Are Infants Conscious?*

Claudia Passos-Ferreira†[1][2]

†New York University

April 20, 2023

Newborn babies[3] are awake, attentive, and responsive to features in the environment. But are they conscious? Is there something it is like to be a newborn baby? In the philosophical literature, some hold that they are conscious (Block 2009), some hold that they are not (Carruthers 2000), and others raise skeptical concerns about whether we can ever know (Prinz 2012).

The problem of infant consciousness is an instance of the distribution question posed by Allen and Bekoff (1997): how is consciousness distributed among various creatures? The distribution question is especially hard for non-linguistic creatures

* Forthcoming (2023) in *Philosophical Perspectives*.

[1] Center for Bioethics, New York University, New York, USA. Correspondence: claudiapassos@nyu.edu

[2] Acknowledgements: For helpful comments and discussion, I'm grateful to Miri Albahari, Ned Block, David Chalmers, Angela Mendelovici, Barbara Montero, Adriana Renero, Rodrigo Garro Rivero, Daniel Stoljar, and Ken Williford. I'm also grateful to audiences between 2017 and 2023 at the ANU and NYU philosophy of mind groups, the Varieties of Mind conference at the Leverhulme Centre for the Future of Intelligence at Cambridge University, the University of Sydney, the Konrad Lorenz Institute, the Latin American Association of Analytic Philosophy, the Icahn School of Medicine Bioethics Program, the 2023 Eastern APA Meeting, and Mindfest at Florida Atlantic University. I gratefully acknowledge funding from the Templeton World Charity Foundation Inc, Grant TWCF0561 (*What do theories of consciousness predict about consciousness in animals, infants, and machines?*).

[3] Regarding terminology: 'Baby' is the common informal term without a precise definition. 'Infant' is a more formal term that usually covers the first year of life. 'Newborn' (or 'neonate') refers to an infant in the first month after birth.

such as infants who cannot make first-person reports about their conscious experience. Other hard cases of this sort are posed by consciousness in non-human animals and by patients with disorders of consciousness (Bayne et al. 2016).

When speaking about consciousness, I refer to phenomenal consciousness throughout. A mental state is conscious if there is something it is like to be in that state. A creature is conscious if there is something that it is like to be that creature. To be a conscious creature is to have subjective experiences.

In this paper, I argue that infants are conscious at birth.[4] I first discuss the epistemological problem that infant consciousness raises and I propose a methodology for investigating it. I present two approaches for determining whether infants are conscious. First, I consider behavioral and neurobiological markers of consciousness. Second, I investigate the major theories of consciousness, including philosophical and scientific theories, and I discuss their predictions about infant consciousness. I argue that, on balance, these considerations give us strong reason to accept that newborn infants are conscious.

1 The Problem of Infant Minds

Infant consciousness raises a distinctive version of the epistemological problem of other minds: how can we know whether infants are conscious? Consciousness more generally raises a central version of the problem of other minds. How can we know whether anyone besides us is conscious? Consciousness is a subjective

[4] The hypothesis of consciousness at birth has been supported by several theorists in the scientific literature, such as Merker (2007), Lagercrantz & Changeux (2009), Zelazo, Gao, Todd (2007), Rochat (2011).

phenomenon, as Nagel (1974) stresses. We cannot directly observe consciousness in others. Knowing the physical facts about others does not seem to entirely settle whether they are conscious. Based on our own conscious experience, we cannot rule out completely the possibility that other creatures are phenomenal zombies (Chalmers 1996).

This skeptical problem raises substantial obstacles to any attempt to investigate consciousness scientifically. This general version of the problem of other minds applies to all creatures other than ourselves, including language-using adult humans. The problem of other minds becomes all the harder once one moves away from language-using adult humans to non-linguistic creatures. In the case of human adults, one standard way to measure consciousness in other people is to rely on first-person reports. In cases where reports are absent – human infants, non-human animals, some neurological patients, anesthesia, cerebral organoids, machines – our standard methods for studying consciousness are limited.

In one respect, the problem of knowing about infant consciousness should be more straightforward than the problem of knowing about animal or machine consciousness. The experience of being a newborn or a toddler is common to all humans. Because of this, we do not face the problem of knowing about experiences that we have never undergone. However, almost none of us can remember the experiences we had during that period – a phenomenon known as infantile amnesia. Infants cannot consciously remember specific past events, differentiate them from current events and retain them for long periods. Because of this, memory of one's past life is not present from birth. If those experiences were once accessible to our consciousness, they are now inaccessible. As we are not able to form memories of those experiences, those experiences remain unknown to us from the subjective perspective. The only access we can have to conscious experience in newborns is from a third-person point of view.

Infant consciousness has often been naturally grouped with adult consciousness. However, the fact that infants lack introspection and first-person verbal reports makes the straightforward analogy with adult consciousness problematic and sometimes misleading. In adults, we can rely on introspection and their verbal reports to understand facts about their conscious experiences. However, in infants, we cannot rely on introspection or verbal reports.

This raises a difficulty, since introspective observation plays a central role in the science of consciousness. Many philosophers have pointed out that introspection is an indispensable epistemic tool for investigating consciousness. Even scientific measurement of consciousness in cognitive science often relies on scientists' introspective insights to form a hypothesis and to design experimental tasks to measure consciousness.

To know whether infants are conscious, we cannot rely on first-person methods such as introspection, memory, or first-person reports of infants' conscious states. It follows that we must rely on other methods, especially third-person methods such as behavioral observation that might help us to attribute mental states and subjective experience. We might infer the existence of consciousness from the observation of infant behavior. We intuitively attribute consciousness to others, to infants and to a variety of animals (at least to mammals), based on the assumption that inner causal structures that are the same or similar causal structures to ours produce the same or similar effects. However, we know that behavior is often inconclusive as a guide to consciousness. There are many intelligent behaviors that we adults perform unconsciously. The same skeptical challenge appears in cases where we intuitively deny the presence of consciousness based on the absence of intelligent behaviors, such as in the cases of disorders of consciousness (such as patients in vegetative states, minimal or cases of locked-in syndrome) (Bayne et al. 2016). Here we face the issue that behavioral observation alone often does not settle the question of whether certain states are conscious.

One challenge comes from unconscious processes. Newborns display a variety of complex behaviors in reaction to the presence of different external and internal pieces of information they mentally process. Are those pieces of information processed consciously or unconsciously? Although newborns show sophisticated cognitive capacities, to empirically demonstrate conscious perception in infants is still a challenge. We know from normal adult behaviors that many mental activities can be performed unconsciously, including perception, memory, and learning (Dehaene & Changeux 2011; Breitmayer 2015; Block 2011, 2016). As a result, it is a challenge to determine through behavioral observation whether an infant behavior indicates a conscious process affecting that behavior or whether the mental process has been carried out unconsciously.

For example, any adult who observes a two-month-old baby smiling at her mother would agree that it looks as if the baby is having a conscious experience. Psychologists call this “social smiling” (Rochat 2001). They describe it as an important landmark in a baby’s psychological development. Parents often describe the emergence of a social smile as the first moment they discover a person in their child. But what kind of experience is the baby undergoing? Is she consciously recognizing her mother and trying to communicate with her? Or is it just an automatic reaction triggered by brain maturation? These questions cannot easily be answered by simply relying on parents' reports or mind-reading inferences based on behavioral observation. Many ordinary hypotheses about infant consciousness may be founded in inaccurate projections of our own phenomenology. Other methodologies must be applied to understand infant consciousness. [5]

2 The Methodological Challenge

We are faced with a methodological challenge. We can put the challenge in the form of a dilemma. We cannot use first-person methods directly to investigate consciousness in infants. But third-person methods alone seem insufficient to determine whether infants are conscious. Is there an alternative?

In my view, the best answer to the methodological challenge combines first-person and third-person methods used on adult humans with third-person observations of infants.

In the recent science of consciousness, scientists have combined first- and third-person methods in studying adult human consciousness. This has enabled them to

[5] There is a considerable body of work in developmental psychology discussing the development of consciousness in infants (see Rochat 2001, 2011; Gopnik 2009; Trevarthen & Reddy 2007; Trevarthen (2009); Zelazo et al. 2009). Especially relevant is the levels of consciousness model proposed by Zelazo and colleagues (1998; 2007) which describes a hierarchical structure of levels of consciousness, starting with a minimal level on the basis of which more complex forms of consciousness are constructed until the development of higher order thoughts. This body of work is highly relevant for understanding infant consciousness and its development. However, most of this work does not address the philosophical and methodological problem of infant consciousness directly and explicitly. Instead, it tends to assume that infants have some level of consciousness and investigates the development and the features of infant consciousness. I address this body of work in forthcoming work on the varieties of infant experience.

learn much about the structure of adult consciousness and its relationship to behavior and to the brain. As a result, theorists have found certain behavioral and neurophysiological markers of consciousness. In principle, we can then observe infants' behavior and use behavioral markers of consciousness to generate and test hypotheses about infant consciousness. The same goes in principle for neurophysiological markers and observations of infants' brain states. Using independently established principles that connect first- and third-person observations in adults, third-person observations about babies can be used to draw conclusions about their consciousness.

