The Subjective Perception of Self:
A Cognitive-Neuroscientific Model of Interoception and Exteroception

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Introduction

What does it mean to be “you”? On one level, there is a “you” that has a body and exists in a specific region of space. This “you” experiences the world from a specific perspective. Perception and experience occur to you from a certain point of view. This “you” is the you that exists in the here-and-now. But there is more to you than your current existence and present experiences. The “you” that exists now is the same you that grew from childhood, went to school, had a lifetime of memories—the same “you” that has certain preferences, knowledge, and personal attributes. There is a distinctive unity to this sense of “you”—a cohesion that binds the subjective perspectival nature of your existence in the here-and-now to your existence in the past, up until the present moment. This feeling of “you”-ness is the focus of the study of the self.

The genesis of a feeling of self integrates some of the most basic as well as the most complex actions of the brain. It involves processes as basic as being aware one has a body, as well as complex ones such as ascribing personality traits to oneself. The feeling of self permeates all aspects of our being—from perception and action to memory and higher-order cognition. How is the brain able to accomplish all of this? What sort of neural-psychological processes support such a nuanced, complex system? This is one of the “big questions” in both philosophy of mind and cognitive science. It is beyond the scope of a single paper or book to fully address. In this paper, my goal is to survey some of the scientific literature and put forth a simple, structured way to think about the cognitive and neuroscientific bases of the feeling of self.

To start, it may be helpful to make some distinctions in what we mean when using the word “self”. I alluded earlier to the “you” that exists in the here-and-now, versus the broader sense of “you” that has a life history. The self that serves as a point-of-view, the self for which present experience occurs, we can refer to as the “core self”. The self that spans an individual’s whole life, has personality traits and memories, we can refer to as the “extended self”. In this paper, I choose to focus on the “core self” and the ways it is grounded in various forms of perception. The literature on the extended self and its basis in autobiographical memory is rich, but outside the scope of this paper to address. I will hone in on the notion of the “core self”, and discuss how the brain may delineate the external from internal world in the present moment.

Neuroscientist Antonio Damasio frames the concept of the core self as “[the] stable representation of individual continuity which serves as a mental reference for the organism within the conscious mind” (Damasio, 2003). The core self is fundamentally about drawing a line between the internal and external world. The brain needs to say: “this is me, and this is the world around me.” In order to accomplish this, it must have a stable representation of self, a reference point from which objects and events can be perceived. I will argue that it is through perception that the brain makes this internal-external demarcation. It does this via interoception, sensing of stimuli originating in the body (section 1), as well as exteroception, sensing of stimuli outside the body (section 2).
1.1 Interoception: tracking the internal state

It is crucial to the concept of the self that it involves a representation of continuity. While the world around you may change, the feeling of “you” stays the same. This constancy is part of what distinguishes our internal world from the external one. How does the brain represent constancy? One proposal, put forth by Antonio Damasio, is that the brain represents constancy through interoception. In being aware of the body and its internal processes, the brain creates a stable representation of self.

Traditionally, sensory perception is thought of in terms of our sensing of external stimuli. We speak often of the “five senses”, vision, audition, taste, smell, and touch. This is far from exhaustive. The brain receives information not just about stimuli outside of our body, but from stimuli within it. These interoceptive senses include:

- **Proprioception** – sensing of the position of the body, via innervation of the musculoskeletal system
- **Vestibular sensation** – awareness of body balance and movement, via inner ear hair cells
- **Visceral sensation** – mechanical and chemical sensation of the internal organs
- **The “internal milieu”** – sensing of homeostatic information, including pain and temperature

It is these senses, of the viscera and internal milieu in particular, that contribute to a stable feeling of self.

![Figure 2. The sensory signals available to the brain](image1)

Information about the body’s internal environment is carried through the C and A delta fiber system. This system is an evolutionarily primitive, and sensitive to a diverse cast of stimuli. C and A delta fibers respond to “local pH, partial pressure of oxygen and CO₂, glucose levels, levels of lactic acid, glutamate, histamine, serotonin, and so on” (Damasio, 2003). These fibers also respond to mechanical stress, temperature, itch, tickle, and sensuous touch. Crucially, the C and A delta fiber system is found in every part of the body, and innervates all types of tissue. No other nerve system is so universal in the body.

