Phenomenological Origins of Psychological Ownership

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Abstract: Motivated by a set of converging empirical findings and theoretical suggestions pertaining to the construct of ownership, we survey literature from multiple disciplines and present an extensive theoretical account linking the inception of a foundational naïve theory of ownership to principles governing the sense of ownership. The first part examines the emergence of the non-conceptual sense of ownership in terms of the minimal self and the body schema—a dynamic mental model of the body that functions as an instrument of directed action. A remarkable feature of the body schema is that it expands to incorporate objects that are objectively controlled by the person. Moreover, this embodiment of extracorporeal objects is accompanied by the phenomenological feeling of ownership towards the embodied objects. In fact, we argue, that the sense of agency and ownership are inextricably linked, and that predictable control over an object engenders the sense of ownership. This relation between agency and the sense of ownership is moderated by gestalt-like principles. In the second part of the account, we posit that these early emerging principles and experiences lead to the formation of a naïve theory of ownership rooted in notions of agential involvement.

Keywords: ownership, property, minimal self, agency, body schema, social cognition, psychology, naïve theory, perception, motor intentionality

1 Introduction

Ownership is a ubiquitous human concept that influences how people use and relate to objects. Its nature and origins have been the subject of major philosophical expositions. Some philosophers have noted that people's personality can sometimes be reflected in their possessions and that property permits self-expression (Knowles 1983). Still other philosophers and legal theorists have argued that personal property promotes self and ethical development (Radin 1982; Waldron 1988).

In recent years, a spate of studies across multiple scientific domains have shed new light on various facets of ownership. These studies probe both the non-conceptual sense of (body) ownership (Gallagher 2000; Synofzik et al. 2008) and the psychological concept of ownership (Nancekivell et al. 2013; Palamar et al. 2012). In addition, there has been a deluge of research into object embodiment via the body schema, and the resulting phenomenological effects of incorporating these (extracorporeal) objects (Maravita and Irki 2004; Short and Ward 2009).

Despite the abundance of such empirical findings, there is a schism between studies exploring the non-conceptual sense of ownership, the psychological concept of ownership, and studies examining changes to the body schema. This paper aims to synthesize these areas of inquiry and provide a theoretical framework that yields a coherent interpretation of the experimental data. In particular, we present a systematic account of the diverse findings on ownership that stems from the human sense of self. The account dictates that the experience of agency over an object is capable of evoking the sense of ownership and that these interactions can give rise to implicit self-object associations. The influence of objective agency in eliciting the sense of ownership is moderated by gestalt-like principles. In addition, we argue that these developmental experiences and their constitutive principles play an important role in the appearance of a naïve theory of ownership.

In what follows, we discuss the basic cognitive mechanisms underlying ownership perceptions and the ways in which these non-conceptual sensory experiences shape psychological ownership. Section 2 introduces the concept of the minimal self, and we demonstrate that the sense of (body) ownership is a key component of rudimentary self-consciousness. Importantly, we also illustrate that the sense of (minimal) self is characterized by a motor intentionality (or a 'motor power') in the form of the body schema—an adaptive action-oriented model of the 'body' that is capable of embodying extracorporeal objects. Section 3 establishes that perceived agency is a powerful cognitive primer to the sense of ownership. Section 4 integrates the preceding two sections with elements of associative psychology to delineate the principles underlying the sense of object ownership. Particularly, we argue that people experience a sense of ownership towards objects that they predictably control, and that they form self-object psychological associations with their possessions. Section 5 employs the

derived principles of ownership to shed light on the psychological aspects of ownership—i.e., judgments and metarepresentations of ownership. These ownership judgments appear to constitute a naïve theory of ownership that is entrenched in ideas of agential involvement. Finally, we conclude by briefly discussing the implications of the account presented.

2 The Minimal Self

The existence of an intrinsic relationship between ownership and the concept of *self* is *prima facie* tenuous. Ownership is a pervasive phenomenon, extending to objects that are not explicitly related to the self; whereas the self generally involves what William James referred to as 'the feeling of the same old body always there' (1890/1983, p.242). The apparent discrepancy suggests that constructing a theory of ownership based on the notion of self is unpromising. But contemporary developments in the cognitive sciences are eroding that impression and instead giving way to the idea that the phenomenal experiences of ownership and self are *in fact* closely linked. The pivotal theoretic notion of the *minimal self* underpins many of these developments. Indeed, the minimal self provides the groundwork for the establishment of a neurocognitive theory of ownership.

2.1 Two Aspects of the Minimal Self

The minimal self is a rudimentary entity restrained to 'immediate self-consciousness' and devoid of temporal continuity. Gallagher (2000) describes the minimal self 'as an immediate subject of experience, unextended in time' and 'almost certainly' dependent on 'an ecologically embedded body'.

The sense of self-agency and sense of self-ownership are two constitutive aspects of minimal self-awareness. Self-ownership is the persistent perception that 'my body' belongs to 'me'. Self-agency is the impression that 'I' am the generator of an action (Synofzik et al. 2008). Gallagher differentiates these two aspects of the minimal self in the context of motor action—the experiences of ownership and agency are extricated by comparing voluntary (or willed) actions (e.g., when I move my arm) with involuntary actions (e.g., when my arm is moved by another person).

Significantly, the formation of the minimal self precedes the development of linguistic and conceptual capacities—the minimal self initially emerges as a 'pre-linguistic' and 'ecological' self-awareness in neonates (Synofzik et al. 2008; Gallagher 2000). Tracing the development of rudimentary self-awareness in young infants, Verschoor and Hommel delineate the relationship between the sense of ownership, sense of agency, and the minimal self in a detailed paper (2017). They discuss evidence that the minimal self emerges by performing actions in the external environment.

2.2 Theory of Ideomotor Learning & Predictive Coding

Elementary goal directed actions can be observed in neonates less than an hour old (Meltzoff and Moore 1983; Butterworth and Hopkins 1988; Bertenthal 1996), whereas 5-month old infants are able to perform the more complex action of grasping interesting physical objects in their vicinity (Bertenthal and Clifton 1998). Movement and corresponding visual information lead to the earliest signatures of self-recognition. In a study conducted by Courage et al. (2004), mirror self-recognition preceded both the use of personal pronouns ('self- referent language') and photo identification. Verschoor and Hommel (2017) posit that these self-recognition studies indicate that the minimal self 'is derived from perceived agency' and 'that infants apparently learn to predict the sensory effects of their bodily movements before they are actually able to experience *ownership of their mirror image* [emphasis added].' An even stronger inference that one can draw from early indices of self-recognition is that the experience of self-agency is a prerequisite for the experience of self-ownership.

This inferred causal sequence conforms with a promising account proposed by Verschoor and Hommel (2017) detailing the emergence of the minimal self. They argue that unequivocal signs of *intentional* goal directed actions—where 'expected action outcomes [are taken] into account when deciding which action to perform'—occur no earlier than 9 months of age. The authors argue that bidirectional associations between actions and their anticipated effects is required for the acquisition of genuine action control (see also Verschoor et al. 2013). In their theoretical framework, the bidirectional associations are established by means of ideomotor learning.

