SOAP Opera: Self as Object and Agent in Prioritizing Attention

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Abstract

■ A growing body of evidence has demonstrated that multiple sources of salience tune attentional sets toward aspects of the environment, including affectively and motivationally significant categories of stimuli such as angry faces and reward-associated target locations. Recent evidence further indicates that objects that have gained personal significance through ownership can elicit similar attentional prioritization. Here we discuss current research on sources of attentional prioritization that shape our awareness of the visual world from moment to moment and the underlying neural systems and contextualize what is known about attentional prioritization of our possessions within that research. We review behavioral and neuroimaging research on the influence of self-relevance and ownership on cognition and discuss challenges to this literature stemming from different modes of conceptualizing and operationalizing the self. We argue that ownership taps into both "self-as-object," which characterizes the self as an object with a constellation of traits and attributes, and "self-as-subject," which characterizes the self as an agentic perceiver and knower. Despite an abundance of research probing neural and behavioral indices of self-as-object and its effects on attention, there exists a paucity of research on the influence of self-relevance of attention when self is operationalized from the perspective of a first-person subject. To begin to address this gap, we propose the Self as Ownership in Attentional Prioritization (SOAP) framework to explain how ownership increases salience through attention to external representations of self-identity (i.e., self as object) and attention to contextually mediated permission to act (i.e., self as subject). ■

INTRODUCTION

Imagine that you are helping a friend move. As you are packing things in boxes and throwing out junk, something in the corner of the room catches your eye. In a pile of clothes, you notice the sweater you thought you lost all those months ago. There is really nothing unusual about the sweater; it's not particularly bright or new, but it grabs your attention because it is yours. It has long been known that, given the complexity of the world, we see what we are looking for and ignore what is irrelevant. However, our attention functions in service of multiple nested hierarchies of goals, and what gets prioritized can be seen in our daily life. Although the neural systems and neuronal mechanisms underlying conscious and deliberate forms of selective attention are well studied, convergent research indicates that attention is also tuned to the aspects of the environment that are relevant to one's wellbeing—including our own possessions. As we will propose, objects that we own enjoy a unique hold on our attention by both operating as external representations of our identities but, also importantly, modifying the environment's landscape of action affordances.

In the current study, we review current research on sources of attentional prioritization that shape our awareness of the visual world from moment to moment and contextualize what is known about attentional prioritization of our possessions within that research. To that end, we briefly review research on implicit attentional sets that are modulated by emotional and motivational relevance. We then review research on effects of self-relevance on cognitive processes in general and of ownership in particular, as well as underlying neural systems, and discuss challenges to this literature stemming from different modes of conceptualizing and operationalizing the self. We argue that, to understand attentional prioritization of our possessions, we need to consider the way attention is shaped by a first-person conception of an active, agentic self and propose the self as ownership in attentional prioritization (SOAP) framework for understanding our capacity to rapidly develop implicit attentional sets for the things we own. Finally, we discuss hoarding as a special test case and outline directions for future research. With the goal of furthering the collective understanding of ownership on attention, we first briefly review what is presently known about the influences that shape our active perception of what is relevant in the visual landscape.

SOURCES OF ATTENTIONAL PRIORITIZATION

Visual selective attention is the process by which we tune ourselves to the world so that, of the millions of bits per second transmitted by the retina (Koch et al., 2006), the

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information that is most important to us reaches awareness and guides action. Recently, new areas of attention research have opened up as classic models dividing attention into top–down and bottom–up systems have been challenged. As any student of cognitive psychology can tell you, top–down refers to volitional, executive attention to task-relevant stimuli, which is mediated by a dorsal attention network (DAN), and bottom–up refers to capture by low-level features of a stimulus, such as color, contrast, or motion, which is mediated by a ventral attention network (VAN; Fox, Corbetta, Snyder, Vincent, & Raichle, 2006; Corbetta & Shulman, 2002). A large body of research has elucidated the role of these systems in biased competition, a primary mechanism of selective attention. In biased competition, activity of visual cortex neurons or BOLD responses sensitive to the location or features of an attended item is enhanced, whereas activity of neurons/BOLD responses tuned to competing stimuli is suppressed (e.g., Desimone & Duncan, 1995). Challenges to this intuitively appealing dichotomy have not arisen because of poor empirical support for these attentional systems—a wealth of research in humans and non-human animals supports the function of both systems (e.g., Reynolds & Chelazzi, 2004; Kastner & Ungerleider, 2001; Kastner et al., 2001; Desimone & Duncan, 1995). Rather, there has been a push toward expanding and refining the model, which was developed in highly constrained laboratory contexts, to accommodate other sources of attentional modulation of perception. Moreover, emerging conversations between researchers coming out of two previously silo-ized lines of research—attention research focusing on reward and emotion research focusing on effects of emotional salience on cognition—are allowing the development of more comprehensive theoretical frameworks of affective and motivational sources of attention across multiple timescales.