A great deal of research on existing research on infant minds already follows this methodology. It is designed to test for the presence of specific reactions that adults would have exhibited if they had been in the same mental state. If infants react in a similar way, this is taken as evidence that infants are in a similar mental state. If the mental state at issue is a conscious state, e.g., a particular tactile experience, the behavior is taken as evidence that infants are in that state, e.g., having that tactile experience.[6]

In effect, this strategy adopts inference to the best explanation. First, we observe regularities between consciousness and behavior or brain processes in adults. Second, to explain these regularities, we infer underlying principles that connect consciousness to brain processes and behavior. Third, we observe the behavior or brain processes in babies. Fourth, we use the inferred principles and the behavior and brain processes observations in infants to attribute the presence or absence of

[6] A recent example of this is Andrew Bremner's work on infant tactile sensation and spatial localization of touch (Begun Ali et al. 2015).

conscious states. The attribution of consciousness will be justified by inference to the best explanation.

An approach like this has been adopted in the case of animal consciousness, where the degree of theoretical uncertainty is high. The research strategy is to identify specific markers of consciousness in animals. Those markers can be neural mechanisms involved in consciousness, or behaviors often associated with conscious experiences, based partly on what we know about consciousness from the adult human case. Once we have identified neural mechanisms (such as neuroanatomical properties and neurophysiological processes) and behaviors that correlate with consciousness in humans, we can try to find them in animals and connect those observable characteristics to conscious experiences. The data from adult humans should work as a reference in comparing neuroanatomical, neurophysiological and behavioral features observed in non-human animals to the human case.

Regarding neurophysiological markers, one current project of the science of consciousness is to find the neural correlates of consciousness. A neural correlate of consciousness is a minimal neural mechanism sufficient for any conscious perception, and it is directly associated with states of consciousness. Neural correlates of consciousness can refer to a specific content of consciousness (e.g., experiencing faces), or the overall state of consciousness (the experience of consciousness as a whole). Identifying a neural correlate of consciousness involves connecting behavioral correlates of consciousness to the neural mechanisms underlying those behaviors. There is no consensus about which neural mechanisms are responsible for consciousness in adult humans, as observed by Koch and colleagues (2016b) in a recent review on the topic, but we are gradually making enough progress to apply our tentative theories to the case of animal and infant consciousness. In principle, if we find a neural correlate of consciousness (from the adult case) in animals or infants, that is some evidence for consciousness.

Regarding behavioral markers, in principle the same methodology applies here, but there are some special difficulties in the case of infants. Typically, it is easier to train a non-verbal animal (e.g., higher nonhuman mammals, especially primates) to perform a task than to train infants (Kouider et al. 2013). For instance, one way to study the neural correlates of conscious sensory perception in adult subjects is to present them to a psychophysical paradigm, e.g., visual masking, that contrasts visible and invisible stimuli (conscious and non-conscious stimuli), and thereby isolate the moment of the conscious stimuli (Dehaene & Changeux 2011). The invisible stimulus is a subliminal stimulus – that is, the visual information is so reduced as to make it undetectable to conscious subjects. The invisible stimulus can be achieved by a method called masking, where the conscious visibility of a stimulus is reduced by the presentation of other stimuli acting as "masks."[7] Monkeys can be trained to give subjective report of the presence or absence of a stimulus, in tasks involving visual masking, either by touching the location of a stimulus on a screen or by pressing a key to indicate the absence of a stimulus (Kouider et al. 2013). However, it is not so easy to train newborns and infants to report the stimuli they perceive in the same way. The abilities to press a key and touch a screen do not appear in human infants until later in their development. To address this challenge, scientists have been developed other indirect ways to have access to infant

[7] One way to test whether a stimulus is consciously experienced is to create minimal contrasts between conscious and unconscious visual processing and to measure when a stimulus is subjectively reportable. There are several "blinding" methods for achieving subliminal or unconscious presentation of a stimulus, such as masking, binocular rivalry, inattentional blindness, to mention a few (see Dehaene & Changeux 2011; Breitmeyer 2015).

consciousness (e.g., looking time paradigm, high frequency), relying on other abilities infants display earlier in development (e.g., sucking a pacifier, eye-tracking).

We can also go beyond the simple use of behavioral and neurobiological signs of consciousness by appealing to theories of consciousness. Philosophers and scientists have developed a number of theories of consciousness, based on both philosophical and empirical considerations. Many of these theories of consciousness make predictions about which systems are conscious and which are not. Various theorists have already appealed to theories to help determine whether non-human animals are conscious. In principle, these theories can be used to help determine whether infants are conscious as well. As in the case of animal consciousness, we can use empirical methods and theories of consciousness to understand the nature of phenomenal experience in infants and to analyze how behavior, phenomenal consciousness and brain reaction are correlated in the case of newborns.

Perhaps the best methodology is to combine evidence from behavior and neurobiology with evidence from theories of consciousness. Both strategies have often been taken in the literature on animal consciousness, but they have been applied less often to infant consciousness. In the next two sections, I will examine both strategies in making a case that infants are conscious.

3 Behavioral and Neurobiological Signs of Consciousness

I will start by examining behavioral and neurobiological signs of conscious experience that are used in the case of non-human animals, and I will apply these signs to the case of infants. As a case study, I will focus mainly on one sort of conscious state: the experience of pain. Pain is often considered a paradigmatic example of conscious experience. A creature that feels pain is considered a conscious creature, a sentient being. Pain has also relevant ethical implications as it is directly related to suffering. There is substantial literature on whether there is pain in various non-human animals, using behavioral as well as neurobiological markers of pain (see Sneddon et al. 2014). However, a similar case could be made for tactile experience, visual experience, auditory experience, and other sensory experiences.

The common-sense view of pain (along with other similar bodily sensations) involves a dual status: pain is a condition of body parts (e.g., "my neck hurts!") and an unpleasant subjective experience (e.g., "it feels bad!"). The ambiguity of the conception of pain has been of main interest in philosophy and has generated differing conceptions of pain:[8] 1) pain as the perception of an objective reality of the body; and 2) pain as a subjective feeling, with an affective dimension. I will be mostly concerned here with the affective dimension of pain experience, namely its negative affective quality.

The International Association for the Study of Pain (IASP) defines pain as "An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage." They distinguish two phenomena: pain and nociception. Nociception is the neural process of detecting and encoding noxious stimuli. It usually involves a reflexive, automatic avoidance movement generated by motor neurons in the presence of noxious stimuli. In nociceptive responses, the nociceptors (sensory neurons of the skin) detect a noxious stimulus, and they produce a signal that communicates the information to the spinal cord. In the spinal cord, motor neurons activate movements to rapidly move the organism

[8] For an overview of the philosophical theories of pain, see Aydede (2006).

away from the threat. Pain is the affective process in which neurons make a second round of process that goes from the spinal cord to the brain; there, a million neurons in multiple regions create the sensation of pain. This is the *subjective feeling of pain*, an unpleasant subjectively felt quality. In humans, this is a well-known process that involves unpleasant and negative affect, associated with emotions of fear, panic, stress, and behaviors such as crying and avoiding the threatening stimulus. In humans, both processes (the sensory and the affective) are connected. Usually when nociceptive responses are activated, we feel the conscious experience of pain although the processes can be dissociated to some degree with analgesics or in case of lesions (Allen et al. 2005).

Do animals feel pain? Earlier researchers often denied the presence of consciousness in nonhuman mammals, such as mice, but these days there is a strong consensus that nonhuman mammals are conscious. The debate over animal consciousness has moved to simpler animals, such as fish, where it is increasingly common to accept that fish are conscious (see Tye 2016).[9] Many researchers are inclined to attribute pain experience even to complex invertebrates, such as octopuses. I will examine the case of animal pain and then apply some of the lessons to the case of infant pain.

In the case of non-human animals, several behavioral signs are often used as evidence of consciousness, both for consciousness in general and for specific conscious states such as pain. Nonhuman mammals (such as primates) that share many behavioral traits with humans and have similar neural mechanisms have been seen as conscious creatures. In addition, they have been used in laboratories to study

[9] For a contrary view on fish pain, see Key (2016) and Michel (2019).

neural correlates of consciousness in humans. For example, monkeys act similarly to humans and have similar brain structures, and they also display similar reactions when faced with some behavioral tasks, e.g., they are able to signal when they do not perceive a stimulus under blindsight conditions (Koch et al. 2016; Kouider et al. 2013). The closer a nonhuman mammal's brain is, in evolutionary and neural terms, to human brains, the more consistent is the analogy with human consciousness.