The process of ideomotor learning leading to the acquirement of voluntary action control is an idea that dates back to William James and Hermann Lotze (1852). In the *Principles of Psychology* (1890/1983, p.487), James writes that '... if, in voluntary action properly so-called, the act must be foreseen, it follows that no creature not endowed with divinatory power can perform an act voluntarily for the first time.' The rule James invokes is that intentional goal directed actions demand knowledge of the expected effects. In turn, that leads to the principle, that to truly 'anticipate the likely outcome of an action' requires 'knowledge about the relationship between the action and its effects'.

The knowledge of goal directed actions and their effects is attained by performing exploratory movements in the environment and forming bidirectional associations between actions and the associated perceptual changes—i.e., ideomotor learning. A bidirectional association entails that sensory effects associated with actions are capable of evoking actions—e.g., 'thinking' of the sensory effect activates the 'effect's internal representation' and prompts the generation of the associated action. In short, bidirectional associations render the possibility of voluntary actions ('action selection'). The database of action-effect associations is constructed during early years of life 'through active interaction with one's physical and social environment.' Young infants may also be learning from actions they do not perform themselves. For instance, 6-month olds are able to predict the action goals of others (Kamewari et al. 2005).

Finally, to explain the sense of agency, Verschoor and Hommel combine ideomotor learning with predictive coding in their theory. The perception of agency arises by matching the predicted effects of movement (derived by ideomotor learning) with the actual effects. A discrepancy between predicted effect and actual effects diminishes (or eliminates) the sense of agency whereas an adequate match generates the experience of agency. The view that agency is a result of 'predictive motor control' is prevalent in contemporary neuroscience (Haggard 2005).

To complete the construction of the minimal self, based on additional recent studies, Verschoor and Hommel hypothesize that the sense of self-ownership arises by integrating sources of information that generate agency with interoceptive information (i.e., internal stimuli). Again, the implication is that the sense of ownership trails the development of the sense of agency and constitutes a more complex experience. The timeline of agency preceding ownership is also conducive to the growth of motor capabilities—people are able to represent the actions of others in analogous manner to their own actions, and the fact that young infants are unable to discriminate between self and other generated actions may be better for motor learning (Verschoor and Hommel 2017, p.139). Later, the acquisition of the sense of self-ownership consummates the minimal self.

2.3 The Body Schema

The notion that perceived agency leads to the sense of ownership, and therefore 'selfhood', is more explicitly supported in theories of the minimal self based on the body schema. Holmes and Head (1911) introduced the notion of the body schema in a paper on sensory disturbances associated with cerebral lesions. The body schema is a 'coherent and dynamically updated' representation enabling actions and movements. It is distinct from the *body image*—a 'conscious representation' based on 'perceptual' body features. Notably, the dynamic nature of the body schema permits action control to extend beyond the body to objects in the external world—i.e., the body schema is intrinsically action oriented (Gallese and Sinigaglia 2010; Gallagher 1986).

The construal of the body schema as a non-conceptual and embodied minimal self originates in the writings of the French philosopher Maurice Merleau-Ponty (1962, p.162):

> In so far as I have a body through which I act in the world, space and time are not, for me, a collection of adjacent points … my body combines with them and includes them … Our bodily experience of movement *provides us with a way of access to the world and the object, with a 'praktognosia', which has to be recognized as original and perhaps as primary*. My body has its world, or understands its world, without having to make use of my 'symbolic' or 'objectifying function' [emphasis added].

According to Merleau-Ponty, the body schema is 'neither the mere copy nor even the global awareness of the existing parts of the body'; it is the 'active integration of these latter only

in proportion to their value to the organism's projects.' In brief, the body schema is characterized by action potentiality—i.e., not 'a spatiality of position, but a spatiality of situation' (Merleau-Ponty 1962, p.114-5; see also Gallese and Sinigaglia 2010).

Another important observation that Merleau-Ponty makes is the notion that the 'body combines with' and 'includes' space and time. This synthesis of body and space is evident in peripersonal space—the dynamic space surrounding body parts coded by certain neurons (Rizzolatti et al. 1997). Neurons dynamically tracking peripersonal space are typically bimodal, possessing both somatosensory and visual receptive fields—i.e., they respond to visual stimuli (occurring in space near the body) and to tactile stimulation of the body. Additionally, these neurons appear to be operating within a motor scheme. The combination of motor and bimodal properties of these neurons coalesces body and peripersonal space into an instrument of directed action, the neural basis of Merleau-Ponty's (1962, p.162) 'motor intentionality'.

Consequently, the body schema (incorporating peripersonal space) yields a conception of the minimal self analogous to Merleau-Ponty's concept of body— a self 'as the potential source of a certain number of familiar actions'. This self gives rise to 'action having a field or scope' determined by the peripersonal space, where the peripersonal space is the 'surroundings as a collection of possible points upon which [the] bodily action may operate' (Merleau-Ponty 1962, p.120-1).

A contemporary account of the minimal self that is also based on the body schema is proposed by Gallese and Sinigaglia (2010). Similar to Merleau-Ponty, the (embodied) self described is 'enactive in nature' and 'primarily given to us as source or power for action'. They argue that the 'minimal sense of self', defined as the set of possible motor potentialities, 'is at the same time a prerequisite and a core component of both the sense of agency and sense of ownership.' Specifically, the 'pre-noetic' self is reflected in the body schema, a 'dynamic binding principle [integrating] multiple sensory modalities' and working 'at the level of [pre-reflective] motor intentionality.' In support, evidence from experimental studies is presented that shows intentional actions (perceived agency) mediate bodily self-awareness. Parieto-premotor networks, involved in goal directed actions, are advanced as the neural correlates of this minimal self experience (Gallese and Sinigaglia 2010, p.749; Haggard 2005).

Theories of the self centred around the body schema complement theories of self based on ideomotor learning and predictive coding—both construe the minimal self in terms of motor cognition. Moreover, they both reach equivalent conclusions regarding the genesis of self-ownership. Verschoor and Hommel (2017), in their paper on ideomotor learning and predictive coding, assert that perceived agency is the precursor of self-recognition and ownership. In the same vein, the theory of Gallese and Sinigaglia (2010) postulates that 'the potentiality for action of our bodily self is a necessary condition to accomplish the sense of body ownership.' The underlying theme in both assertions is that the pre-reflective corporeal self-awareness, i.e., the experience of 'the body as one's own body', is dependent on the availability of motor intentional

features. In fact, it may very well be that ideomotor learning plays an integral role in the development of the body schema.