ADDITIONAL SOURCES OF ATTENTIONAL PRIORITIZATION

Recent research has elucidated ways in which, within the time span of an experimental task, practice, perceptual learning of statistical regularities, and the history of choices made previously in the experiment can modulate attentional prioritization (Cosman & Vecera, 2014; Zhao, Al-Aidroos, & Turk-Browne, 2013; Awh, Belopolsky, & Theeuwes, 2012; Kristjánsson & Campana, 2010). For this reason, it has been proposed that attention is continuously guided by an implicit memory system focused on features of stimuli (Kristjánsson & Campana, 2010; Kristjánsson & Nakayama, 2003). On longer timescales, an individual's semantic associations with stimuli (Moores, Laiti, & Chelazzi, 2003), as well as past experience of associating certain categories of stimulus with emotional arousal or reward, also strongly shapes attentional prioritization (for reviews, see Chelazzi, Perlato, Santandrea, & Della Libera, 2013; Pourtois, Schettino, & Vuilleumier, 2013; Todd, Cunningham, Anderson, & Thompson, 2012; see also Baruni, Lau, & Salzman, 2015; Chelazzi et al., 2014; West, Anderson, Ferber, & Pratt, 2011; West, Anderson, & Pratt, 2009; Anderson, 2005; Keil & Ihssen, 2004). In particular, we have emphasized the importance of a developmental history of associative learning in biasing affective/motivational attention to prioritize specific categories of stimulus (Todd, Cunningham, et al., 2012). For example, whereas children learn early on to associate happy faces with rewarding consequences and angry faces with unpleasant ones, we and others have previously demonstrated that which of the two expressions is typically prioritized may typically depend on one's developmental phase of life, as well as one's own unique history and temperament (Picardo, Baron, & Todd, 2015; Todd, Lee, Evans, Lewis, & Taylor, 2012; Todd, Evans, Morris, Lewis, & Taylor, 2010; Mather & Carstensen, 2005; Mather et al., 2004).

Moreover, there is increasing evidence that what gets prioritized at any given time can shift as different goals are emphasized (Chelazzi et al., 2013; Cunningham, Van Bavel, & Johnsen, 2008), revealing what Chelazzi and colleagues have referred to as experience-dependent attentional flexibility (Chelazzi et al., 2013). Prioritized goals can range from short-term task-related goals involving explicit executive attentional processes typically studied in the laboratory, such as looking for a unique item in a visual search task, to long-term, mostly implicit goals that include staying alive, avoiding pain, and approaching pleasure. These nested hierarchies of goals can be seen to serve as different sources of salience, each subserved by distinct (if often overlapping and interacting) neural systems. For example, in monkeys the amygdala has been found to play a role in allocation of spatial attention to motivationally salient stimuli (Peck, Lau, & Salzman, 2013), and V4 neurons show greater activity for a neutral stimulus when its receptive field is linked to greater reward (Baruni et al., 2015). Similarly, in humans greater patterns of functional connectivity between BOLD response in the amygdala and regions of visual cortex have been observed for affectively/motivationally salient relative to more neutral stimuli (Todd, Talmi, Schmitz, Susskind, & Anderson, 2012; Sabatinelli, Bradley, Fitzsimmons, & Lang, 2005; Pessoa, Kastner, & Ungerleider, 2002).

ATTENTIONAL SETS

Traditionally studied in the context of executive attention, attentional sets are mental templates that tune attention to prioritize object features or spatial locations relevant to the demands of a particular task (Folk, Remington, & Johnston, 1992). To use a classic example, when searching for one's keys on a crowded desk, one maintains an attentional set for such features of the keys as shiny metallic color and key-like shapes so they more readily stand out from the background clutter. Typically, as studied in the lab, attentional sets have been determined by such explicit and intentional task-related goals (e.g., Becker, Folk, & Remington, 2010, 2013; Correa & Nobre, 2008; Rushworth, Passingham, & Nobre, 2005; Folk & Remington, 1999). However, mounting evidence indicates implicit attentional sets can be built up over the course of a task through learning (Zhao, Cosman, Vatterott, Gupta, & Vecera, 2014; Kristjánsson & Campana, 2010). We have further suggested that one can maintain implicit attentional sets related to longer-term goals (Todd, Talmi, et al., 2012). The term "affective/motivational attentional sets" describes such implicit attentional sets for stimuli associated with sustained goals of avoiding pain and approaching pleasure. In support of this claim is behavioral and neural evidence that visual prioritization observed for affectively/motivationally salient stimuli resembles prioritization elicited by common manipulations of explicit executive attention (Chelazzi et al., 2013, 2014; Hickey & van Zoest, 2012; Miskovic & Keil, 2012; West et al., 2009, 2011; Hickey, Chelazzi, & Theeuwes, 2010; Serences & Saproo, 2010; Kiss, Driver, & Eimer, 2009; Raymond & O'Brien, 2009; Anderson, 2005). Moreover, such effects have been found to be independent of executive strategy (Della Libera & Chelazzi, 2009).