How can we detect animal pain? Animals similar to us, like mammals, exhibit behaviors that resemble the way we behave when in pain, which allows us to naturally infer the presence of pain. Although they cannot report their pain verbally, we can perceive when they are hurt; they show similar pain-related behaviors as humans do in similar contexts. But it is disputable that we can infer pain experience from mere visual observation of behaviors. The presence of pain-related behaviors can indicate pain, but we can always ask: is the pain a conscious experience, or is it just a nociceptive reflex?

Animal studies have found nociceptive responses in all vertebrates and in a range of invertebrate animals (Sneddon et al. 2014). These animals have the neural mechanisms to react to a noxious stimulus. In the case of nonhuman mammals, these neural mechanisms are quite similar to those in humans. It is widely accepted among scientists that the mammalian pain system has both a sensory and an affective pathway, and that both systems are connected in the same way as it is observed in human pain systems. Mammals also display similar pain-related behaviors, such as awareness of threat, vocalizations, wound grooming and reclusive behavior. Withdrawal, avoidance and nursing behaviors in mammals strongly suggest that their pain systems are comparable to human pain system and are used to infer that they have the capacity of consciously experiencing pain (Allen et al. 2005). Additionally, there is evidence that the anatomical systems involved in the neural processes essential to human consciousness are shared among all mammals (Merker 2007; Baars & Gage 2010), which is taken to suggest that mammals are conscious.

When we consider animals that are more distant in the evolutionary chain, such as birds, fish or invertebrate animals, their nervous systems have different architectures and the neural mechanisms and pain-related behaviors are less similar to mammals. If it is the case that invertebrates are able to feel pain, this capacity must be achieved by a neural mechanism different from that found in mammals. Thus, if non-mammalian consciousness exists, it relies on different neural mechanisms. At one extreme, simple invertebrates have simple nervous systems with nociception response, but without the other part of the process that suggests conscious experience. However, some other invertebrates are more complex. For instance, consider the case of octopuses (Godfrey-Smith 2016a). Octopuses have a sophisticated brain and intelligent behavior; they display flexible and non-reflexive behaviors in response to noxious stimuli. An injury of an arm in an octopus led to a range of wound-directed responses, such as grooming and protecting the hurt arm, sensitization, long-term decreased thresholds for escape responses, and, unusually, amputation of the arm (Alupay et al. 2014). Octopuses seem to make value judgments around the sensory input instead of just reacting reflexively to harm, and they also show memory of the physical stimulus. As Godfrey-Smith argues (2016a, 2016b), it is hard to know with certainty if octopuses experience pain, but their wound-tending and flexible protection of injured areas is at least suggestive of pain.

What about pain in infants? Until recent decades, it was widely believed that infants could not feel pain. Much of the twentieth century was characterized by skepticism toward infant pain, and infant surgery was routinely performed without anesthesia (Rodkey & Riddell 2013). One central cause for infant pain denial was the idea that infant brain and nervous systems are still developing, so their brains are not developed enough to feel pain (Rodkey & Riddell 2013). In recent years, researchers' views have evolved to the point where the most common view is that newborn infants feel pain (Ranger & Grunau 2015).

To investigate whether infants feel pain I will use the same strategy as in animal pain studies. I will consider behavioral, neurophysiological and anatomical evidence of nociceptive responses that correlates with pain in adults and which have been used to indicate pain in animals, that can be used to indicate pain in infants. These responses are biomarkers of pain if they correlate with the subjective experience of pain. The evidence includes the presence of three types of nociceptive responses: autonomic responses, behavioral responses (such as reaction to bodily damage in mammals in general and facial expressions specific to adult humans), as well as evidence of similar brain regions and neural mechanisms activated in infants exposed to noxious stimuli (Moultrie et al. 2016).

Physiological reactions include altered vital signs, such as change of breathing pattern and increasing heart rate and blood pressure. Premature neonates as early as 25-week gestation display those signs. However, those signs lack nociceptive specificity and can be elicited by other conditions such as hunger and distress (Moultrie et al. 2016), so they are unreliable markers of pain.

Considering the analogy with the case of animal pain, the relevant signs for conscious pain are the nociceptive behaviors, which indicate the ability to react to noxious stimuli. Infants display a number of complex behavioral responses, such as pain crying (with changes in pitch, temporal pattern and harmonic structure), changes in facial expressions (e.g., their brows bulge, eyes squeeze shut, lips purse, mouth opens wide, chin quivers), body movements to protect the injured body part (such as limb withdrawal), actions to avoid a noxious stimulus, and agitation.

Facial expressions are often considered a relevant sign of feeling pain in neonates. Most of the standardized pain scales used in clinical practice (e.g., Neonatal Facial Coding System (NFCS)) rely on infants' patterns of crying and facial expressions to assess pain intensity in newborns (Grunau & Craig 1987). However facial pain develops early in fetal life and can be present in the absence of noxious stimulation, as in the case of cerebral damage (Fitzgerald 2015). Moreover, there is evidence that cortical pain processing can occur in the absence of behavioral changes such as facial expression (Moultrie et al. 2016). Thus, facial expression alone, without understanding the neural basis of this behavior, is not sufficient for pain experience.

Neonates also display spinal nociceptive reflexes, such as limb withdrawal and flexor muscle activity, in response to tissue damaging stimuli (Fitzgerald 2015). One concern is that spinal nociceptive reflexes have different profiles in infants and adults. For example, infants' flexion reflexes have longer duration, can be evoked by tactile stimulation and have a lower threshold for sensitization. During development, reflex magnitude and tactile sensitivity decrease, whereas nociceptive specificity and spatial organization increase (Fitzgerald 2015). This may indicate that reflex behavior in newborn infants is not tightly linked to the input modality; so low-intensity mechanical stimuli can trigger the similar behavior in newborns (Fitzgerald 2015).

As a result, observation of behavioral responses such as facial expressions and limb withdrawal, seem insufficient to indicate pain in infants. Those behaviors might occur merely as consequence of nociception reactions, not necessarily caused by an experience of pain. To understand newborn pain, we need to know whether noxious sensory information processed in the spinal cord and the brainstem is transmitted to and processed in the infant cerebral cortex.

In the case of neurophysiological responses, there is evidence that noxious sensory information is processed in the infant cortex (Slater 2006; Hartley et al. 2015; Fitzgerald 2015). A study shows a strong correlation between spinal reflexes (such as limb withdrawal) and cortical responses evoked by experimental pinpricks, confirming that the spinal cord and the cortex share a nociceptive input. Correlations between reflex withdrawal and nociceptive brain activity suggest that noxious stimuli intensity information is encoded in the infant brain (Hartley et al. 2015). However, it's not clear whether this encoding of nociceptive information correlates with pain experience.

Recent brain imaging studies have found that brain networks activated in infants exposed to noxious stimuli are similar to those activated found in adults (see Goksan et al. 2015). Using functional Magnetic Resonance Imaging (fMRI), which measures brain activity by detecting changes in blood oxygenation level, these studies compare brain activity in adults and infants when they are poked with a special retracting rod stimulating a sensation of pain. The study identified the network of brain regions that are active following acute noxious stimulation in newborn infants and compared the activity to that observed in adults. They demonstrated that most of the brain regions (eighteen out of twenty regions) active in adults experiencing pain were active in newborns, including primary somatosensory cortices, anterior cingulate cortex, bilateral thalamus and divisions of the insular cortices, but not in the infant amygdala or orbitofrontal cortex (Goksan et al. 2015). They found that the fMRI response in newborn babies occurs at lower sensory thresholds than in adults – infant brains had the same response to a weak poke (of force 128mN) as adults did to a stimulus four times as strong (512mN) (Goksan et al. 2015). The findings suggest that infants are able to experience both sensory and affective aspects of pain, although they have a much lower pain threshold than adults, confirming the heightened pain sensitivity in newborns reported in previous studies with behavioral responses.

This evidence relies on the idea that the observed neural network activity correlates with pain experience. However, there has been some disagreement regarding the existence of a "pain matrix" specific to pain – a complex network of brain activity that underlies the experience of pain (Mouraux & Iannetti 2018). Evidence shows that most of those cortical processes identified by these studies are not specific to pain as they can be activated by salient non-nociceptive stimulus, such as auditory, tactile, and visual stimuli (Legrain et al. 2011). Because of this, it's not clear whether the infants' brain activity reflects reactions to pain or to salient sensory stimulus. According to opponents, the idea of a "pain matrix" involves an incorrect reverse inference, in which pain experience is inferred from a pattern of neural activation (Iannetti & Mouraux 2010, 2015). If so, these brain responses cannot be assumed as a direct neural basis of pain in the human brain. Recently, however, there has been a new interpretation of the neural basis of pain with the notion of a “dynamic pain connectome” in which pain experience emerges from a dynamic change in a widespread network of brain activity (Verriotis et al. 2016; Mouraux & Iannetti 2018). Although this hypothesis still needs confirmation, the current consensus is that while these brain regions are not specific only to pain, they are involved in pain experience and they are necessary for pain experience.