Not only is the interoceptive system broadly sensitive and practically omnipresent, it is continuously active, and entirely out of our control. Interoception is involved in ensuring
the basic functioning and survival of the organism. It is a sense that is constantly monitoring the state of the body, and the only times it would not be sending signals to the brain is if the organism is seriously ill, or dead. Due to this continuity, it is a good candidate for the brain’s representation of core self.

Furthermore, interoception via C and A delta fiber nerves is contained within a dedicated neural pathway. They ascend via the spinal cord separate from A alpha and A beta nerves. While the source and nature of interoceptive information varies, from temperature sensation in the extremities, to distention of the intestines, it eventually converges through a pathway that terminates in the insular cortex. It is here in the insula that the global interoceptive sense resides. The insula, like visual, auditory, and somatosensory cortices, is topographically organized. The body’s interior is mapped from back to front, going from the posterior to anterior subregions of the insula (Parvizi & Damasio, 2001).

1.2 The role of the insula

The significance of the insula in bodily awareness and awareness of the self is well documented. It becomes active when subjects view pictures of themselves, as opposed to close friends and strangers (Devue, 2007). This result is consistent across different pictorial representations of the person, suggesting the insula is involved in tracking an abstract concept of self. It also is activated during the rubber hand illusion, a form of body transfer illusion, where subjects are made to feel as if a prosthetic hand is part of their body (Tsakiris et al. 2007). This suggests that the insula is associated with the sense of bodily ownership.

The insula is involved in a large number of other phenomena, many of which seem at first to be unrelated to representation of the self. The insula is involved in emotion, time perception, motor control, and object-recognition, for instance. Craig (2009) has argued that the common theme in the insula’s various duties is self-awareness. With respect to emotional awareness, the insula is not just involved in emotions like anger, fear, sadness, and love. It is also implicated in feelings of “trust, empathy, sculptural beauty, and ‘state of union with God’” (Craig, 2009). Thus, the insula seems to be involved in subjective feeling in general, rather than just the “basic emotions”. The insula’s involvement in time perception, too, has to do with awareness of the self. The insula is implicated in cross-modal time synchronization, in which subjects must create a unified sense of “the moment” (Bushara et al. 2003). It is also involved in mental time-keeping (Coull, 2004). While bodily awareness can be thought of as locating the self in space, time perception can be thought of as locating the self in time.

Thus, the insula seems to be involved with self-awareness in general, in a way that spans many modalities and is related to a range of human behavior. Anatomically, this makes sense, as the insular cortex is buried deep within the brain and is highly interconnected with many regions throughout the brain, including frontal cortex, the limbic system, and sensorimotor cortex. Since the insula’s primary input is interoceptive information, this establishes a close relationship between self-awareness and sensing of the body’s internal state.

Figure 3. A sampling of insular activity
1.3 Insula, interoception, and self-awareness

Further evidence linking interoception, the insula, and the self comes from cross-species comparison. While many other species, mammals in particular, share a similar interoceptive pathway that travels from the spinal cord through the brainstem and hypothalamus, the final convergence of these neural pathways from the thalamus to the insular cortex is something that is unique to primates. It may be the case that mammals lacking this convergence to the insula have some basic, primitive senses of self that are highly related to survival and homeostasis. Humans and other primates (notably, chimpanzees and bonobos) have more abstract, higher-order representations of self-awareness (MacPhail, 1998, deWaal, 2008). Perhaps it is the pathway from the thalamus to the insula that is critical for higher-order self-awareness.

What in the insula specifically leads to this higher-order capacity? Craig (2008) has proposed that it may be the high density of von Economo neurons (VENs) in humans. These spindle-shaped neurons are uniquely concentrated in the insular cortex, and little is known about them. However, they may be involved in establishing high interconnectivity between the insular cortex and other areas of the brain such as the anterior cingulate cortex (AIC). Craig’s proposal is that this would allow for highly integrated representations of emotional behavior using interoceptive input.

While this is mostly speculative, there is a convincing association between VEN density and self-awareness. In patients with frontotemporal dementia, there is a correlation between the loss of self-conscious behavior and emotional awareness and the degeneration of VENs (Sturm et al. 2006, Seeley et al. 2006). Additionally, VEN density tracks self-awareness across other mammalian species. While VEN density is high in human adults, it is lower, but present among infants, great apes (chimpanzees, bonobos, and gorillas), cetaceans (dolphins and whales), and elephants (Nimchinsky et al. 1999, Allman et al. 2005). VENs are absent in lower primates such as macaques, as well as reptiles and rodents. The same animal species that have VENs also pass the mirror test of self-awareness, which measures whether an animal recognizes its mirror reflection as itself rather than another animal. Only humans, great apes, and cetaceans (dolphins, whales) have consistently passed the mirror test.