In the absence of explicit cueing, implicit attentional sets can be challenging to measure; however, one phenomenon that is sensitive to such implicit templates is a prior entry effect, which is observed in temporal order judgment (TOJ) tasks, in which observers must judge which of two stimuli appears first. Prior entry effects have been observed when an attentional set for one hemifield is established with spatial cueing. In this case, when two stimuli are presented simultaneously, observers perceive the stimulus appearing in a precued hemifield as appearing first (Schneider & Bavelier, 2003; Shore, Spence, & Klein, 2001). This attention-mediated distortion in perception is referred to as the prior entry effect, and subsequent systematic variation of the stimulus onset asynchronies help to quantify the magnitude of the effect. More recently, it has been observed that stimuli with well-established and species-typical emotional relevance can also elicit prior entry effects similar to those elicited through spatial cueing (West et al., 2009, 2011). Here participants judged the order of appearance of pairs of angry and neutral faces in a TOJ task. When an angry face was paired with a neutral face, participants were significantly more likely to report that the angry face had appeared first (West et al., 2009).

Yet implicit prioritization is not just observed for stimuli that are (arguably) universally salient. Recent work has established the malleability of prioritization for both object features and spatial locations that have come to be associated with reward. With regard to the latter, spatial priority maps are neural representations of the most salient features of the environment—neural instantiations of attentional tuning that predict where gaze will be directed from instant to instant in a complex environment. Although these are known to be influenced by low-level featural salience, recent research has provided evidence that such maps can also be modulated by reward-based learning (Chelazzi et al., 2014). In a study by Chelazzi and colleagues (2014), on Days 1 and 4 of a 4-day experiment participants had to identify either one or two briefly presented, masked targets (letters or digits) in a circular array of stimuli in a task that they performed both before and after training. On Days 2 and 3, participants underwent a training task in which they also had to identify a target (the color of a triangle) in a spatial configuration that was identical to that of the baseline/test task. Here, correct performance was rewarded, but some target locations were associated with higher reward than others (Figure 1A). They then performed the baseline/test task again on Day 4. Crucially, when there were two targets, the target at the more highly rewarded location was more likely to be correctly identified at test but not at baseline (Figure 1B), indicating that priority maps had been reshaped to favor locations that had a history of being more highly rewarded (Chelazzi et al., 2014). These findings provide evidence that reward not only influences attentional tuning to currently rewarded aspects of the environment, but that such tuning to the environment is shaped by a longer term history of association with reward.

With regard to neural substrates of such biased attentional tuning, specific patterns of brain activity will vary depending on the task; however, many sources of visual cortex modulation involve not only nodes of DAN and VAN, but also subcortical hubs, including the amygdala (Sabatinelli et al., 2005) and key nodes of reward networks (Weil et al., 2010; for reviews, see Chelazzi et al., 2013; Pourtois et al., 2013; West et al., 2009). They also likely involve multiple and mutually interacting neuromodulator systems. Whereas some models have emphasized the role of dopamine in reward-biased attention (Hickey et al., 2010), our own biased attention by norepinephrine model has emphasized the role of the locus coeruleus and norepinephrine systems in modulating visual cortex activity both directly and via the amygdala and ventromedial pFC (VMPFC) for both positive and negative salient stimuli (Markovic, Anderson, & Todd, 2014).

SELF-BIASED ATTENTION

Another body of research, reviewed below, suggests that self-relevance is another source of stimulus salience. This line of research, which has developed independently of research on affective-motivational biases, indicates that self-relevant stimuli, including our own possessions, command more attentional resources and are preferentially remembered than stimuli that are not self-relevant (Turk, Van Bussel, Brebner, et al., 2011; Gray, Ambady, Lowenthal, & Deldin, 2004). In particular, ownership—as a distinct manifestation of self-relevance—has been found to exert a robust pull on attentional prioritization (Truong, Roberts, & Todd, in press). But how might effects of self-relevance and specifically ownership fit into a model of stimulus salience determined by shifting hierarchies of goals?