Although newborn’s nociceptive brain areas are still developing, there are structural and functional similarities between the newborn and adult brain. In the newborn brain, the framework of connections required for somatosensory input from thalamic and subcortical areas to be processed is developed. It is able to discriminate innocuous and noxious stimuli and to process somatosensory and nociceptive information separately (Verriotis et al. 2016). There are some differences in infant cerebral processing of nociceptive information compared to adults. For example, infants show lack of activation of emotional and motivational areas involved in pain (Goksan et al. 2015), possibly reflecting an absence of expectation, motivation, and modulation associated with pain (Duff et al. 2020). However, many of the core structures for pain experience appear to be present.

Overall, the current findings tend to favor the hypothesis of an early onset of pain experience over the hypothesis that a fully developed cortex is needed for pain. Additionally, these findings show a reliable relationship between nociceptive brain activity, spinal reflex withdrawal and pain behaviors in newborn infants. Arguably the best explanation for these findings is that newborns feel pain.

Is this evidence enough to attribute conscious experience of pain to infants? Some may still worry that this behavioral and neurophysiological evidence reflects unconscious pain behavior with no subjective feeling associated. One way to address this worry is to invoke a general criterion for consciousness.[10]

Recently, Michael Tye (2016) has proposed *flexible behavior* as a general condition for consciousness. Flexible behavior is the ability to rapidly change from one course of action to another allowing a variety of responses and adjusting to novel circumstances. Tye's idea is that mental states allow for flexibility in behavior: if a stimulus allows multiple different behavioral responses, it shows flexible behavior, which is a sign that a creature is conscious of the stimulus. If there is no flexibility in behavior in response to a stimulus, this is evidence that no conscious mental state is operative in the production of the behavior (Tye 2016). This provides us with what Tye calls a *zombie test*[11] for living things. According to Tye, conscious experience is what enables a conscious subject to perform a certain sort of action in the actual world; if a creature cannot perform that sort of action, it is not subject to that experience. Additionally, Tye's flexibility condition says that the content of a mental state must be available for action control to be phenomenally conscious.

[10] There is no behavioral sign that is widely accepted among philosophers and neuroscientists as a criterion for consciousness, which is, in addition, suitable for cases of non-linguistic conscious creatures. Chalmers (2010) proposes that *global availability for behavior control* may play this role. His idea is that wherever there is conscious experience, the contents of the experience correspond to contents that are made directly available for global control of the behavior in a cognitive system (Chalmers 2010). So, if I feel pain, for example, the contents of my experience are exhibited in the control of behavior: it can cause me to cry out, to nurse my injury, to avoid the source of the noxious stimulus, to make defensive movements, and so on.

[11] The zombie test aims to evaluate if a creature meets a necessary condition for consciousness (Tye 2016). Tye's necessary condition for consciousness is a general functional role played by mental states in behavior. Mental states allow for a flexible behavior. Changes in mental states often produce changes in behavior. Experiences allow for mental learning and changes in behaviors in response to stimulus. Thus, if no flexibility in behavior is observed, no mental states (no experience in particular) are producing the behavior.

Tye uses the criterion of flexible behavior to analyze whether several species (from fish to birds, from crabs to bees) are phenomenally conscious. He applies his zombie test to detect living things which lack phenomenal consciousness, and to decide which living creatures are conscious. Tye's verdict is optimistic. Among the species submitted to the zombie test (protozoa, plants and caterpillars), only protozoa and plants are considered as lacking phenomenal consciousness. Caterpillars seem to be a borderline case, although Tye prudentially claims that there is no strong evidence of the presence of phenomenal consciousness in caterpillars.

There is a wealth of evidence that infants satisfy the flexibility condition. Newborns display a variety of action systems at birth, which involve flexible behaviors under the control of previous experience, capable of changing based on learning experience and adjusting to novelty. Those behaviors vary from orienting, avoiding, sucking, rooting, to head turning, grasping objects, eye tracking (Rochat 2015). Thus, there is good reason to hold that infants pass Tye's behavioral test for the presence of consciousness in general.

A skeptic might still argue that the evidence presented (both behavioral and neurophysiological) does not show that a subjective feeling of pain plays any causal role in those reactions. They can argue that the connection between the behaviors and the mental state is nothing but a reflex (automatic) response.

In reply, we can argue that inference to the best explanation supports the claim that babies' reactions are associated with feeling of pain. It is rational to attribute pain experience to others in the presence of this behavioral evidence. Standard scientific inference supports the correlation between pain experience and these neural and behavioral markers.

This inference to the best explanation can take two forms. First, if we assume that consciousness plays a causal role in behavior, we can argue that the attribution of feelings of pain to infants provides the best explanation of the evidence of pain-related behaviors and activation of same brain areas. We can appeal to the causal efficacy of pain experiences to rationally explain the pain-related behavior. Pain feels bad. Negative feelings usually cause the desire to get rid of or avoid a stimulus. It causes the desire that it ceases or moves away. Thus, the presence of feelings of pain seems the best available explanation for those reactions in infants.

Second, even if we are unwilling to assume that consciousness plays a causal role in behaviors, we can argue that the best explanation of regularities connecting brain processes and consciousness suggests that flexible behavior is associated with consciousness. The evidence we have suggests that consciousness typically goes with flexible behavior and vice versa and induction from this evidence suggests that conscious pain is present in babies. In this case, even if epiphenomenalism is true and consciousness has no causal power, and thus the experiences of pain are not causing infant behaviors, babies can still be said to be conscious, as they meet the condition for consciousness specified earlier, i.e., the presence of flexible behavior. If so, infants pass Tye's zombie test, and they have pain experiences.

A skeptic might still deny that flexible behavior is a sufficient condition for consciousness. It might still be possible to have a baby that displays flexible behaviors in response to a noxious stimulus without any associated conscious feelings. As I have argued, in addition to flexible behavior, a number of behaviors in infants are similar to behaviors associated with consciousness in adults. These behaviors include the ability to detect novel stimulus (to react to novelty), the ability to react with surprise when a stimulus violates an expectation, the ability to feel bothered when facing a habituated stimulus, and the ability to respond with pleasure when an action achieves the goal. All of these are behaviors that we would not normally expect to be accomplished without consciousness. Of course, we cannot prove to a skeptic that these behaviors must be accompanied by consciousness. Still, by normal standards of evidence, these provide reasonable evidence of consciousness in infants.

To make further progress on this question, it helps to bring in philosophical theories of consciousness to determine in general whether mental processes in babies might be conscious.

4 Infant Consciousness and Theories of Consciousness

There are many different theories of the relationship between consciousness and physical processes, both scientific and metaphysical.[12] Here I will be concerned mainly with the most prominent theories that have consequences for the distribution question of which creatures are conscious. Some metaphysical theories, including for example varieties of materialism and dualism, do not have strong consequences for the distribution question. Other theories, for example, theories about which physical processes correlate with consciousness, have stronger consequences, at least to the extent that they postulate necessary and/or sufficient conditions for consciousness. I

[12] See Chalmers (2010) for a comprehensive taxonomy of views on the metaphysics of consciousness. See Bayne and Seth (2022) for a comprehensive view of scientific theories of consciousness.

will be primarily concerned with theories that take consciousness to be a real phenomenon, setting aside illusionist theories that deny the reality of consciousness.[13]

First, I will discuss three leading philosophical theories: first-order theories, higher-order theories and panpsychism. Then I will discuss two major scientific theories: global workspace and information integrated theory. I will consider the consequences of each theory for infant consciousness. At the end, I will stand back and make a general argument for infant consciousness on this basis.

1. *Panpsychism.* Panpsychism[14] is the view that some fundamental physical entities have mental states. The relevant sorts of mental states here are conscious experiences. According to panpsychism, some fundamental physical entities are conscious – that is, there is something it is like to be, for example, a member of some fundamental physical type (Chalmers 2015). On this view, consciousness is fundamental and ubiquitous. Consciousness is ubiquitous because all the constituents of reality have some phenomenal properties. Consciousness is fundamental in the sense that it cannot be reduced to or explained in terms of anything else. The most

[13] Among theories of consciousness, we find two opposing positions: *illusionism* and *phenomenal realism*. Illusionism is the view that holds that phenomenal consciousness is an illusion, and it aims to explain why experiences *seem* to have phenomenal properties. Illusionists explain conscious states in functional terms and deny that experiences have phenomenal properties; experiences seem to be a real phenomenon, but they are illusory (see Frankish 2016; Dennett 1991). Phenomenal realism is the view that holds that there are phenomenal properties, and those phenomenal properties are not conceptually reducible to physical and functional properties. The phenomenal properties characterize the mental states by what it is like to have them or how they feel (see Chalmers 2010).