In summary, interoceptive awareness is a strong candidate for a biological grounding of the core self. It involves a diverse array of internal stimuli that are perceived through a dedicated system. The terminal nexus of this system, the insula, has been demonstrated to be intimately linked with several forms of self-awareness. I take this evidence thus far as demonstrating the necessity of interoception in establishing the core self. However, while necessary, interoception may not be sufficient in explaining the core self as formulated earlier. I will now turn to evidence that exteroception—sensing of stimuli outside the body, also plays a crucial role in forming the core self.

2.1 Exteroception: perceiving the Self in the world

As mentioned in the beginning of section 1, what the core self is fundamentally about is drawing a line between the internal and external worlds. It is about establishing the perspectival nature of experience: creating the “me” that perceives the “other”, whether that “other” is a visual scene, a sound, another person, or anything else outside the body. We have already seen the importance of perception in explaining the core self in the form of

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1 A single Asiatic elephant was also shown to pass the mirror test in 2006. This further strengthens the correlation between VEN density and self-awareness.
interoception. But to illustrate the insufficiency of this to explain core selfhood, imagine a person who, while maintaining all the interoceptive capabilities mentioned throughout section 1—proprioception, vestibule-sensation, visceral and homeostatic sensation—is devoid of any other sensory input. Vision, audition, taste, smell, and external touch are all absent. It is hard to imagine that this hypothetical human being would have a sense of self that is embedded in some external world. By stipulation, the only information being accessed by this person is internal information—without reference to the external world, the internal world is all this unfortunate person can know. To have a sense of self is to inhabit a particular point-of-view. It requires a sense of “me” but also a sense of “not me”. It is the latter that comes from exteroception.

What does it mean to be aware of an object? One formulation comes from Chris Frith (1999). Frith proposes that awareness of an object requires three things:

1) A mental representation of oneself as a sentient (feeling) entity
2) A mental representation of the object
3) A mental representation of the salient interrelationship between oneself and that object in the present moment (now)

The first of these requirements, representation of oneself as a sentient entity, corresponds nicely to the account of interoception and the self that we have already seen. It is also natural to associate the second requirement, mental representation of objects, with the traditional exteroceptive senses: sight, hearing, smell, taste, and touch. However, it is the third requirement that reveals the importance of exteroception in grounding the self. In perceiving objects in the world, we necessarily represent them to be a certain way in relation to us. This relationship tells us not only about the nature of the object of awareness, but something about us as well. As psychologist James J. Gibson said, “Egoreception accompanies exteroception like two sides of a coin…one perceives the environment and copeceives oneself” (1979, p. 126). To see how perception of the external world informs our sense of self, let us first turn to some examples from vision.

2.2 The ecological self: examples from vision

Work on the role of exteroception in generating a sense of self is much indebted to the work of both James Gibson and Ulric Neisser, who coined the term “the ecological self”. Neisser defines the ecological self as consisting of the “[knowledge that] one is an active agent in a real environment” (Neisser, 1988, 1991). Neisser, in his 1997 paper “Perceiving It, Self, and Thou”, discusses some ways optic flow in vision helps construct the ecological self. I will discuss some of these examples in this section.

Our visual world is more than a collection of static images on the retina. When we move in our environment, our point of observation moves. This movement of our point of view causes the apparent motion of objects, surfaces, and edges in the visual scene. This movement-induced change in the visual scene is called optic flow. Optic flow provides information about both the layout of the environment as well as the perceiver’s path of motion. Consider the simple case of movement parallel to an extended surface, such as a wall. As the person (and so, the point of view) moves forward, the visual information of the wall moves backward in synchrony. Similarly, if we start to move backwards, the static
objects in our environment seem to move forward in the visual world. Generally, this kind of optic flow gives us reliable information about our own movement\(^2\).

Another kind of optic flow is called *looming*. When an object moves towards the viewer, it appears to get larger and larger until it occupies the entire visual field. The rate of apparent magnification is also salient. The magnification rate tells the viewer how soon the object will collide with the viewer, assuming no change in velocity (Lee, 1980). In this way, optic flow can inform the viewer about their place in the environment “not only in the present but also...in the immediate future” (Lee, 1993).