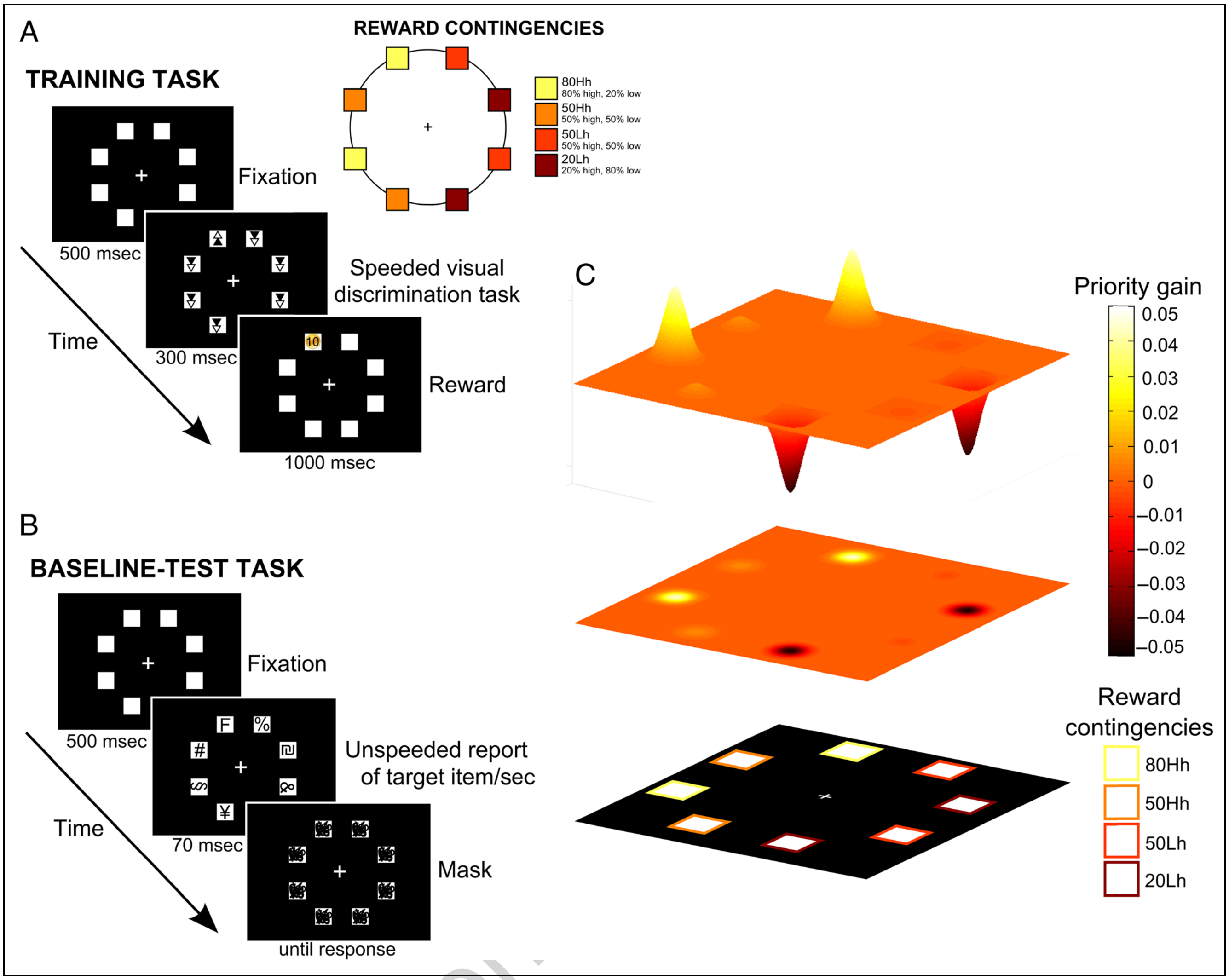

Figure 1. Study examining the influence of reward-based learning on spatial priority maps by Chelazzi et al. (2014). (A) Illustration of the training task in which participants learned to associate specific spatial locations with differing probabilities of reward and example of reward contingencies. At the beginning of each trial, a fixation display appeared on the screen. After 500 msec, the stimulus array was presented on the screen for 300 msec. Participants were asked to discriminate the color of the upper triangle (either black or white) of the target stimulus as quickly and accurately as possible. Correct responses were followed by a reward feedback, which could be high or low, and the amount gained was indicated at the target location. The probability of receiving high versus low reward was predetermined and systematically biased on the basis of the specific spatial location in the display, such that each location could be assigned to one of four reward categories: 80Hh, 50Hh, 50Lh, and 20Lh. (B) Illustration of the baseline/test task in which participants had to discriminate briefly presented shapes at the locations in which contingencies varied in the training task. The spatial array was identical to the one used in the training task. At the beginning of each trial, a fixation display appeared on the screen consisting of a circular array of eight white squares, marking spatial locations for the upcoming stimuli. After 500 msec, the stimulus array was briefly displayed and was immediately followed by a mask. Participants were to identify one or two targets (letters or digits) among seven or six distractors (nonalphanumeric characters), respectively, by pressing the corresponding key on a standard computer keyboard. In the crucial condition, participants had to identify two targets locations that, in the training task, had come to be associated with differing reward probabilities. (C) Average priority gain as an illustration of the plasticity of priority maps, such that with training participants prioritized regions of space associated with higher probability of reward (indexed by higher accuracy for high reward locations in the array). Priority gain was computed for each reward-associated spatial location, both in a 2-D plane (middle) and in a 3-D representation (top). For a given reward level, the average priority gain was calculated by averaging the change of probability between baseline and test for accurately reporting targets at the spatial location associated with that reward level. Figure adapted from Chelazzi et al. (2014).