[14] Panpsychism can be contrasted with the opposing view of emergentism. Emergentism holds that the mental arises from, or is reducible to, completely non-mental features. All popular forms of physicalism, such as the neural identity theory and functionalism, are emergentist theories fundamentally opposed to panpsychism (Goff 2017).

popular form is *constitutive panpsychism* (Seager 1995; Goff 2017),[15] the view that holds that facts about consciousness are grounded in facts about the consciousness of their fundamental material parts. Accordingly, consciousness exists in extremely basic forms, and it is from these simple forms that the complex consciousness of humans and animals are derived. The consciousness of a human is more complex than the consciousness of a bird; the consciousness of a bird is more complex than the consciousness of a fish; the consciousness of a fish is more complex than the consciousness of an insect; and the light of consciousness can continue indefinitely into inorganic matter with fundamental physical entities. Consciousness is a uniform property of the universe varying from a simple system with simple phenomenology to a complex system with complex phenomenology.

On this view, fundamental particles are conscious, so all kinds of things are grounded in some sort of consciousness in the micro-level. So micro-physical entities or the cosmos have some sort of conscious states. But what about nonfundamental entities? What about complex systems such as infants? Animals? Machines? What other things are conscious (infants, animals, machines) depends on the auxiliary theory as to what kinds of combination amount to a conscious subject.[16] There are two versions of panpsychism: a restricted and unrestricted one. For unrestricted panpsychism, everything is conscious, so infants are conscious. For restricted panpsychism, only some entities are conscious; there can be systems that are conscious, but they do not combine to form a complex consciousness like ours; typically, only sufficiently integrated systems with organic unity are conscious. To

[15] For other forms of panpsychism – such as emergentist panpsychism, panprotopsychism (the view that fundamental entities are proto-conscious), panqualityism, cosmopsychism (the view that the world as a whole is conscious), see Seager (1995) and Goff (2017).

[16] I am grateful to Miri Albahari to press me to clarify this point.

know whether infants are conscious, restricted panpsychism has to face the combination problem: how do micro-physical entities combine according to some principle to give rise to a unified conscious subject in the macro-level. So, most animals are conscious. It's plausible that infants are integrated and unified, so infants are conscious.

Panpsychism makes very likely (more than other theories, such as emergentism) that infants are conscious. Infants are among the kind of complex entities (organisms) that panpsychists claim that are conscious subjects. That is, it feels like something to be an infant, and even to be a fetus although a natural consequence of the view is that their conscious experiences are less complex than adult conscious experiences. However, panpsychism does not specify the conditions under which infant conscious experience occurs, or when in their biological development their conscious experiences emerge, or how complex their experiences are, or which states are conscious and which are not, or how their brain system evolves to form adult consciousness.

2. *First-Order Representationalism*. First-order representationalism holds that conscious states represent the world, and that they are exhausted by their intentional or representational properties. The phenomenal character of the experience is a representational property of the experience. For example, an experience of red represents something red in the world. Perhaps the most well-known version of representationalism is the externalist approach taken by Michael Tye (1995, 2000), Fred Dretske (1995), and William Lycan (1996).

How do we distinguish a representational content that is conscious and phenomenally characterized from an unconscious representation? On Tye's view, for a representational content to be identified with phenomenal character, it must meet some further conditions. The representational content must qualify as 1) poised; 2) abstract; 3) non-conceptual; and 4) intentional content (with the acronym "PANIC"). The first condition is that the representational content must be non-conceptual – that is, the subject does not need to possess any concept necessary for the correctness conditions of the application of the content.[17] The second condition is that the relevant content must be abstract; that is, no concrete object or surface may enter in the content of the state. The third condition is that the content must be *poised*; that is, the content must play a certain functional role in the control of action. The idea is that the information those phenomenal states carry must be directly available to make a direct impact on beliefs and desires. For example, a feeling of pain should cause an immediate cognitive effect of the desire to protect the body, to move away from what is causing the pain.

Do infants meet Tye's conditions for consciousness? I have argued elsewhere (Passos-Ferreira 2017) that infants can represent the world, and that this representation is nonconceptual and abstract. Aside from this, the key question is whether infants' representations are *poised* for the control of action in Tye's sense. Infants are still developing their cognitive systems, so perhaps: not all sensory representations that are available to us may yet be available to them. But they seem to have a variety of representational states that are poised, in the sense that they are directly accessible to the relevant cognitive centers and to action control.

[17] Against the conceptualist view, Tye (1995, 2000) claims that our conscious experiences are not constrained by our conceptual capacities. The content of conscious perceptual states is a nonconceptual representational content. He argues that the content of perception is more fine-grained than the content of thought; that is, conscious experience provides detailed, rich and determinate information.

In the case of pain, for example, infants display a range of behaviors when they feel pain (they cry, they scream their lungs out, they show facial expressions, they change their body postures and movements in a particular way; they also show avoidance movements when they detect the source of pain) that suggest they are conscious of pain sensory inputs. Infants are sensitive to warmth and cold and to changes in temperature at birth. Thermal stimulation in their mouth elicits mimetic reactions, mouth movements, head movements, and squirming, but they also change their sucking behaviors. Their sucking responses become irregular, and it leads to disorganization and cessation of the response – they refuse to suck if the milk in their bottle is too hot (Pratt 1954). This evidence suggests that infants' sensory system produces tactile sensory representations that are poised to have an impact on controlling infants' sucking actions.

This suggests that, at least according to Tye's version of representationalism, infants meet PANIC criteria for consciousness, and infants will have many conscious sensory states.

3. *Higher-Order Theories*. Higher-order approaches analyze consciousness in terms of some relation between conscious states and higher-order representations (either perceptual representation or thought representation) of that state. A phenomenally conscious mental state is a mental state that is the object of a higher-order representation of a certain sort (perception-like or belief-like). In this approach, what makes a mental state (e.g., perceptual states, mental images, bodily sensations, emotional feelings) phenomenally conscious is the fact that it is accompanied by a simultaneous and non-inferential higher-order state whose content is that one is now in that state. One disagreement among higher-order approaches concerns how each

theory cashes out the notion of higher-order states. Higher-order theories come in three variants: higher-order perception theories, higher-order thought theories and self-representational theories.

On higher-order perception theories (HOP), the higher-order states are perception-like; humans (and perhaps other animals) have first-order non-conceptual perceptions of states of their environments and bodies, but they also have higher-order non-conceptual perceptions of their first-order perceptual states. A popular version of higher-order perception theory is the "inner-sense theory" defended by Armstrong (1968, 1984) and Lycan (1996). The inner-sense view holds that humans have first-order senses that detect properties of the environment and the body to produce non-conceptual representations that can then serve to ground thoughts and action-planning, but they also have *inner* senses, which detect the outputs of the first-order senses (i.e., perceptual experiences) to produce non-conceptual higher-order representations of those outputs (i.e., higher-order experiences). In this view, a phenomenally conscious mental state is a state with non-conceptual intentional content, which is the target of a higher-order non-conceptual intentional state, via the operations of a faculty of "inner sense."

Many objections have been raised against the idea of an inner sense (or an intra-mental monitoring system) that generates higher-order experiences of our first-order experiences (Dretske 1995; Sturgeon 2000; Carruthers 2000), and it remains as a challenge for the view to explain the existence of such a complex organization. In the case of infants, there is no evidence of a faculty of "inner sense" that generates higher-order experiences. There is evidence that infants have perceptual experiences with non-conceptual content representing the fine-grained content of the experience

(Evidence!), but there is no clear evidence that they have such a complex mechanism that generates higher-order representations. So, it is inconclusive whether infants have higher-order perceptions of first-order perceptions.

The most popular version of higher-order thought theory (HOT) has been proposed by Rosenthal (1997, 2000, 2005). According to Rosenthal, a phenomenally conscious mental state is a state which is the object of a higher-order thought and which causes that thought non-inferentially. This theory aims to explain the difference between conscious and unconscious mental states. What makes a mental state unconscious is the lack of relevant higher-order states about it. What makes a mental state conscious is that one is aware of having it, and being aware of something is a matter of having a representation of it. A conscious mental state is a state we are reflexively and directly aware of being in. Mental states are conscious because they are themselves the representational contents of higher-order representations. The *what-it's-likeness* of a mental state enters only when we become aware of that first-order state and its qualitative properties by having an appropriate meta-state (a reflexive thought) directed at it.

There is no evidence that infants have higher-order thoughts, or that they can be reflexively aware of their conscious states. It seems implausible to attribute any higher-order concept to infants, at least at birth. They do not seem to be able to entertain thoughts about their mental states. They do not seem either capable of having concepts of their mental states. If higher-order thoughts are necessary for making a state phenomenally conscious, and if infants do not have concepts of their mental states, it follows that infants (and non-human animals) may not have phenomenal consciousness.

Traditionally, an important objection to HOT theory has been that it denies phenomenal consciousness to non-human animals and infants. According to Carruthers (2000), all forms of higher-order theory (e.g., HOT, HOP, or self-representational theories) entail the rejection of common-sense intuition that infants and non-human animals are conscious, and this is a source of resistance to the theory. Carruthers' position on this issue is to challenge the common-sense intuition. He claims that this intuition can be explained away as a mere by-product of our imaginative identification with infants: we imagine that their experiences are phenomenally conscious, and we assume that the experiences *imagined* are similarly conscious (Carruthers 1999, 2000).