The phenomenon of *occlusion* can be due to optic flow as well. An object that is fully visible from one point of view may disappear or become *occluded* by another object when the point of view moves. Occlusion provides a layout of the objects in the environment of the perceiver. Objects that become occluded are always further away from the viewer than the occluding object. When navigating a world with many objects of varying distances from each other, and from the viewer, occlusion helps the viewer generate a map of the surroundings, and crucially, their position and path of motion within it.

In these and many other ways, optic flow provides information to the viewer not just about the objects in the environment, but how the viewer is related spatially to those objects. It simultaneously tells a story about the external world and the viewer’s place and situation within it. Visual perception is far from the only modality for which this occurs. When we hear a noise, the sound reaches our two ears at very slightly different times (interaural time difference), giving us information about the source of the sound *in relation to the head*. When we hold an apple in our hand, we feel the force of the object *acting on the body*. Part of being a perceiving entity is not only generating mental representations of objects, but generating a representation of our unique relationship *as a perceiver* to the object.

However, we are not just perceivers. We also are “doers”. Recall Neisser’s definition of an ecological self as being an “*active agent* in a real environment.” A vital part of our feeling that we are an active agent in the world is perceiving our own actions. We act on and in the world, and we can perceive the effects of our actions. Neisser provides the following example: “I grasp a glass of water: the visual and auditory and tactile feedback thus produced coincides appropriately with the intention that drove the movement in the first place” (1997, p. 23). Thus, another vital facet of exteroception that drives a feeling of self is perception of our interactions with the external world. That is, our awareness of ourselves as causal agents in the world. This feeling of causal agency is what I will turn to next.

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\(^2\) Exceptions can produce strong illusions. Consider the “railroad illusion”: when sitting in a stationary train, upon observing the adjacent train beginning to move forward creates the illusion that one is moving backward.
2.3 Ecological self and feeling of causal agency

The examples I brought up in the last section about optic flow demonstrate that perceiving the external world provides information about the self, in the sense that perceiving the external world necessarily involves conceiving of a certain relationship between the external world and the perceiver. It is through this relationship between internal and external that the concept of a self can arise. I will now explore another way that this relationship can be perceived, namely, when the individual acts on or in the world, and subsequently perceives the effects of their action.

The feeling that one is interacting with the external world is referred to as the “feeling of agency”. There are several dominant models of how the feeling of agency is generated, chiefly, the comparator model and the theory of apparent mental causation. While these two theories in particular have generated debate as to the exact mechanisms that produce a feeling of agency, they are both fundamentally perceptual in nature. For the purposes of this paper, I will remain agnostic as to which model is correct. I will present both views and empirical evidence for both. My aim here is to demonstrate that whether it is the comparator model or the theory of mental causation, or some combination of both that is correct, the feeling of agency fundamentally relies on exteroception, and therefore is another way that perceiving the external world informs the concept of core selfhood.

The comparator model has roots in early theoretical models of action (ex. Helmholtz, 1866; Sperry, 1950), but has been elaborated upon recently by Frith et al., (2000) Frith (2005), Lindner et al., (2006), and Wolpert & Flanagan, (2001), among many others. This model focuses on the role of sensorimotor information in generating a feeling of agency. Under this view, the motor system can be considered as a “control system with the input being a ‘desired state’ and the output being the ‘estimated output state’” (Synofzik, Vosgerau & Newen 2006). The system calculates motor error via sensory feedback. Perceiving the state of the world after the motor command has been issued allows the system to determine what command to send next, in order to correct the disparity between the desired and actual state. It also predicts motor error through the use of efference copies. An efference copy is a mental “copy” of an outgoing motor signal that is rerouted to other sensory areas. In effect, the efference copy is a way for the brain to anticipate and keep track of its own activity, and predict motor outcomes before they actually happen. In summary, the brain makes use of efference copies as well as sensory feedback of motor actions post facto to compare the desired state of the system and the actual state of the system. When the desired state and actual states match, we have the feeling of agency. When they do not, we do not feel authorship of the action.