2.4 Mirror Mechanism & Object Affordances

Gallese and Sinigaglia (2010, p.752-3) also propose their own process of motor intentional development—i.e., the process of acquiring *praktognosia*. They point to the evidence showing that neonates and infants engage in social interactions to support the claim that the minimal self is nurtured by interacting with 'other bodies'. More precisely, their theory states that social reciprocal capacities powered by the mirror neuron mechanism modulates the minimal self. Mirror neurons encode both self-actions and the actions of other people— i.e., they discharge both when we perform an action and also when we observe the action of others. In the early years of life, motor resonance produced by mirror neurons facilitates 'proto-conversation' and imitation. These simple social interactions 'promote the first forms of motor (and emotional) attunement with other bodies enabling infants to carve out their own [primitive] motor potentialities.'

The mirror neuron mechanism is not only important in understanding action, but, more interestingly, it creates the possibility of understanding observed actions 'from the inside' and yield a 'first-person grasp of another individual's motor goals and intentions' (Rizzolatti and Sinigaglia 2010). In other words, these neurons provide a knowledge of motor actions distinct from both simple action-effect associative mechanisms (i.e., void of motor representation) and inference (Rizzolatti et al. 2001). In light of this, Sinigaglia and Rizzolatti (2011), after conducting an extensive review of the literature on mirror neurons, reiterate the conception of a minimal self grounded in motor possibilities, a conception where 'we primarily experience ourselves and others in terms of our own and of their motor possibilities respectively.'

The instinctive understanding of another person's motor intentions is achieved by means of a special type of neuron termed 'action-constrained' neurons. These neurons (recorded in monkeys) are activated during specific actions but are fully activated when the associated action is performed in the context of a specific goal. For instance, the neurons maximally fire when a monkey grasps something to eat, but they partially fire when the primate grasps the object in order to place it elsewhere. Importantly, a subset of these neurons are also mirror neurons. The 'action-constrained' neurons with mirror properties maximally fire when the monkey observes the specific goal directed action (e.g., grasping food to eat) but not when the action is performed external to the associated goal (e.g., grasping to simply displace). This selective activation allows these neurons to be predictive of intentions underlying specific actions (Fogassi et al. 2005). A slew of brain imaging studies reveal that mirror networks also modulate action intentions in humans (Sinigaglia and Rizzolatti 2011; see also Cattaneo et al. 2007). Significantly, these mirror neuron networks present a cogent functional framework for understanding the emergence of intentional goal directed actions in infants (Gallese and Sinigaglia 2010, p.753).

In culminating their study (2011), Sinigaglia and Rizzolatti, arrive at the minimal sense of self by considering affordances in the environment. The concept of affordance, introduced by James Gibson (1979/2014), denotes the assortment of motor actions *afforded* by objects in the surroundings. Affordance does not simply entail the physical properties of an object but refers to a property that involves both object and agent—i.e., the action possibilities that a particular object presents to a particular agent. For instance, a walking cane offers several motor possibilities to a person; they can use the cane to assist in walking or wield the stick to defend themselves. Strikingly, evidence from neuroimaging studies and neurophysiology shows that the visual perception of an object generates 'the suitable set of grasping-related motor representations' irrespective of whether the person intends to interact with the object (Sinigaglia and Rizzolatti 2011, p.70; see also Craighero et al. 1999). The implication being that object perception is 'intertwined' with action prospects.

The characterization that 'action constitutively shapes the content of perception' leads to the impression that 'we become aware of ourselves as of the selves that can grasp, throw or kick.' More importantly, it 'implies that we do not experience ourselves as a given entity (e.g., a physical body) and then realize that such an entity can grasp or kick', but on 'perceiving something as graspable or as kickable' we become aware of ourselves as a motor potentiality (Sinigaglia and Rizzolatti 2011). The mirror mechanism not only cultivates this sense of self but enables us to see others in virtue of their motor possibilities and actions, to the extent that their motor possibilities overlap with ours.

We have seen from three differing approaches (ideomotor learning, the body schema, and mirror neuron mechanism) that the minimal sense of self is formed enactively and that this sense of self is distinguished by a motor intentionality—i.e., the self is expressed as a motor capacity. Furthermore, the self as a 'motor power' is represented in the body schema, a versatile and dynamic action-oriented model of the 'body'. Interestingly, both the body schema approach and the theory of ideomotor learning indicates that perceived agency is a sense of ownership prompt. A plausible interpretation of this correlation may be that the tangible perception of agential control promotes the engenderment of the phenomenological sense of ownership. To corroborate this supposition, the next section will examine studies on body ownership in neuropsychology and cognitive neuroscience. These studies will help clarify connections between aspects of agency and the sense of ownership.

3 The Sense of Agency & Sense of Ownership

The precise relation between agency and ownership is a topic of ongoing research and debate. In the realm of neuropsychology and cognitive neuroscience, there are two contending positions on the causal constitution of the relationship. The first position (see Tsakiris et al. 2010) states that ownership and agency are 'qualitatively different experiences, triggered by different inputs, and recruiting distinct brain networks.' A second

view asserts that agency modulates or promotes the sense of ownership. This position is consistent with the evidence reviewed delineating the emergence of the minimal self. In fact, the second viewpoint corresponds to the hypothesis derived from the body schema approach and theory of ideomotor learning, proclaiming that perceived agency induces ownership. In this section, we review evidence relevant to evaluating the latter point of view.

3.1 Evidence from Atypical Neuropsychological Experiences

People's sense of limb ownership is helpful in gauging the connection between the sense of agency and the sense of ownership. Baier and Karnath (2008) examined hemiparetic stroke patients with defective perception of their motor weakness, anosognosia for hemiparesis/hemiplegia (AHP). They discovered that 92% of examined patients with AHP 'showed additional disturbed sensation of limb ownership (DSO) for the paretic/plegic limb.' Specifically, patients with AHP did not only have disturbances in the awareness of their motor weakness, but also manifested feelings of disownership and estrangement towards the affected limb(s).

An extensive review by Vallar and Ronchi (2009) surveyed reports of 56 patients with symptoms of somatoparaphrenia and hemispheric lesions. Somatoparaphrenia involves delusional beliefs regarding contralesional body parts. People with somatoparaphrenia generally either deny ownership of the affected body part(s) or defer ownership to someone else. The investigation concluded that proprioceptive impairments, and not tactile or visual field defects, causatively contribute to the onset of somatoparaphrenia. The reasoning for this connection, according to Vallar and Ronchi, is that proprioceptive feedback 'is closely related to, and dependent on, movement, and may be a basic component of the sense of ownership.'

The review also points to the fact that placing the affected body part in the region of space not suffering neglect (the ipsilesional side) does not alleviate somatoparaphrenia. As noted by Gallese and Sinigaglia (2010, p.751), the denial of body part(s) ownership independent of actual spatial position, implicates the body schema. This is because the body schema is not 'uniquely conceived as a spatial map of different body parts' but instead functions 'as the source of our potentiality for actions.'