SELF AS A SOURCE OF ATTENTIONAL PRIORITIZATION

For over half a century, researchers have observed that aspects of the world that are linked to the self receive prioritized cognitive resources. One's name is preferentially attended to and liked over others' names (Nuttin, 1985; Cherry, 1953), and one's own face preferentially captures and holds attention relative to others' faces (Devue, Van der Stigchel, Brédart, & Theeuwes, 2009; Tong & Nakayama, 1999). Whereas face and name are representations of identity that remain relatively stable over time, other research suggests that the cognitive advantage for self-relevant stimuli is not solely the domain of longstanding associations. In fact, self-relevance can be rapidly acquired. In a recent study, geometric shapes were randomly assigned to represent specific individuals (self, close other, stranger; Sui, He, & Humphreys, 2012). A subsequent matching task presented participants with shape–label pairs that were either congruent or incongruent with the initial linkages and participants judged whether a shape was matched with its original label. Participants were faster to respond when they saw a correctly matched self-pair relative to the other pairings. Follow-up experiments revealed that the comparative strength of the self-shape relationship could not be accounted for by other stimulus properties (Sui et al., 2012). Thus, effects of self-relevance may prioritize attention in a malleable manner similar to effects of reward reviewed above (Chelazzi et al., 2014). Such malleability may in turn extend to items that have gained self-relevance through ownership.

OWNERSHIP AS A CATEGORY OF SELF-RELEVANCE

Ownership may be seen as a specific instance of self-relevance. Like words, images or symbols that are perceived as descriptive of the self, stimuli that have become self-relevant through ownership are better attended and remembered (Cunningham, Turk, Macdonald, & Macrae, 2008; Turk, Van Bussel, Brebner, et al., 2011). Ownership can also influence complex downstream behavior such as patterns of buying and selling that reflect higher valuation of one's own possessions—an instance of the well-known endowment effect (Ashby, Dickert, & Glöckner, 2012). It has been suggested that the endowment effect can be partially explained by differences in attentional focus and that participants demonstrate biased information uptake due to ownership (Ashby et al., 2012).

Until recently, however, effects of ownership on attentional prioritization had not been directly tested. In a recent study, we examined whether ownership can engage implicit attentional sets to bias initial attentional deployment. We reasoned that, in light of the evidence that affectively salient stimuli can bias attention, the enhanced stimulus value afforded by ownership might engage a similar attentional set. Our own research thus examined whether self-owned objects could elicit a prior entry effect in a TOJ task adapted from the task, described above, originally employed by West et al. (2009). In our study, participants first learned whether arbitrarily assigned everyday objects belonged to them or to the experimenter and were tested for recall on these categories until performance was at ceiling (Truong et al., in press). Following successful memorization of the ownership categories, participants completed a TOJ task in which they viewed pairs of object images (one self-owned, one other-owned) presented at various onset asynchronies and judged which object appeared first. Participants were significantly more likely to perceive self-owned objects as appearing first if presented simultaneously with an other-owned object, revealing a prior entry effect for self-owned objects and suggesting a bias in initial attentional deployment (see Figure 2). In addition to an average bias toward self-owned objects, we also observed considerable interindividual variation in the size of the prior entry effect. However, this variability was uncorrelated with other self-related variables including (independent and interdependent) self-construal, loss aversion, and implicit positive associations with ownership—a null finding we will discuss further below.

Overall the findings of a prior entry effect for self-owned objects speak to a surprisingly powerful influence of ownership on attention. Whereas emotional faces such as those used in West et al. (2009) represent a category of stimuli that is effectively universal in importance, ubiquitous in daily life, and relatively consistent in form, the self-relevant objects in our study were randomly assigned in-lab to be self-owned. Nevertheless, the very recent designation of self-relevance to these objects was sufficient to reliably bias attentional tuning. This suggests that, similar to findings for recently learned associations with reward reviewed above (Chelazzi et al., 2014), attentional sets arising from ownership can be quickly and flexibly formed. Such evidence challenges the often-expressed belief that affective sources of attentional prioritization are "hardwired" (Öhman, 2002) and is consistent with a view of flexible prioritization modulated by contextual goals.

Such findings speak to the potency of self-relevance such that the mere image of a stimulus that has only (arbitrarily and recently) been imagined to be self-owned is sufficient to influence the prioritization of attention in a manner similar to more universally salient or biologically significant stimuli. But why does self-relevance through ownership exert such a potent attentional pull? What goals do attending to our own possessions serve? Differences in subjective valuation are often interpreted in relation to calculation-based valuation (Hsee & Rottenstreich, 2004) or attention to affective reactions (Shu & Peck, 2011) for self-owned objects, consistent with a goal of increasing reward; however, our findings showed no relationship between individual differences in either loss aversion or implicit valuation of owned objects. Another longstanding theory is that possessions (i.e., self-owned objects) contribute to and reflect one's identity (Belk, 1988). Indeed, the contents of one's room or office may be perceived as reflections of one's personality (Gosling, Ko, Mannarelli, & Morris, 2002). However, the TOJ effect we observed was not associated with objective evaluations of personality—at least with regard to self-construal, which has been linked to the endowment effect (Maddux et al., 2010).