In fact, I favor Moore’s “cue integration theory”, which treats the comparator model and theory of apparent mental causation as not being mutually exclusive, and integrates parts of both theories. See Moore et al., 2009; Moore and Fletcher, 2012.
There is considerable empirical evidence supporting the comparator model’s prediction that the sensorimotor system is heavily involved in the feeling of agency. Artificially producing a mismatch between expected and actual sensory feedback of motor actions affects subjects’ recognition of those actions as their own (Daprat et al., 1997; Franck et al., 2001). An interesting case comes from neurosurgery, when patients are operated on while conscious. Surgeons were able to induce motor actions such as arm-raising by stimulating motor-control areas of the brain. They immediately questioned the patients about the action. Not only did patients report that they initiated the action, they confabulated explanations such as “I was trying to get your attention”, despite the fact that the action was entirely induced by the external stimulation of the brain (Delgado 1969; Gazzaniga 1994). This is a testament to how heavily our feeling of agency relies on the sensory perception of our own actions. It is by seeing the arm movement and perceiving the motor command (perhaps via efference copies) that these patients inferred an illusory intention to move and a false ascription of agency.

Unlike the comparator model, the theory of apparent mental causation posits that the motor system and our awareness of it actually has little to do with the feeling of agency. The theory of apparent mental causation was developed by Daniel Wegner (Wegner and Wheatley 1999; Wegner 2002). It holds that, in contrast to the comparator model, we do not have conscious access to the motor control system. After all, we feel agency in making the elevator doors close with the “close door” button and the traffic light changing with the “walk” button, despite these buttons usually having no real effect. Under Wegner’s model, we are aware of two things that contribute to the sense of agency: the intention to act and the act itself. Moore summarizes the view as follows: “If our intention to act happens before we act, is consistent with the action, and is the only plausible cause of the action, then we feel as though we have caused the action” (Moore 2016). This view still grounds the feeling of agency in perception—we perceive the effects and occurrence of our actions, and depending on the inferred relationship of these events to our intentions and goals, we feel a sense of agency. Where this view differs from the comparator model is that it places the objects of perception not in the motor system, but more abstractly as the anticipated effects of the action. It relies more on internal, cognitive processes that assign causality as a result of temporal proximity and explanatory power.
The strength of the theory of apparent mental causation is that it can explain certain well documented phenomena in social psychology. Prompting participants to think negative or hostile thoughts about a person, and then making that person seem to have suffered negative consequences makes participants more likely to view themselves as responsible. For instance, giving a participant a voodoo doll and having them perform a “voodoo curse” on it and form intentions to harm a target, and subsequently having the target feign a headache causes participants to feel like they caused the headache. Similarly, cheering and imagining positive outcomes while watching sporting events leads to increased feelings that one has influenced the outcome (Wegner 2002; Nahmias 2007). In another experiment, participants were asked to click on objects on a computer screen. Participants were told they shared control of the mouse with another participant, who was in fact a confederate of the experimenters. The participant believed he/she was controlling the mouse when in fact the object selection was ultimately controlled by the confederate. Yet, participants reported a feeling of agency when selecting objects when they had been primed to think about the object immediately before (e.g. hearing the word “swan” via headphones just before the confederate nudged selection of the swan image. Wegner 2002; O’Connor 2009). These and other examples support the theory of apparent mental causation. Again, it is not relevant to this paper which of these models of the feeling of agency is superior, and there is a significant body of evidence demonstrating the importance of both motor control and more abstract perception of causation in determining a feeling of agency. The key point is that for all of these models, the feeling of the self as an agent that has an effect on the world is generated in response to certain external perceptual (i.e. exteroceptive) cues. In the comparator model, these cues come both from the external world (seeing your hand reach for a glass), and the internal world (effference copies, intentions to move). In the theory of apparent mental causation, the cues are the observed action (pressing of the elevator button, stabbing of the voodoo doll), and the effects of the action (closing of the elevator door, the apparent headache of the voodoo target). These inform judgments about the causal relationship based on temporal proximity, among other things. In both models, a mix of exteroception and cognition produce a judgment about the self—that there is a relationship between the internal and external worlds.

Awareness of our role as an active agent in the environment informs us about the core self in a fundamental way. When we feel that we are interacting and having an effect on the world, we sharpen the boundaries between the internal and external. In the processes, this helps form a more cohesive picture of the “you” that exists in the here-and-now, and experiences the world from a particular point of view.

3.1 Integration of intero- and exteroception: Concluding remarks

We can characterize the roles of interoception and exteroception in building the internal-external distinction of the core self in the following way. Interoception serves to define the internal world, by anchoring the representation of the self in a stable, continuous percept. Exteroception provides information about the relation of this stable percept to a messy, unstable external world. It relates us to objects out in our environment, whether we are passively perceiving them or actively interacting with them. In this way, it sets us up as an “active agent in a real environment”. Intero- and exteroception are both essential for creating the core self as we have defined it. However, they do not operate wholly independently; their functions are intimately related. In this final section, I will point to a
couple of interesting studies that have explored the relationship between intero- and exteroception in forming the core self.