More evidence for the role of motor intentional networks in regulating body ownership comes from an insightful case study (Arzy et al. 2006) involving a patient with asomatognosia of the left arm—the impression that parts of the body are missing or that they have vanished from corporeal awareness. Throughout the experience, the patient was unable to move the affected arm. Subsequent behavioral assessments showed that the patient had deficits in imagining the rotation of body parts. Magnetic resonance imaging (MRI) results attributed these symptoms to damage in the right premotor and motor cortices. This complements functional magnetic resonance imaging (fMRI) based probes into body ownership; they indicate that neural activity in the premotor cortex reflects limb ownership (Ehrsson et al. 2004). Neuroimaging of people with body integrity identity disorder (BIID) corroborates the involvement of the motor cortices in the sense of

ownership—the feeling of disowership in BIID correlated with decreased neural activation in the premotor cortex (van Dijk et al. 2013).

3.2 Evidence from The Rubber Hand Illusion & Self-Recognition

Next, we consider the extensive research on illusory body ownership. The paradigmatic experimental design is the rubber hand illusion (RHI). In the experiment setup, the participant's hand is hidden from visual view and tactile stimulation is applied to a visible rubber hand in conjunction to the unseen real hand. If the tactile stimulation applied to the out of view real hand and the visible rubber hand is synchronous, the participant experiences a shift in position (*proprioceptive drift*) of the real hand towards the position of the rubber hand. In addition, the participant adjudges that the rubber hand is a part of their body. They feel ownership towards the rubber hand (Botvinick and Cohen 1998).

The RHI framework is important in demonstrating the elasticity of the body schema—showing that subjecting an individual to the appropriate visuotactile stimulation leads to the embodiment of the rubber hand. Significantly, synchronous visuo-tactile stimulation is not sufficient to cause the illusion; the illusory embodiment induced by visuo-tactile stimulation is contingent on the congruency of the rubber hand with respect to the real hidden hand (Pavani et al. 2000; Tsakiris and Haggard 2005). For instance, positioning the rubber hand perpendicular to the orientation of the real hidden hand, extinguishes the illusion.

The dependence of the illusion on congruency suggests, as cogently argued by Gallese and Sinigaglia (2010, p.751), that the RHI is constrained by the 'action-compatibility' of the observed rubber hand with that of the real hand: 'If the dummy hand occupies a position in space incompatible with the power for action intrinsic to the body schema, the illusion does not occur.' This means that the RHI is not merely a product of Bayesian statistical correlations, but instead the illusion is regulated by the possibility of actions (generated by the body schema) corresponding to the particular hand. In short, the rubber hand illusion vividly showcases the dependence of ownership on action potential characteristics.

Indirect signatures of the sense of ownership, in particular self-recognition and identification, are also mediated by agency. A shrewd study by Tsakiris et al. (2005) discovered that increased efferent information (neural signals conveying motor stimuli) improved self-recognition of body parts considerably—despite there being no difference in proprioceptive and visual information (see also Tsakiris et al. 2007). This is consistent with prior self-recognition research. A determinative study found that motor intentional knowledge regulates self-recognition in conditions of scarce morphological information. In particular, the experimenters found that the presence of movement overrode other sources of information (including proprioceptive information) and subjects achieved near perfect recognition (Van Den Bos and Jeannerod 2002). The evidence from self-recognition perception coincides with an astute neuroimaging inquiry into the bodily self, revealing

that the capacity to differentiate self from others is partly based on a sensorimotor representation (Ferri et al. 2012).

The role intentional action plays in the production of a coherent and cohesive sense of ownership is explicitly discernible in a study where synchronous tactile stimulation was applied to an individual finger in three separate conditions: active finger movement (self-generated intentional action), passive finger movement, and (bare) tactile stimulation. With both passive finger movement and simple tactile stimulation, the RHI was localized to the stimulated finger. However, in the active finger movement condition, the proprioceptive drift associated with the RHI extended to 'the whole hand' (Tsakiris et al. 2006). Another study examining the impact of movement on the RHI found that active synchronous movements produced stronger illusory ownership effects than passive synchronous movements (Dummer et al. 2009). Studies also show that the RHI directly effects action-oriented representation(s) of the body (Newport et al. 2010). These effects are stronger when induced via voluntary synchronous movement as opposed to synchronous visuo-tactile stimulation (Riemer et al. 2013; Kokkinara and Slater 2014).

Supplementing the findings on the observed interplay between movement and ownership, Burin et al. (2015) administered the RHI on people with complete upper left limb hemiplegia (paralysis of left upper limb) and compared the effects with those measured in healthy subjects. Proprioceptive drift for the affected hand was significantly greater than the proprioceptive drift observed in healthy individuals, implying that lack of movement weakens the sense of body ownership, occasioning a more flexible body representation, which in turn leads to the paretic hand being more prone to the embodiment illusion. Remarkably, the unaffected (right) hand of the hemiplegics did not display substantial susceptibility to the rubber hand illusion. A possible interpretation of the last result (proposed by Burin et al.) is that the 'regular and repeated overuse of the healthy arm' generates increased 'number of movement-related signals'—leading to elevated body ownership.

The combined evidence from these studies support the hypothesis gleaned from the body schema approach and theory of ideomotor learning: agency modulates ownership and perceived agency engenders a coherent and cohesive sense of ownership. As we will see in the ensuing sections, this relationship between agency and ownership is an important aspect of the phenomenological basis of non-corporeal object ownership.

4 Extracorporeal Object Ownership

A case study reported in 1996 (Aglioti et al.), described a woman with delusional disownership of her left hand (somatoparaphrenia) due to right brain damage. In addition to the hand itself, the patient displayed selective disownership of objects typically associated with the left hand. Notably, this delusional disownership of objects only manifested when the articles were viewed on the affected hand itself, such as when she

wore the objects on her left hand. In contrast, the objects were correctly recognized by the patient as belonging to her when viewed on her right hand, or in the hands of the examiner. Personal objects that were not ordinarily associated with the disowned hand were correctly recognized by the patient irrespective of where they were viewed.
This peculiar case study intimates that the body schema is capable of altering ownership perceptions. It also suggests that systematic associations between the self and embodied object(s), shape and strengthen these perceptions. And finally, it evinces the interconnectedness between the sense of ownership and memory. The patient couldn't recall the autobiographical information related to the object when seeing it on the left affected hand; whereas by simply moving the object to the right hand, the patient recognized the object and retrieved the related memories. In the rest of this section, we consider how these factors may underpin a comprehensive theory of ownership.

4.1 Object Embodiment

In probing the origins of non-corporeal object ownership, it should be emphasized that the body schema is a functional representation that extends beyond the body to objects in the external world. It is a mechanism of directed action. To that end, there is overwhelming evidence that the body schema incorporates external (physical) objects: the body schema can expand to embody objects that are not naturally part of the body. We will examine the evidence presented in the review of Maravita and Irki (2004), and more recent studies, that delineate the incorporation of paraphernalia into the body schema.