With regard to self-relevance in general, many explanations have been proposed for the range of cognitive biases toward the self that have been observed. Research on the self-reference effect (for a review, see Klein, 2012) points toward the self as an especially rich source of organization, elaboration, and evaluation. Consequently, stimuli processed self-referentially have the potential to be linked to multiple memories, experiences, and relationships (whereas stimuli processed other-referentially may not be afforded as many links), thus increasing the probability of being attended and recalled. Finally, neuroimaging research has pointed to overlap between resting state default mode network activity and regions activated by paradigms using words and images associated with the self (Northoff, 2016; van Buuren, Gladwin, Zandbelt, Kahn, & Vink, 2010). Such findings have been interpreted as suggesting that reference to the self is pervasive throughout the moment to moment processing of external stimuli. Yet some challenges to interpretation of this literature arise from difficulties in operationalizing the construct of self.

TWO MODES OF OPERATIONALIZING SELF

To contextualize the literature on effects of self-relevance on attention, it is necessary to discuss two distinct ways in which the concept of self has been defined and operationalized in psychology and cognitive neuroscience: self-as-object and self-as-subject (Christoff, Cosmelli, Legrand, & Thompson, 2011; Legrand & Ruby, 2009; Ruby & Legrand, 2007). The study of self-as-object has focused on patterns of brain and behavior elicited when physical features or descriptive traits are attributed to the self relative to another person. Stimuli are evaluated for self-relevance in a context where the self is construed from the third-person perspective, as if one were looking at oneself through the eyes of another. In contrast, the study of self-as-subject focuses on patterns of brain and behavior where the subject is operationalized from the first person as an embodied, sensing agent seeing through his or her own eyes. In other words, the study of self-as-object involves the study of self as "me," the study of self-as-subject involves the study of the self as "I" (Christoff et al., 2011). The two operationalizations of self are probed through widely divergent experimental paradigms and, not surprisingly, evoke activity in distinct brain systems. As several recent reviews have pointed out (Christoff et al., 2011; Legrand & Ruby, 2009), the genre of neuroimaging paradigms used to map self-specifying brain networks have a narrowly restricted operationalization of self-relevance. Zahavi and Roepstorff (2011) concluded that, in simplifying the self-concept to make it easier to study, the specificity of these studies has been somewhat forgotten. As a result, what once was a narrowly defined instantiation of self has morphed into an overgeneralized characterization of the self. We will argue that an important and understudied aspect of attentional tuning toward our own possessions centers upon an object's availability for action as experienced by the first-person agentic "I."