However, there is no consensus among HOT proponents about infant consciousness. Some higher-order theorists (Gennaro 2004; Van Gulick 2004) have been trying to resist this theoretical entailment. They argue that HOT is compatible with infant consciousness (and perhaps even late fetal consciousness). The standard strategy is to claim that the higher-order representation is simpler than the reflexive and introspective or mind-reading cognitive structure required by some intellectualized versions of the theory. Recently, Gennaro (2012) has suggested that a HOT approach is jointly consistent with conceptualism and animal and infant consciousness. He accepts that consciousness requires the capacity to have mental concepts, and he argues that some rudimentary mental concepts can be possessed by infants. His view is that infants have primitive conceptual representations, which enable them to have primitive forms of the requisite higher-order thoughts, which enable them to be conscious of their experiences. Gennaro presents empirical evidence from developmental psychology suggesting that infants possess core concepts that are innate: concepts of self, time, cause, agent, body-awareness (Rochat

2001; Carey 2009). He also presents evidence that young infants possess mental concepts: belief, desire, intention, perception. Other concepts, such as pain and hunger, might have been acquired very early via the application of innate concepts.

On Gennaro's view, infants acquire mental concepts within the first year of life. If this is right, then the HOT view can allow infants to be conscious within the first year of life. However, if newborn babies lack mental concepts, then the HOT view cannot allow consciousness in newborns. It is still a potential objection to the HOT view that when a newborn infant screams with apparent pain, there is no conscious experience of pain.

The third variant of higher-order approaches is the self-representational theory proposed by Kriegel (2006) and others. On this view, a phenomenally conscious mental state is a state that also, at the same time, possesses a higher-order intentional content, which represents itself to the person who is the subject of that state. The relationship between the first-order state and the higher-order state is constitutive, or internal; the conscious state is internally connected with its representation. Kriegel claims that the first-order state and the higher-order representation need to be integrated with one another in order for the resulting complex state to be phenomenally conscious. The integration of first-order perceptions with higher-order representations gives rise to the properties that are distinctive of phenomenal consciousness. On this view, a first-order state of a subject is conscious if and only if the subject has a higher-order mental state that is an appropriate representation of the first-order state, and the first-order state is logically connected with the higher-order state. Thus, the conscious mental state is literally directed back at itself, and the first-order state becomes "self-presenting." All and only conscious states are *self-*

representing; whatever a conscious experience represents, it always also represents itself, and it is in virtue of representing itself that a mental state is conscious. Recently, Kriegel (2009) reformulated his self-representational theory. In the new version, he distinguishes two components of a phenomenally conscious state: a qualitative character (representation of properties of the environment) and a subjective character, the *for-me-ness* component (representation of the state itself in the appropriate way). What makes a state phenomenally conscious, what constitutes its subjective character, is a certain kind of self-representation. A mental state is phenomenally conscious if its subject is aware of it, if its subject has inner awareness of the state.

Like higher-order theories, self-representational theories explain phenomenal consciousness as involving a certain sort of metacognitive abilities. In this sense, self-representational theory may be as demanding as higher-order theories: if infants lack metacognitive abilities, the theories will deny phenomenal consciousness to infants. There is no evidence that infants have awareness of their own mental states, emotions and motivations. However, Kriegel (2009) argues self-representational theory can accommodate the case of infant consciousness. Infants may be aware of their beliefs and experiences in a way that does not employ any concept. They may possess a nonconceptual self-representation, which requires only minimal metacognitive abilities. This nonconceptual self-representation grounds the inner awareness that is the key to phenomenal consciousness. As long as infants have nonconceptual self-representation, there is no obstacle to them being conscious.

If infants have nonconceptual self-representation (as some philosophers would agree), then Kriegel's self-representation theory allows that infants can be conscious.

4. *Integrated Information Theory (IIT)*. IIT has been developed by Giulio Tononi (2008);[18] its central idea is that consciousness is identical to integrated information, and information integration is necessary and sufficient for consciousness regardless of the substrate in which it is realized. Tononi's φ is a mathematical measure of integrated information. It measures the information contained in the system as a whole over and above the information in its parts. An object can contain many overlapping systems, and the system with the highest φ value will be conscious. IIT uses a φ to represent conscious experience and then derives predictions about which circuits in the brain are necessary to produce conscious experiences. Additionally, it claims that consciousness varies in quantity and comes in many degrees, which correspond to φ values. Even a simple system (e.g., a thermostat) can be conscious to some degree. IIT also aims to explain the quality of consciousness, and phenomenal consciousness is determined by the totality of informational relations within the relevant integrated complex.

What does IIT predict about infant consciousness? It is highly probable that even newborn infant brains have some degree of integrated information, and that the infant brain will have φ higher than any subsystem of the brain. If so, IIT predicts that newborns are conscious because their systems present some degree of integrated information. IIT probably predicts that infants are less conscious than adults due to the low level of informational relations within their systems compared to the high level of complex relations in adults' systems.

5. *Global Neuronal Workspace Theory*. The global neuronal workspace theory was initially proposed by Bernard Baars (1988) and further developed by Stanislas

[18] See Tononi (2008) for a detailed presentation of the information integrated theory.

Dehaene (Dehaene & Naccache 2000; Dehaene 2014). The main idea is that the brain has a global workspace, which is a momentary memory storage that broadcasts information for widespread access and use by other systems. Once the information is loaded in the workspace, many cognitive processes can make use of it. An entry into the global workspace allows information to be broadcast. This gives rise to consciousness. The contents of the global workspace are the contents of consciousness. Thus, whenever we become conscious of a sensory input (e.g., the sound of a familiar voice) we can retain that information in a short-memory; consciousness is the brain-wide sharing of this information that is stored. In Dehaene's model (Dehaene & Naccache 2000), consciousness occurs when the relevant content enters the larger global network involving both primary sensory areas as well as frontal and parietal areas associated with attention. Conscious perception begins with the activity ("ignition") of that larger global network; activity in the primary sensory areas will not suffice no matter how intense or recurrent. The main challenge to the theory has been finding a measure of brain activity that can detect when sensory information becomes consciously perceived, and when it is unconsciously perceived. Dehaene and colleagues (2011) have been using electroencephalogram (EEG) to measure the brain's electrical activity. They reported finding a neural signature of consciousness, that is, a particular type of electric wave, called P300, that occurs whenever an adult is attending to a consciously perceived stimulus (e.g., a photo or a sound). The electric activity starts around 300 milliseconds after the onset of the image; and it is not present when the image is not consciously perceived because the image has been masked.[19] The

[19] For measuring the P300 wave, they use the method of visual masking, which consists of rendering an image invisible by flashing it very briefly onto a screen and by adding a distracting image just after the first image to mask the first image from the subject's mind (the first display vanishes from consciousness).

electrophysiological component correlates with adults' reports of consciously perceived stimuli. It allows identifying the exact moment when a stimulus becomes consciously seen by subjects. For Dehaene, this measure is one of the *signatures of perceptual consciousness*. It is a necessary and sufficient condition for consciousness, so the lack of the neural marker means lack of consciousness.

What does global neuronal workspace theory predict about infant consciousness? In Dehaene's model, it is not clear whether infants are conscious. If an infant shows the P300, then Dehaene's model predicts that the infant is conscious. If an infant shows no P300, Dehaene's model predicts that the infant is not conscious. A recent study showed evidence for the appearance of broadcasting with brain maturation (and presumably higher level of consciousness) in young infants. Dehaene and colleagues (with Sid Kouider as first author) used the electrophysiological marker of conscious perception (the P300 brain wave) found in adults to map when consciousness first arises in infants (Kouider et al. 2013). They recorded the brain activity (EEG recordings) of five- to fifteen-month-old infants while they looked at face photographs at various durations, using the masking patterns that prevent visual consciousness. They show that infants have a stage of conscious processing functionally similar to the neural marker found in adults. They found a wave resembling the P300 in five- to fifteen-month-old infants even though the electric wave found in infants is weaker and more variable, and it is triggered much later than in adults. By the age of one year, infants clearly display similar brain activity patterns as adults display when they are seeing something. From this evidence, Kouider and colleagues (2013) concluded that perceptual consciousness is present in infants from five months of age. However, it might not be present before then.[20]

However, it is controversial whether the P300 wave constitutes a reliable neural index of conscious perceptual information in pre-verbal infants. In a recent review on neural correlates of consciousness, Christof Koch and colleagues (2016a) argue that this neural signature of consciousness – the P300 wave – might not be a sufficient condition for consciousness. They present evidence that shows that a similar wave (P3b-like) can be both present in the absence of consciousness, as in cases of comatose patients, and absent in the case of some conscious adults; thus, no inference about infant consciousness can be drawn relying on this evidence.