As mentioned in Section 2, neurophysiological studies in primates have identified bimodal neuron networks in the ventral premotor cortex (possessing both somatosensory and visual receptive fields) that dynamically track peripersonal space. These visual receptive fields (vRFs) move in synchrony with the associated body part and not the eye (Graziano et al. 1994). In an important study, Iriki et alia (1996) showed, that after training macaque monkeys to use an instrument for weeks, bimodal neurons in the trained macaque's caudal postcentral gyrus could also track the space surrounding the instrument during active use. This showed that the neurons comprising the body schema subsume tools during active use—i.e., the space around the non-corporeal instrument is coded in the same manner as the space near the body. Additional studies have reported equivalent findings (i.e., the expansion of these bimodal receptive fields to include visual space accessible with the instrument) immediately after instrument use (Maravita and Iriki 2004, p.79-80). To emphasize, these studies symbolize that the body schema can extend to include external objects. Interestingly, a later investigation using light and electron microscopy revealed the emergence of novel functional neural connections in prefrontal areas of monkeys that underwent training in tool use (Hihara et al. 2006).

An ingenious study by Iriki et al. (2001) replicated the extension of the body schema to encompass virtual objects. In their experimental setup, the monkey performed tool use by observing visual feedback from a video monitor. After the requisite training, the visual receptive fields corresponding to the bimodal neurons in the monkey's intraparietal cortex, 'projected' to incorporate the virtual hand (corresponding to the real hand) on the

video monitor. Furthermore, immediately following tool use, the visual receptive fields coding the image of the hand on the monitor, extended to incorporate the virtual tool (the vRFs expanded to encompass the length of the virtual instrument). More surprisingly, the compression and displacement of the virtual hand prompted corresponding changes to the visual receptive fields of these bimodal neurons. The modification to the vRFs materialized despite no changes to the actual posture, position, and size of the real hand. Markedly, the same visual receptive fields coalesced around the instrument tip ('akin to a computer cursor') when every other image was filtered out (including the remainder of the instrument).

The above results signify that the virtual (*functional*) counterparts of the hand and instrument become an extension of the monkey's body. This body extension is not merely functional in nature; there is perhaps an element of ownership over the virtual hand as depicted by the fact that the monkey retracts the real hand when a threat is presented near the image. Maravita and Irki (2004, p.81) suggest that these neurons might represent the neural correlates of the 'distal presence' felt during teleoperators (e.g., a controllable robot) and contingent virtual displays (Loomis 1992). Inquiries into tool usage in humans reveal the existence of analogous body schema based extension mechanisms. A study by Berti and Frassinetti (2000), involving a patient that had suffered a right-hemisphere stroke, demonstrated that visual neglect restricted to peripersonal space could be extended to distant spaces by artificially extending the patient's body by means of wielding a rod. That is, the visual neglect would extend to areas surrounding the rod upon use of the long implement, indicating that external objects become incorporated in the 'body' representation.

Analogous effects can be discerned in patients suffering from cross modal extinction. These patients ignore sensory stimuli of a specific modality (e.g., tactile stimulus) on the contralesional side (opposite side of the lesion) when a stimuli of a different modality (e.g., visual stimulus) is presented simultaneously on the ipsilesional side (same side of the lesion). Interestingly, the extinction of the contralesional tactile stimuli is moderated by the distance of the ipsilesional visual stimuli—i.e., the closer the visual probe is to the ipsilesional hand, the greater the tactile extinction on the contralesional hand (Pellegrino et al. 1997). Singularly, Maravita and colleagues (2001) discovered that the distance effect is attenuated by holding a stick with the ipsilesional hand to touch the distant visual stimuli. The attenuation of the distance effect when wielding a reaching stick signals the extension of the peripersonal space to also include space around the tool. Moreover, the effect could not be replicated by merely placing the stick near the ipsilesional hand (tangible control over the stick via wielding was necessary).

There are also more direct studies on tool-induced changes to the body schema in humans. An important study conducted by Cardinali et al. (2009) explicitly demonstrated that the kinematics of movement are modified after using a mechanical grabber—i.e., the kinematics of a person's empty hand (*without* the mechanical grabber) became distorted, as if their arm had lengthened, after performing actions with a mechanical grabber that

increased reach. The altered arm kinematics observed in the study indicated changes to the action oriented body schema—the arm morphology represented in the schema expanded to incorporate the external reaching instrument.

Significantly, the modified motor behavior ensuing the use of the mechanical grabber, lasted (at the minimum) for the duration of the 'post-tool' monitoring period (~ 10 to 15 minutes), and occurred without any training in wielding the mechanical grabber. This rapid change in motor-based representation stands in contrast to lower primates that require a period of training. A possible explanation may be that 'evolutionary pressure' triggered full expression of primitive 'body' integrating features in humans, which first developed in a primitive primate ancestor. This precursor would exist today in closely related primates, explaining the capability of macaque monkeys to embody external objects into their body representation only after some familiarity with the object. On the other hand, in humans, the fully developed body schema is capable of embodying objects almost instantaneously. There is evidence that this difference in elasticity of body representation corresponds to expanded prefrontal and intraparietal areas in humans compared to monkeys (Maravita and Irki 2004, p.80; see also Orban et al. 2004).

4.2 Glimpsing Ownership in Afterimages

In addition to studies focusing on kinematics of action, the afterimage experimental paradigm is also useful in probing the incorporation of objects into the body schema, and, more importantly, the subjective feeling of ownership over embodied objects. In an afterimage experiment, participants in a dark room are exposed to a brief light flash, the momentary flash creates an enduring afterimage of the whole field of view, moreover, when the afterimage contains a body part, the body part 'fades' or 'crumbles' when it is displaced (actively or passively) from its manifest position in the afterimage, however the rest of the afterimage remains intact (Davies 1973).

Hogendoorn et alia (2009) discovered that the disruption of the afterimage can be completely inhibited by 'disowning' the limb present in the field of view—the subjective feeling of ownership over the limb is decreased (or eliminated) by relocating the limb during the brief period of time between the end of the flash of light and formation of the afterimage. This suggests that the afterimage disruption is not simply a result of the conflict between vision and proprioception, but that it is also influenced by the higher-order subjective feeling of ownership.

Ritchie and Carlson (2010) replicated the disruption effect in afterimages of mirror reflections. The afterimage comprised reflections of the subject's arm using both (alternatively) a frontally placed mirror and mirror box. Ritchie and Carlson posit that the 'crumbling' effect observed in their experiment is partially explained by the subject's 'sense of ownership' towards its reflection and bodily self-awareness. This again suggests that the crumbling effect is modulated by the subjective feeling of ownership—movement

is a necessary, but not a sufficient, condition. In order to occur, *the crumbling effect requires a feeling of ownership towards the active object represented in the image*.

This derived determinant for the crumbling effect (i.e., the subjective feeling of ownership) is going to be important when considering rapid first-order extensions (integration of objects that are held directly) of the body schema in the afterimage experimental paradigm. In that regard, there have been several significant experiments conducted. The principal among these is a clever study where an afterimage-based experimental study demonstrates the rapid incorporation of first-order objects into the body schema (Carlson et al. 2010). In the study, both object and hand would fade from the afterimage after displacement from its envisaged position. Additionally, an object held by the subject faded from the afterimage upon being dropped. Inversely, objects also faded when the observer grasped the object and displaced it from the area incorporated in the afterimage. These results demonstrate that external objects were rapidly ('within a few seconds') integrated into the body schema (for fading of second-order objects, see Rademaker et al. 2014).