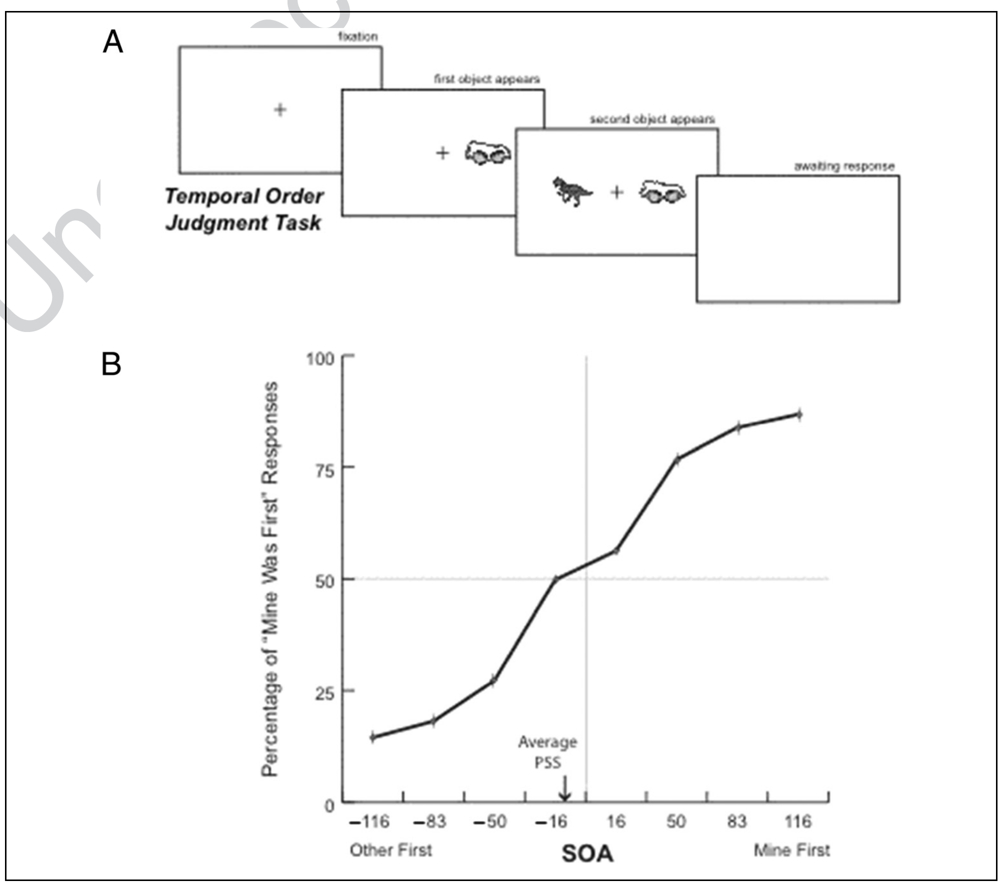

Figure 2. (A) Trial sequence for the TOJ task in which participants viewed pairs of images presented asynchronously onscreen (Truong et al., in press). Each pair was comprised of one self-owned object and one other-owned object and the onset asynchrony between the first and second object varied between 16 and 116 msec, with side (left or right) of first object counterbalanced within participant. Participants judged which side (left or right) contained the image that appeared first. (B) The average percentage of "My object appeared first" responses as a function of SOA in the TOJ task indicating a prior entry effect for self-owned objects. On average, the point of subjective simultaneity was negative (see arrow), indicating an other-owned object needs to be presented before a self-owned object to be perceived as appearing at the same time. Figure adapted from Truong et al. (in press).

NEUROIMAGING STUDIES OF SELF AS OBJECT

The neurophysiological study of the self as object has often been investigated through trait ascription paradigms (Sul, Choi, & Kang, 2012; Zhu, Zhang, Fan, & Han, 2007; Heatherton et al., 2006; Kelley et al., 2002; Craik et al., 1999). In such studies, participants are presented with adjectives describing personality traits (e.g., outgoing, shy, etc.) and judge whether a trait is highly self-descriptive (the self condition) or highly descriptive of another person (the other condition). Across several meta-analyses, cortical midline structures including the ventral medial pFC, dorsomedial pFC, ACC, and posterior cingulate cortex have been identified as differentiating self-referential processing from other-referential processing (for reviews, see Li, Mai, & Liu, 2014; Schneider et al., 2008; Northoff & Bermpohl, 2004). In light of this research and given the current body of knowledge on neural underpinnings of selective attention, researchers have begun to propose neural systems underlying attentional biases for self-related information.

THE SAN MODEL

Recently, Humphreys and Sui (2015) proposed the Self Attention Network (SAN) as a neural substrate of self-biased attention. Drawing from their own previous work (Sui, Liu, Mevorach, & Humphreys, 2015; Sui, Rothstein, & Humphreys, 2013; Mevorach, Hodsoll, Allen, Shalev, & Humphreys, 2010) as well as that of others' (e.g., Bar et al., 2006; Gronau, Cohen, & Ben-Shakhar, 2003), Humphrey and Sui adopt the classic dual process model of top–down and bottom–up attention. Their model of SAN is thus characterized by interactions between brain systems involved in self-representation with the DAN and VAN. In this model, individual and group differences in self-related processing are instantiated via modulation of the SAN through experience, culture, and social context. This model of selective attention posits that the VMPFC is a node for self-representation that biases attention toward self-relevant stimuli via excitatory connectivity with the posterior STS, a node of the VAN. It is notable that VMPFC is also an important hub of reward circuitry. In fact, self-relevance has been found to recruit the same VMPFC regions as reward, leading to the conclusion that our self (as object) may be based on reward (Summerfield et al., 2006). More specifically, VMPFC is implicated in the evaluation of both short- and long-term value of stimuli. It also plays an important role in modulating visual activity based on past experience, thus qualifying as a neural system that instantiates implicit attentional sets (Gamond et al., 2011).

The SAN model further proposes that the DAN acts to inhibit this biasing activity during instances in which deployment of attention toward self-related stimuli is not called for. It should be noted that according to the SAN framework the attentional control network can moderate self-related activity in the VMPFC, which SAN characterizes as bottom–up (again, this notion has been challenged); however, this does not preclude all self-related information from being processed and perceived. Although the capacity of such DAN-mediated executive processes to override attentional capture by emotional or visual salience has been hotly debated for over a decade, Humphrey and Sui's claim is consistent with findings that effects of emotional capture can be dependent on DAN-mediated attention (Pessoa, Padmala, & Morland, 2005; Pessoa et al., 2002). However, other current views propose a more complex ecology of attention in which multiple neural systems influencing priority cooperate or compete depending on context.

