We started with the observation that the problem of consciousness cannot be addressed in isolation from the question of experiences, which in turn are intrinsically linked to the question of experiencing subjects. Making explicit the fact that consciousness is fundamentally linked to experiencing subjects flags out the idea that humans are embodied and situated living organisms, essentially concerned with self-preservation within a precarious environment.

Next, we built upon the influential Predictive Processing framework in philosophy of mind and computational neuroscience to motivate the claim that in order to understand the nature of conscious experiences, one needs to go back to prior experiences, which are fundamental in shaping the experiences of an embodied subject situated in the here and now. We employed the metaphor of a growing tree to argue that in order to understand the nature of our conscious experiences one must explore its pre-reflective and implicit bodily roots. Indeed, pre-reflective bodily forms of (self)-consciousness may serve as a basis for more sophisticated and meta-cognitive types of (self)-consciousness.

Then, we drew attention to a universal, essential, yet overlooked aspect, namely that the earliest and closest environment of human experiencing subjects is the body of another human experiencing subject. Embodied experiencing subjects are thus

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fundamentally and biophysiologically linked to another embodied experiencing subject from the outset. We presented evidence speaking in favour of fairly sophisticated forms of early sensorimotor integration of bodily sensory signals and movements already being established *in utero*. Examining the early and pre-reflective roots of the 'growing tree' of embodied minds may teach us something essential not only about its directly accessible aspects (i.e. the contents of conscious experiences that we can explicitly attend to and report) but also about the entire structure of minds, understood as a whole.

This fundamental ontological and biophysiological dependence of an embodied experiencing subject on another embodied experiencing subject may have profound implications on the way we understand the very nature of conscious experiences. Future work needs to address in more detail what are the implications of this primitive and universal co-embodiment on the very nature of our conscious experiences. For example, it may question the idea of an integrative model of consciousness restricted to and built mainly upon adult-centric and vision-based conscious experiences. Cashing out all conscious experiences in terms of primarily visual processing may cause us to overlook the fundamental multisensory, relational and dynamic nature of our perceptual experiences from the outset, in early life. Second, setting the focus on the nature of early experiences may also shed light on the question of consciousness (or its lack) in non-human animals. It may even help speak to debates on the potential conscious status of non-neural organisms such as plants (Trewavas *et al.* 2020), single cells (Delafield-Butt *et al.* 2012; Baluška *et al.* 2021) or perhaps more pertinently, complex brain organoids grown in the laboratory (Bayne *et al.* 2019).

Finally, endorsing a developmental view may help us develop a more dynamical, 'real-life' understanding of conscious experiences, based on an explanatory model focusing on how we 'relate' to our self, body and the world, rather than exploring how we statically and photographically 'detect' and report a small dot on a screen.

Data availability

There is no data involved in this paper.

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Conflict of interest statement

None declared.

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