According to the previous afterimage studies (Hogendoorn et al. 2009; Ritchie and Carlson 2010), the subjective sense of ownership mediates the crumbling effect. Applying that constraint to the study by Carlson et al. (2010), the observed crumbling effect not only suggests that the external object was incorporated into the body schema, but that the process of embodiment extends the phenomenological experience of body ownership to the encompassed object. To reiterate, the afterimage experiment paradigm indicates that incorporating objects into the schema may also involve a (transient) non-conceptual sense of ownership towards the incorporated object.

4.3 The Principles of Object Ownership

There is direct evidence for the above hypothesis. In a formative study, Short and Ward (2009) examined the distinctive coding of body (personal) space, which is the external region of space 'occupied by our body' and corresponds to the body schema. They conducted a series of experiments involving virtual limbs (hands or cones) to determine the properties required to provoke the distinctive coding of space that enables efficient motor movements. The results revealed that visual space controlled by a person ('visual space subject to predictable consequences from movement') garnered a distinctive spatial code. Therefore, stimuli located within the controlled visual space resulted in faster motor responses than stimuli presented just outside this space. In addition, Short and Ward found that the appearance of the virtual limb, and the spatial correspondence between visual and proprioceptive feedback, did not modulate the distinctive coding of the virtual object. *Predictable control* was the governing factor in extending the body schema.

Importantly, the researchers found that participants not only experienced subjective agency, but also *ownership* of the virtual limb, in those experiments where they had objective control over the simulated object. In light of their results, Short and Ward hypothesized that the body schema is capable of incorporating any controllable 'space or objects' and that

that ‘may make an individual feel as though the object has become a part of his/her own body.’

The results of Short and Ward demonstrate that objective agency not only leads to object incorporation into the body schema, but also that perceived agency engenders the subjective feeling of ownership towards the integrated object. This hypothesis is corroborated by subsequent studies. In particular, an innovative study by Ma and Hommel (2015a) showed that the phenomenological experience of ‘body ownership’ is conceived for ‘actively operated non-corporeal objects.’ Specifically, participants controlled virtual balloons, and virtual squares by moving their real hand— i.e., the hand and the virtual object moved in synchrony. In addition, participants could change the size of the virtual balloon (by opening and closing their hand), and either the size or color of the virtual square. This agential control over the virtual (non-corporeal) object garnered a sense of body ownership, in addition to a subjective sense of agency, towards the operated object. Though, not a necessary condition, the ownership illusion was stronger when the virtual object and the real hand appeared spatially close and connected. This suggests that the phenomenological sense of ownership is moderated by gestalt laws of proximity and continuity (Ma and Hommel 2015a, p.84; see also Koffka 2013).

A follow up study by Ma and Hommel (2015b) set out to corroborate the role of objective agency in ownership perceptions. They compared virtual illusions induced through synchronous visuo-tactile stimulation, with those induced via synchronous visuo-motor stimulation (i.e., through maintaining objective control of the effector). They found that agency strengthened the sense of ownership. Interestingly, they also discovered that agency played a greater role when the virtual object didn’t resemble a body part. In the case of the passive virtual hand, the visual resemblance with the participant’s real hand compensated for the lack of objective control.

In order to consolidate the findings on non-corporeal object ownership into a more systematic theoretical framework, and because of the interplay between perceived agency and ownership, Ma and colleagues (2018) conducted a study to determine if Wegner’s three criteria for the experience of conscious will extended to the perception of ownership. Wegner’s three principles mediating causality perception are priority, consistency, and exclusivity. These principles enable us to ‘draw the inference that our thought has caused our action’ (Wegner 2003). The first two principles, priority and consistency, are already discernible in illusory ownership studies. Adequate temporal synchrony, required to engender virtual object embodiment, is a manifestation of the priority principle, intimating a connection between motor intentions and action effects. The moderation of illusory ownership perception due to factors such as natural connectivity between object and person can be classified as a facet of the consistency principle. In their study, Ma et al. (2018) demonstrated that Wegner’s final principle, exclusivity, also had a pronounced effect on virtual object ownership. Ownership perception increases when there is certainty that the movement of the controlled virtual object does not have a plausible alternative cause.

These findings provide us with an integrated framework to analyze ownership and agency experiences. In particular, Wegner's principles allow us to apprehend, that with the proper multisensory integration and presence of *action-compatibility*, even a discrete volume of space can be embodied (Guterstam et al. 2013). It appears that the class of non-corporeal objects that can be embodied, and over which ownership can be experienced, is not critically constrained by physical features.

In fact, there is evidence from the RHI that the exact opposite is the case. Longo et alia (2009) discovered that objective similarity (skin luminance, hand morphology, and third person hand similarity ratings) between the rubber hand and the subject's real hand did not influence the illusion, but embodiment of the rubber hand lead to perceived similarity. Importantly, the increase in perceived similarity was selectively linked to the subjective experiences of ownership and agency, not to the proprioceptive drift associated with the illusion. This salient finding suggests that the experience of ownership is powerful enough to alter perception in a way that leads a person to attribute certain self-features onto the embodied object. The sentiment that possessions mirror particular qualities of their owner (to themselves, and to others) is not an uncommon notion in the annals of philosophy and psychology. In *Being and Nothingness*, Sartre (1943/1956, p.591-2) remarks that 'the totality of my possessions reflects the totality of my being ... I am what I have ... What is mine is myself'. In the same vein, William James (1890/1983, p.183) notes that the 'line' between the conceptions of 'me' and 'mine' is often 'difficult to draw'.

The impression that owned objects are assimilated into the self-image is supported by the implicit association test (IAT) paradigm. In an original study, Nicole LeBarr and Judith Shedden (2017) employed a new version of the IAT to assess implicit cognitive associations between self concepts and owned objects. In trials where self related words required the same response key as the color corresponding to self-owned objects, the response times were significantly faster. Interestingly, there was no marked difference in response times between trials with 'already-owned' and 'newly-owned' objects. This suggests that cognitive associations are formed rapidly (within minutes) between the self and newly-owned objects. According to the authors of the study, a possible mechanism that enables the rapid formation of these self-object associations is the act of physically grasping or using the object. In addition to manufacturing self-object psychological associations, ownership also appears to have an appreciable effect on the visuomotor system; there is evidence that ownership status influences grasping actions and perception of object affordances (Constable et al. 2011).