In addition, Koch and colleagues (2016a) suggest a paradigm shift in the research of the anatomical neural correlates of consciousness from the front to the back of the head. Past studies have directly related consciousness with activity in the fronto-parietal network involved in task monitoring and reporting. Koch and colleagues (2016a) argue that the prime candidate for neural correlates of consciousness might be a "hot zone" primarily located in a posterior cortical region associated with sensory areas.[21] It is still an open debate about the accurate anatomical location of this hot zone and the mechanism underlying it, but there is a lot of support for the idea that the future direction for identifying neural correlates of consciousness is to search for activity in sensory areas. If this is right, it suggests that cognitive theories of consciousness, including frontal global neuronal workspace and higher-order

[20] See Koch (2013) for a discussion on Kouider's study on infant brain activity.

[21] There is evidence that most lesions in the anterior cortical area fail to affect consciousness directly; this suggests that the anterior cortex might not be necessary for consciousness. (see Koch et al. 2016b)

theories, may be too demanding and imposing cognitive requirements for consciousness.

These findings have an important consequence in favoring the case of infant consciousness. The frontal-parietal cortex is associated with higher-order functions (with thought-like experiences) involved in task monitoring and reporting, and with areas that are still developing in infant brains and have restricted connectivity. The posterior cortical hot zone includes sensory areas, areas that mature first in infants and show high connectivity in the first three months of life.

5 Conclusion

Overall, what can be concluded from these philosophical and scientific theories of consciousness? Most of the philosophical theories are friendly to infant consciousness. Panpsychism and Representationalism (PANIC) strongly suggest that infants are conscious. Some forms of higher-order theories (Kriegel's self-representationalism and Gennaro's HOT) are compatible with infant consciousness. Some versions of higher-order theories are inconclusive. A clear negative is Carruthers' version of higher-order theory, which explicitly claims that infants do not meet the necessary and sufficient conditions for consciousness. Among the scientific theories, integrated information theory predicts that infants are conscious. For global workspace theory, it depends on how the global workspace is defined. Some frontal/ higher-order versions of global workspace theories suggest that newborn infants may not be conscious.

For those theories that deny infant consciousness (certain higher-order and global workspace theories), the main obstacle seems to be the association of consciousness with demanding cognitive capacities, such as higher-order thinking and accessibility for verbal reports. These capacities are present in adults but not in infants.

In my view, there are independent reasons to think that higher-order theories and frontal global workspace theories impose overly demanding criteria for consciousness. It is independently implausible that consciousness requires higher-order thought and higher-order concepts. Phenomenal consciousness often involves sensory experience without higher-order thoughts. If so, the most plausible theories are consistent with consciousness in newborns.

Ned Block (2009) has raised similar concerns about what he calls "ambitious" higher-order theories. Block (2009) presents evidence from research on synaptogenesis in the human brain that suggests that areas of the brain that specialize in sensory and motor function develop earlier than the prefrontal cortex areas associated with thinking (Huttenlocher & Dabholkar 1997; Baars & Gage 2010).[22] In a newborn brain, synaptogenesis starts simultaneously in different cortical regions, but synaptic density in sensory and motor areas reaches a peak at about three months, whereas the prefrontal cortex area does not reach its peak until well after the first year. Sensory and motor processes mature first, followed by areas involved in top-down control of behavior. It is plausible that infants first acquire sensory and motor consciousness, and only later acquire higher-order functions and cognitive consciousness. On this natural interpretation, consciousness does not require higher-order thought or cognition.

[22] Evidence shows that synaptogenesis in human cortex begins around the third semester of gestation and the first two post-natal years and that there are regional differences: the process occurs earlier in sensory and motor areas and later, in prefrontal cortex; sensory areas synaptic density peaks at about 3 months, whereas the association areas of the frontal cortex peak at about 15 months (Huttenlocher & Dabholkar 1997; Baars & Gage 2010).

None of this provides decisive evidence that infants are conscious. The problem of infant minds remains a difficult philosophical and scientific problem. However, the combined weight of evidence from neurophysiological and behavioral markers of pain along with evidence from theories of consciousness tends to make at least a presumptive case in favor of infant consciousness. Perhaps the evidence presented here in favor of infant consciousness can be defeated by further considerations drawn from neurophysiology and behavior, or from philosophical and scientific reasoning about consciousness. But as things stand, it is reasonable to conclude that the evidence favors the view that newborn infants are conscious.

References

Allen, C.; Bekoff, M. (1997). *Species of Mind: The Philosophy and Biology of Cognitive Ethology*. Cambridge, MA: MIT Press.

Allen, C.; Bekoff, M. (2007). Animal Consciousness In: Velmans, Max and Susan Schneider (eds). *The Blackwell Companion to Consciousness*. Oxford: Blackwell Publishing.

Allen, C.; Fuchs, P.N.; Shriver, A.; Wilson, H.D. (2005). Deciphering animal pain. In Murat Aydede (ed.), *Pain: New Essays on Its Nature and the Methodology of Its Study*. Cambridge MA: Bradford Book/MIT Press.

Alupay, J.; Hadjisolomou, S.; Crook, R. J. (2014). Arm injury produces long-term behavioral and neural hypersensitivity in octopus. *Neuroscience Letters* 558: 137–142.

Armstrong, D. M. (1968). *A Materialist Theory of the Mind*. Routledge.

______. (1984). ‘Consciousness and causality,’ in D. Armstrong and N. Malcolm (eds), *Consciousness and Causality*, Oxford: Blackwell.

Aydede, M. (ed). (2006). *Pain: New Essays on Its Nature and the Methodology of Its Study*. A Bradford Book. Cambridge, Mass.: MIT Press.

Baars, B. (1988). *A Cognitive Theory of Consciousness*. Cambridge: Cambridge University Press.

Baars, B. J.; Gage, N. (2010). *Cognition, brain, and consciousness: introduction to cognitive neuroscience*. Elsevier.

Bayne, T.; Hohwy, J.; Owen, A. M. (2016). Are There Levels of Consciousness? *Trends in Cognitive Sciences* 20 (6):405-413.

Seth, A.K., Bayne, T. (2022) Theories of consciousness. *Nat Rev Neurosci* **23**, 439–452. https://doi.org/10.1038/s41583-022-00587-4

Block, Ned (1995). On a confusion about a function of consciousness. *Brain and Behavioral Sciences* 18(2): 227-–247.

______. (2002). The harder problem of consciousness. *Journal of Philosophy* 99(8): 391-425.

______. (2005). Consciousness, philosophical issues about. In L. Nadel (org), *Encyclopedia of cognitive science*. Hoboken, NJ: Wiley.

______. (2009). Comparing the major theories of consciousness. In Michael Gazzaniga (ed.), *The Cognitive Neurosciences IV*: 1111-1123.

______. (2011). Perceptual consciousness overflows cognitive access. *Trends in Cognitive Sciences* 15(12): 567-575.

______. (2016). The Anna Karenina Principle and Skepticism about Unconscious Perception. *Philosophy and Phenomenological Research* XCIII(2).

Carruthers, P. (2000). *Phenomenal Consciousness: A Naturalistic Theory*. Cambridge: Cambridge University Press.

______. (2004). Suffering without subjectivity. *Philosophical Studies* 121: 99–125.

______. (2005). *Consciousness: Essays from a Higher-Order Perspective*. Oxford: Oxford University Press.

Chalmers, D.J. (1996). *The Conscious Mind*. Oxford: Oxford University Press.

______. (2002). Consciousness and Its Place in Nature. In: David Chalmers (ed.) *Philosophy of Mind: Classical and Contemporary Readings*. Oxford: Oxford University Press, 247–72.

______. (2010). *The Character of Consciousness*. Oxford: Oxford University Press.

______. (2015). Panpsychism and Panprotopsychism. In: Torin Alter; Yujin Nagasawa (ed.). *Consciousness in the Physical World: Perspectives on Russellian Monism*. Oxford: Oxford University Press.

Trevarthen, C. & Reddy, V. (2007). Consciousness in infants. In Max Velmans & Susan Schneider (eds.), *The Blackwell Companion to Consciousness*. Blackwell.

Dehaene, S. (2014). *Consciousness and the Brain: Deciphering How the Brain Codes Our Thoughts*. Viking Press.

Dehaene, S.; Naccache, L. (2000). Towards a cognitive neuroscience of consciousness: basic evidence and a workspace framework. *Cognition* 79:1–37.

Dehaene, S.; Changeux, J. (2011). Experimental and Theoretical Approaches to Conscious Processing. *Neuron* 70 (April 28): 200–227.

Dennett, D. (1991). *Consciousness Explained*, New York, NY: Little, Brown.

Dretske, F. (1995). *Naturalizing the Mind*. Cambridge, MA: MIT Press.