A recent study by Ainley, Jiménez, Fotopolou, and Tsakiris (2012) found that exteroceptive processes can affect interoceptive sensitivity. In their experiment, participants performed a heartbeat detection task (a standard measure of interoceptive sensitivity) while looking either at a mirror or a blank screen. Participants who had a lower baseline rate of interoceptive sensitivity (i.e., performed poorly on the heartbeat detection task prior to test trials) significantly improved in the heartbeat detection task when looking at their reflection in the mirror. The mirror-self observation relies on exteroception, as it involves perceiving the body from the outside. The results of this study suggest that here, exteroception enhances interoceptive sensitivity. A tight interconnection of self-perception via intero- and exteroception is to be expected. As discussed earlier, the insula is implicated both in visual self-recognition and is the terminal nucleus of interoceptive inputs. The integrative role of the insula in self-perception is further supported by findings such as these in which exteroception can affect interoceptive capabilities.

The converse is also true: interoception can play “an active modulatory role in weighting and integrating exteroceptive percepts of the body” (Ainley, Jiménez, Fotopolou, and Tsakiris 2012). In a 2014 study by Jiménez and Tsakiris, a multisensory illusion involving face-recognition, the enfacement illusion, was used to measure the contribution of exteroceptive information in distinguishing self from other. In the illusion, participants are lightly stroked on the left side of the face while viewing an unfamiliar face being stroked in synchrony. This unfamiliar face is either being stroked on the right side, so that when viewed straight on it was like viewing a mirror reflection, or on the left side, which does not look as a mirror reflection does. Similar to the rubber-hand illusion, the enfacement illusion describes the tendency to see the unfamiliar face as one’s own, or to feel the strokes on one’s face as the same as the one’s touching the unfamiliar face’s. Participants were also measured for interoceptive sensitivity prior to testing, using a heartbeat detection task.

Jiménez and Tsakiris found that low baseline levels of interoceptive sensitivity resulted in larger changes in self-other boundaries as captured by the enfacement illusion. That is, participants with lower interoceptive sensitivity were more likely to “fall for” the enfacement illusion, feeling as if the unfamiliar face was their own. The enfacement illusion captures the importance of exteroceptive information in self-perception. The fact that the unfamiliar face is mistakenly identified as one’s own demonstrates the reliance of the brain on processing external information, such as the seen and felt touch.

So what could explain the tendency for those with lower baseline rates of interoceptive sensitivity to “fall for” the enfacement illusion more easily? Jiménez and Tsakiris propose an intriguing answer: “When seeing another face being touched in synchrony with one’s face, the visuo-tactile signals prime a sense of self, but the interoceptive prediction of how it feels to be oneself is in conflict with what the exteroceptive evidence suggests” (Jiménez & Tsakiris 2014, my emphasis). Presumably, when this interoceptive prediction is weaker, or relied upon less heavily, there is not the same level of conflict, leading to a greater reliance on the exteroceptive cues. This may be what is happening when participants with low interoceptive sensitivity experience the enfacement illusion more intensely. Jiménez and Tsakiris propose a Bayesian-like self-recognition mechanism that integrates interoceptive and exteroceptive information, and judges on the basis of these collective data whether stimuli are belonging to the self.

The insula may be the relevant convergence zone of interoceptive and exteroceptive information, as it is a higher-level, multimodal region that integrates multimodal sensory
information from all over. This theory is in line with the evidence implicating interoception and the insula in recognizing the self, as well as the evidence showing the importance of exteroceptive cues in recognizing the self. Interestingly, where in the 2012 study (Ainley, Jiménez, Fotopolou and Tsakiris) exteroceptive activity modulated interoceptive sensitivity, here it is the opposite: interoceptive sensitivity modulates the influence of exteroceptive information in self-recognition.

Collectively, these recent studies provide convincing evidence for the importance of both interoception and exteroception in generating the core self. What they demonstrate is that interoception and exteroception do not represent independent modalities that give distinct information, but are highly integrated and are tightly interwoven in the way they inform the brain about the self. The concept of core self, representing the stability of our internal world amidst the external environment, is fundamentally perceptual in nature. Whether the percepts come from within us, or without, understanding how the brain creates a feeling of self is a matter of perceiving.
Citations