4.4 A Phenomenological Theory of Ownership

We have now completed the review of empirical evidence delineating the various aspects of

the sense of ownership. To summarize, the phenomenological sense of ownership is a powerful neurocognitive phenomenon. It is capable of altering phenomenal perceptions, object affordances, and motor intentionality (reflected in changes to the visuomotor system). Notably, these effects take place within minutes of ownership induction (Longo et al. 2009; LeBarr and Shedden 2017; Constable et al. 2011). Most important, the cognitive processes leading to the sense of ownership are based on the *perceived agency* rule.

The foundational principle that perceived agency over an object induces the sense of ownership is evident in studies where subjects feel ownership towards objects that they objectively control (Short and Ward 2009; Ma and Hommel 2015a). Importantly, the perceived agency rule is modulated by three gestalt-like principles: priority, consistency, and exclusivity (Ma et al. 2018). In addition, the inextricable relation between action control and the body schema (i.e., the body schema enables volitional actions) suggests that the integration of an object into the schema is a neurocognitive primer to object control (see Section 2.3). Consequently, incorporation of an object into the body schema leads to a non-conceptual sense of ownership towards the integrated object (Short and Ward 2009). This is also supported by synthesizing the findings from tool embodiment literature and the afterimage paradigm (see Section 4.2).

The final cognitive process underpinning the account is the rapid formation of self-object associations immediately ensuing the inception of ownership. The associations are likely strengthened over time as suggested by the case study discussed at the beginning of Section 4 (Aglioti et al. 1996). These psychological associations form the basis for a range of ownership related phenomenon, including the endowment effect and the mere ownership effect (Gawronski et al. 2007).

These processes form the basis of the phenomenological theory of ownership, which we posit as a theoretical model to unify and explain existing findings on the non-conceptual sense of ownership. In particular, integrating these mechanisms with emergent aspects of the minimal self, it becomes evident that the sense of ownership extending to external objects is a natural correlate of processes involved in the development of self-perception and representation. To see this, recall that the theory of ideomotor learning stipulates that voluntary action is attained through continual motor interactions with the physical environment (see Section 2.2). Add to that the fact that visual perception of an object generates the range of possible actions afforded by the object—i.e., our perception of objects is intrinsically action oriented (Sinigaglia and Rizzolatti 2011). Together, this implies that during the requisite exploratory movements leading to voluntary action acquisition, children and infants will inevitably incorporate objects into their body schema. They will form action and effect associations corresponding to these objects—in part, aided by the mirror mechanism. Eventually, the infants will learn to intentionally operate objects frequently present in their environment.

These important developmental interactions yield the nascent instances of non-corporeal object ownership. Namely, embodying objects (by way of the body schema) and exercising objective control over things leads to the subjective experience of ownership. Furthermore, after acquiring possession of these objects, the mind forms rapid self-object associations (associative self-anchoring). These associations strengthen and intensify over time if the object remains in the child's possession. As noted by Susan Sutherland Isaacs (1933, p.225), the full-fledged self-object associations may lead to the conspicuous perception on the part of the child that 'what is mine becomes (in my feelings) a part of ME.'

These self construction processes suggest that the appearance of the concept of ownership is a corollary of the minimal self. That is to say, children acquiring possessions is a normal part of self-development, somewhat akin to the acquisition of language (Chomsky 2014). It follows that the purely conventional account of property, asserting that there is no natural 'mine' or 'thine', is misguided (Bentham 1840; Hume 1739/1978, p.489-90). Instead, the phenomenological theory of ownership is reminiscent of Hegelian notions of property. The Hegelian account says that property is the externalization of will or the embodiment of personality. This fits with the fact that the body schema enables action control to extend beyond the body to objects in the external world and leads to the phenomenological experience of ownership (Riaz 2018).

Additionally, there is evidence from some linguistic and anthropological theories that the concept of ownership is a universal feature of human languages and societies. The strongest example of the former is the theory of Natural Semantic Metalanguage (NSM). The theory stipulates that terms denoting possession (e.g., 'mine') are 'semantically irreducible' and likely expressible in all human languages (Goddard and Wierzbicka 2016). Property is among the list of human universals compiled by the anthropologist Donald Brown (1991). Experimental studies in nonhuman primates also favor theoretical accounts that involve a biological basis for personal property. Psychological patterns such as the endowment effect (overvaluing objects that are owned by the subject) and pragmatic ownership behavior (e.g, bartering) have been observed in other primates (Brosnan 2011).

Add to all this the fact that humans have the capacity to identify with others and engage in prosocial behaviors, we see that people can devise property rules based on their shared perspective and the inherent human instinct to acquire possessions in order to adequately express themselves (Tomasello and Vaish 2013).

In regard to young children's comprehension of ownership, developmental studies show that the concept of ownership rights emerges in children at ages 2- to 3-years. Two- to 3-year olds begin to assert ownership rights over their personal possessions (Nancekivell et al. 2013). The process of acquiring these ownership concepts originates much earlier, at around 9 months of age, when infants start to form triadic relationships 'that [link] self, people, and objects in the environment'

(Rochat 2011). Interestingly, children uphold ownership rights and side with owners over non-owners in disputes much more strongly and consistently than adults. During ownership disputes, adults also take into account alternative entitlement principles such as continued use and duty to share (Neary and Friedman 2014). The stringent adherence to ownership rights displayed by children (in contrast to adults) does not conform with purely conventional accounts of ownership. In fact, studies suggest that the ownership rights inferred by children are an extension of the bodily rights that they intuitively possess. This fact also fits the phenomenological theory of ownership. Specifically, researchers found no evidence that children distinguish between body parts and personal property when making moral judgments about ownership (Vondervoort and Friedman 2015). In the next section, building on these findings, we argue that the processes constituting the phenomenological theory of ownership result in the emergence of a naïve theory of ownership.

5 Metarepresentations of ownerships

Extending the research on the role of agency in ownership, a clever paper investigated the effect of *past agency* on the composition of non-corporeal object ownership. Researchers conducted a version of the RHI using several different objects: a computer mouse, rubber hand, smart phone, and a wooden block. Implicit measures of ownership were significantly greater for objects that people had past agency experiences with. According to the authors, these results show that 'ownership can be obtained for virtual non-corporeal objects that either currently move with our body or that have been moving with our body in the past'—i.e., suggesting 'that what we perceive as our body is affected by knowledge about our past interactions with objects.' This indicates that episodic memory and past experiences of agential control can generate the sense of ownership (Liepelt et al. 2017).

5.1 Ownership Judgments

The indication that past experiences and memories can modulate the sense of ownership is a useful starting point in the analysis of ownership judgements, which operate at a conceptual level and are interpretive in nature. These judgments inform our thoughts and behavior, and are necessary for socially appropriate conduct. In fact, Nancekivell et al. (2019) have argued 'that people's understanding of ownership' is shaped by 'an early-emerging, causally powerful, naïve theory [i.e., folk or intuitive theory] of ownership.' In their estimation, a naïve theory of ownership comes with its own distinct ontology and causal-explanatory reasoning principles. Interestingly, they suggest that certain aspects of ownership reasoning could have been derived from domain specific principles and early life experiences.