Duff EP, Moultrie F, van der Vaart M, Goksan S, Abos A, Fitzgibbon SP, Baxter L, Wager TD, Slater R. (2020) Inferring pain experience in infants using quantitative whole-brain functional MRI signatures: a cross-sectional, observational study. *Lancet Digit Health*. 2020 Aug 24;2(9):e458-e467. doi: 10.1016/S2589-7500(20)30168-0.

Fitzgerald M. (2015) What do we really know about newborn infant pain? Exp Physiol. 2015 Dec;100(12):1451-7. doi: 10.1113/EP085134.

Frankish, K. (2016). Illusionism as a Theory of Consciousness. *Journal of Consciousness Studies* 23(11-12).

Gennaro, R. J. (ed.) (2004). *Higher-Order Theories of Consciousness.* Amsterdam and Philadelphia: John Benjamins.

Gennaro, R. J. (2012). *The Consciousness Paradox: Consciousness, Concepts, and Higher-Order Thoughts*. Cambridge, US: Bradford Books.

Godfrey-Smith, P. (2016a). *Other Minds. The Octopus, the Sea, and the Deep Origins of Consciousness*. New York: Farrar, Straus and Giroux.

______. (2016b). Pain in Parallel. *Animal Sentience* 2016.028.

Goff, P. (2017). Panpsychism. In Schneider, S. & Velmans, M. (Eds.) *The Blackwell Companion to Consciousness*, NJ: Wiley-Blackwell.

Gopnik. A. 2009. *The Philosophical Baby: What Children's Minds Tell Us about Truth, Love and the Meaning of Life*. New York: Farrar, Straus and Giroux.

Grunau RV, Craig KD. (1987). Pain expression in neonates: facial action and cry. *Pain.* 1987; 28:395–410.

Huttenlocher, P.R.; Dabholkar, A.S. (1997). Regional differences in synaptogenesis in human cerebral cortex. *The Journal of Comparative Neurology 387*(2): 167–178.

Iannetti, G.D.; Mouraux, A. (2010). From the neuromatrix to the pain matrix (and back) *Experimental Brain Research* (2010) 205:1–12.

Iannetti, G. D.; Mouraux, A. (2015). The "Pain Matrix": Myths and (Unpleasant) Truths. *The Brain Adapting with Pain: Contribution of Neuroimaging Technology to Pain Mechanisms*. A. V. Apkarian (ed). Philadelphia: Wolters Kluwer.

International Association for the Study of Pain. *Terminology* https://www.iasp-pain.org/ resources/terminology/ (2011).

Koch, C. (2009). When Does Consciousness Arise? In *Consciousness Redux. Scientific American Mind*, Sep/ Oct 2009.

______. (2013). The Conscious Infant. In *Consciousness Redux. Scientific American Mind*, Sep 2013.

Koch, C.; Massimini, M.; Boly, M.; Tononi, G. (2016a). Neural correlates of consciousness: progress and problems. *Nature Reviews Neuroscience 17*(5): 307-321.

Koch, C.; Massimini, M.; Boly, M.; Tononi, G. (2016b). Posterior and anterior cortex — where is the difference that makes the difference? *Nature Reviews Neuroscience* 17(10): 666-666.

Kouider, S. et al... (2013). A Neural Marker of Perceptual Consciousness in Infants. *Science* 340: 376–380.

Kriegel, U. (2002). PANIC theory and the prospects for a representational theory of phenomenal consciousness. *Philosophical Psychology* 15(1): 55-64.

Kriegel, U. (2006). The same-order monitoring theory of consciousness. In Uriah Kriegel & Kenneth Williford (eds.), *Self-Representational Approaches to Consciousness*. MIT Press. pp. 143--170.

______. (2009). *Subjective Consciousness: A Self-Representational Theory*. UK: Oxford University Press.

______. (2015). *The Varieties of Consciousness*. Oxford: Oxford University Press.

Lagercrantz, H.; Changeux, J. P. (2009). The Emergence of Human Consciousness: From Fetal to Neonatal Life. *Pediatric Research* 65(3): 255–60.

Legrain, V.; Iannetti, G.D.; Plaghki, L.; Mouraux, A. (2011) The pain matrix reloaded
A salience detection system for the body. *Progress in Neurobiology* 93 (2011) 111–124.

Lycan, W. (1996). *Consciousness and experience*. Cambridge, MA: The MIT Press.

Merker, B. (2007). Consciousness without a cerebral cortex: A challenge for neuroscience and medicine. *Behavioral and Brain Sciences 30*(1): 63–81.

Michel, M. (2019). Fish and microchips: on fish pain and multiple realization. *Philos Stud* **176**, 2411–2428 (2019).

Moultrie, F., Goksan, S., Poorun, R. and Slater, R. (2016). Pain in neonates and infants. In *An Introduction to Pain and its Relation to Nervous System Disorders*, A.A. Battaglia (Ed.). https://doi.org/10.1002/9781118455968.ch11

Mouraux A, Iannetti GD. The search for pain biomarkers in the human brain. *Brain*. 2018 Dec 1;141(12):3290-3307. doi: 10.1093/brain/awy281.

Nagel, T. (1974). What is it like to be a bat? *Philosophical Review* 83(04): 435-450.

Passos-Ferreira, C. (2017). *The Development of Consciousness*. Doctorate Thesis.

______. (2017) Varieties of Infant Experience. (Manuscript in preparation)

Pratt, K. C. (1954). The Neonate. In: L. Carmichael (ed.) *Manual of Child Psychology*. New York: Wiley, 215-291.

Prinz, J. (2012). *The Conscious Brain: How Attention Engenders Experience,* Oxford: Oxford University Press.

Ranger, M, Grunau, RE (2015). How do babies feel pain? *eLife* **4**, e07552.

Rochat, P. (2001). *The Infant's World*. New York: Harvard University Press.

______. (2011). What is it like to be a newborn? In S. Gallagher, ed. *The Oxford Handbook of The Self*. Oxford: Oxford University Press.

______. (2015). Innate Experience of Self-Agency. In Patrick Haggard and Baruch Eitam (Ed.) *The Sense of Agency*. Oxford: Oxford University Press.

Rosenthal, D.M. (1997). A theory of consciousness. In: Block N, Flanagan O and Güzeldere G (eds) *The Nature of Consciousness: Philosophical Debates*. Cambridge: MA: MIT Press, 729–754.

______. (2000). Metacognition and higher-order thoughts. *Consciousness Cognition 9*(2): 231–242.

______. (2005). *Consciousness and Mind*. Oxford: Oxford University Press.

______. (2011). Exaggerated Reports: Reply to Block, *Analysis* 71(3): 431–437.

Seager, W.E. (1995). Consciousness, information, and panpsychism. *Journal of Consciousness Studies* 2: 272-88.

Slater R, Cantarella A, Gallella S, Worley A, Boyd S, Meek J, Fitzgerald M (2006). Cortical pain responses in human infants. *J Neurosci* **26**, 3662–3666.

Sneddon, L. U., Elwood, R. W., Adamo, S. A., & Leach, M. C. (2014). Defining and assessing animal pain. *Animal Behaviour*, *97*, 201–212. https://doi.org/10.1016/j.anbehav.2014.09.007

Sturgeon, S. (2000). *Matters of Mind: consciousness, reason and nature*. London: Routledge.

Tononi, G. (2008). Consciousness as integrated information: a provisional manifesto. *Biological Bulletin* 215: 216–42.

Trevarthen, C. (2009). Infant Consciousness. In *The Oxford Companion to Consciousness*, edited by Tim Bayne, et al., Oxford University Press, Incorporated, 2009.

Trevarthen, C.; Reddy, V. (2007). Consciousness in infants. In Max Velmans & Susan Schneider (eds.), *The Blackwell Companion to Consciousness*. Blackwell.

Tye, M. (1995). *Ten Problems of Consciousness: A Representational Theory of the Phenomenal Mind*. Cambridge: MIT Press.

______. (2000). *Consciousness, Color, and Content*. Cambridge: MIT Press.

______. (2016). *Tense Bees and Shell-Shocked Crabs: Are Animals Conscious?* Oxford: Oxford University Press.

Van Gulick, R. (2004). Higher-order global states HOGS: an alternative higher-order model of consciousness. In Gennaro, R. (ed.) *Higher-Order Theories of Consciousness.* Amsterdam and Philadelphia: John Benjamins.

Verriotis, M., Chang, P., Fitzgerald, M., and Fabrizi, L. (2016). The development of the nociceptive brain. *Neuroscience 338*, 207–219.

Zelazo, P. R., Zelazo, P. D. (1998). The emergence of consciousness. *Advances in Neurology,* 77, 149-165.

Zelazo, P. D., Gao, H. H., & Todd, R. (2007). The development of consciousness. In P. D. Zelazo, M. Moscovitch, & E. Thompson (Eds.), *The Cambridge handbook of consciousness* (pp. 405–432). Cambridge University Press. https://doi.org/10.1017/CBO9780511816789.016