We posit that the general character of young children's ownership judgments is based on two interacting cognitive components. In the first instance, the principles that govern the phenomenological sense of ownership as experienced early in life. This primal perception and its underlying principles lay the groundwork for the development of a naïve theory of ownership embedded in notions of agency and causality. Later, inferential reasoning

extends the concepts learned in the first-person case to other people and abstract situations.

Specifically, we propose that the basic principles constituting ownership judgments are derived from early life experiences involving object control and the phenomenological sense of ownership. As a result, people tend to take into account past agency over objects when making ownership judgments involving self and others.

There is good evidence from developmental psychology that that is the case. One study showed that preschoolers infer plausible person-object history when understanding and explaining ownership (Nancekivell and Friedman, 2014). Children seem to think that 'past investment,' or agential involvement, in an object implies ownership of that object. In addition to the evidence from developmental psychology, a slew of psychological studies in adults corroborate the role of agential involvement, and causal considerations in ownership judgments. One article exploring people's reasoning about the acquisition of ownership compared 'first possession' considerations against 'necessary for possession' logic (Friedman, 2010). The results of the study clearly favored the necessary-for-possession rationale. In light of the results, Friedman suggests that ownership judgements may be based on 'processes akin to those used to make judgments about causality.' In fact, the necessary for possession justification conforms with the perceived agency precept and obeys the three gestalt-like principles of priority, consistency, and exclusivity that underpin agency perception.

The notion that ownership judgments are based on 'an agent's intent and control in bringing about an outcome' was reaffirmed in a subsequent study (Palamar et al. 2012). They conducted three separate experiments that showed that people judge ownership by considering the intentional will to bring about possession—i.e., they judge ownership based on the 'attribution of responsibility' principle. The authors go on to suggest that their findings indicate that ownership reasoning is not entirely conventional and are instead based on psychological processes underlying perception of causality.

The principle of *agential involvement* offers a cogent base for the conceptual analysis of ownership intuitions, including the effects of labour on ownership. In this regard, a study showed that children and adults transferred ownership of an object from the original owner to the person that invested creative labor into the object. In other words, preschool children and adults transfer ownership of an object from the original owner to a person who creatively laboured on it to make a new object. Intriguingly, the effect was significantly more pronounced in children than in adults (Kanngiesser et al. 2010). The results of this study are in line with the proposal that human ownership intuition takes into accounts forms of agential involvement. In particular, *intentional creative labor*, an archetypal example of agential involvement, appears to play a prominent role in the ownership attribution schemata.

To determine whether agential involvement is a prevalent precept in ownership attributions, it is instructive to note occurrences of the principle in young children across cultures. In this regard, an important cross-cultural study of ownership in children appears to indicate that creation (a prominent derivation of agential involvement) is a universal and primal principle of attributing ownership. The study involved children from seven distinct social, economic and cultural situations, and found that only the creation principle got used consistently, and that principles such as first contact, familiarity and disparity of wealth did not get used uniformly (Rochat et al. 2014). This was despite the fact that the principle of first contact is an easier precept to cognitively comprehend.

Supplementing the above findings, a research study found that adults predominantly applied the creation principle to judge ownership. In addition, they discovered that intention to create mattered in judging ownership: accidental creation diminished the creator's claim to ownership. Interestingly, the creation criterion operated even in the absence of physical possession and the study showed that creation led to ownership even if the created object had a lower value than the original material (Levene et al. 2015).

Since the creation precept is a specific form of the more basic agential involvement principle, these results provide additional evidence that agential involvement is a powerful factor in ownership judgements.

5.2 Ownership of Ideas

This section offers a few brief theoretical suggestions to elucidate the amorphous notion of idea ownership that is consistent with the framework developed in previous sections. Our basic proposal is that thought-generation is somewhat akin to action. In particular, intentional thinking bears resemblance to intentional physical actions. They both demand conscious will and appear to be subject to its jurisdiction in ordinary cases. In fact, the notion that thinking is a 'kind of action' has been suggested previously in order to account for certain schizophrenic experiences (Gallagher 2000, p.17; Frith 2014; Campbell 1999).

If we presume that thinking consists of intangible actions, and that these actions can be combined in original and creative ways, then thoughts and ideas are subject to the perceived agency precept and the creation principle can be invoked to justify ownership. The former is applicable because intentional thoughts are analogous to intentional physical actions, and intentional actions entail the feeling of agency. This would mean that intentional thoughts are accompanied by the phenomenological feeling of agency, a feeling that disappears in certain schizophrenic experiences. According to the perceived agency precept, there should also be a feeling of ownership towards these thoughts in typical (i.e., non-pathological) circumstances. Furthermore, in cases where the thoughts are strung together in novel and creative patterns, these thoughts constitute a new entity. If that is the case, then the author(s) of the novel thought pattern can invoke the creation principle in order to claim ownership over their ideas.

There is some evidence in support of this account from studies in developmental psychology. A study demonstrated that 6 to 8-year-old children apply ownership principles to ideas (but not to common words), including the necessary-for-possession principle, non-transfer by theft, and control-of-permission rules (Shaw et al. 2012). A subsequent study investigated whether children value ideas more than labor in artistic creation (Li et al. 2013). Researchers found that 6-year-olds valued ideas over labor. They chose pictures containing their ideas over pictures that merely contained their labor. By contrast, 4-year-olds did not particularly appreciate ideas. They appeared to simply prefer pictures with their 'idiosyncratic preferences.' This suggests that it takes children longer to apply ownership concepts to ideas as compared with physical objects. A plausible conjecture is that 6-year-olds but not 4-year-olds value ideas as unique and precious, and that they need to learn the value placed on at least some ideas before they begin to extend ownership rights over them.

As further evidence, a cross cultural study demonstrated that 5- and 6-year-olds from three different cultures responded negatively to plagiarism. It follows that these children value ideas as things over which ownership rights are applicable (Yang et al. 2014). A later study suggested that children's negative reaction to plagiarism is based on the fact that it takes away credit from the rightful owner (Shaw and Olson 2015). This suggests that children evaluate plagiarism negatively because it violates the attribution of responsibility principle.

These results from developmental psychology support the hypothesis that the phenomenological feeling of ownership extends to the domain of ideas and that they are broadly subject to the principles (e.g., perceived agency, creation, and attribution of responsibility) that govern object ownership. Indeed, ownership of ideas may be a natural development that reflects the ability of human children to appreciate more abstract concepts.

6 Conclusion

Convergent evidence from multiple disciplines points toward a deep connection between the sense of agency and the sense of ownership. This connection extends beyond the body due to the dynamic nature of the body schema. As we have reviewed, people feel a sense of ownership towards objects that they embody (via the body schema) or objectively control. This relation between agential control and the sense of ownership informs the structure of an early emerging naïve theory of ownership. As a consequence, people's ownership judgments tend to be based on past agential involvement in objects. Altogether, we believe that the theoretical account presented explains a wide range of psychological phenomenon, and we hope that it is a fruitful framework for future research on ownership across scientific disciplines.

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