The SAN's inclusion of the VMPFC as a node for self-representation is consistent with the aforementioned body of work examining the neural correlates of self, and it has been received positively by other researchers in the field (Conway, Pothos, & Turk, 2016). Nevertheless, it may not be a complete model for understanding how self-relatedness or self-relevance modulates attention. Like other studies of self-as-object, the studies cited by Humphreys and Sui (2015) involved recognition of an identifiable representation of self. Specifically, these studies utilized faces (e.g., Tao, Zhang, Li, & Geng, 2012), names (e.g., Harris, Pashler, & Coburn, 2004), and shapes (see Sui et al., 2012, above) in various contexts. These works and related works are undoubtedly important in understanding how the self biases attention, but they depend solely on a single dimension of self-as-object.

In contrast to experiments that target self as object (of attribution), it has been proposed that experiments that explore how the self works as a knower and an agent targets self as subject (Christoff et al., 2011). This latter operationalization of self is experiential and specifies the self through such processes as sensorimotor integration, homeostatic regulation, voluntary movement, body ownership, and a sense of agency. In contrast to activating VMPFC as a hub of the SAN network, such processes are mediated by neural structures such as the angular gyrus, premotor cortex, temperoparietal junction, dorsolateral pFC, and pre-SMA (for reviews, see Chambon, Sidarus, & Haggard, 2013; Sperduti, Delaveau, Fossati, & Nadel, 2011). In the next section, we will discuss evidence for the influence of self-as-subject on attention and suggest that operationalizing self-as-object and self-as-subject both may uniquely and interactively contribute to selective attention.

SELF AS SUBJECT

In contrast to the body of research reviewed above, which operationalizes self-relatedness from the third-person perspective in the form of traits and descriptors, embodied-enactive approaches to cognition have focused on a first-person description of self as bodily self-consciousness

(Mandrigin & Thompson, 2015; Blanke & Metzinger, 2009). That is, rather than thinking of the self as others would, as an object of contemplation with a signature appearance and characteristics, this approach focuses on a more basic sense of oneself as locus of perception and action. The most fundamental form of first-person self-awareness has been described in terms of a minimal phenomenal self (MPS), which is involved in the primary experiential distinction between self and the surrounding environment. The MPS has been described as the experience of being a distinct entity capable of control over attention and action (Blanke & Metzinger, 2009). Specifically MPS is thought to involve (1) awareness of the body as a whole, (2) a sense of location in space and time, and (3) a first-person perspective that involves direction of this whole system in performing an action or attending an object (Blanke & Metzinger, 2009). Although such a construct can be difficult to operationalize experimentally, neural systems proposed to be associated with this most basic sense of self are distinct from those that have been found to be active in studies focusing on the third-person perspective. For example, it has been suggested that ventral intraparietal cortex may encode large areas of bodily surface important for whole body awareness and that the vestibular system also plays a key role (Blanke & Metzinger, 2009). Other embodied models of the first-person sense of self focus on sensorimotor integration as the foundation of self-as-subject. They highlight the role of the TPJ in integration of sight, sound, touch, and one's own body movement as well as in perspective switching (Mandrigin & Thompson, 2015). For example, research on out of body experiences indicates that stimulating regions of the TPJ can produce feelings of being outside of and above one's body (Blanke, Ortigue, Landis, & Seeck, 2002), lesions of the TPJ have been associated with denial of ownership of the contralateral (left) hand (Bottini, Bisiach, Sterzi, & Vallarc, 2002), and TMS of the TPJ increases the ambiguity between what is part of the body and what is not (Tsakiris, Costantini, & Haggard, 2008). Other research on the TPJ showing that it is also engaged during stimulus evaluation (Han & Marois, 2014) and context updating and adjustments of top–down expectations (Geng & Vossel, 2013) fit well with the findings on out of body experiences, as they involve reconciling unusual sensory input with longstanding representations of bodily experience. Other brain regions thought to be important for the sense of body ownership and the distinction between one's body and the world include primary and secondary somatosensory cortices and potentially posterior insula as (putative) primary interoceptive cortex (Tsakiris et al., 2008).

With regard to attention, we argue that operationalization of the first-person perspective is key to answering the question of how we draw on this subjective sense of self to prioritize aspects of the external world. We will next review evidence that operationalizing the active agentic first-person self is key to understanding how the self affects the way attention is allocated, specifically with regard to the influence of object ownership as a distinct instantiation of self-relevance.

One possibility is that things we own elicit attentional prioritization because we see them as extensions of our bodies—as extensions of the first-person sense of self. A line of research in humans and non-human primates indicates that bodily self-awareness is expanded by tool use to incorporate the tools into the body schema. For example, experiments in humans exploiting a phenomenon in which tactile TOJs are reversed when hands are crossed have found similar findings when holding sticks, suggesting that when a stick is held the sense of touch extends along the length of the stick (Yamamoto & Kitazawa, 2001). Research in non-human animals suggests that this corporeal extension involves expansion of receptive fields in the caudal postcentral gyrus to include tools. Famously, in one study, macaques were trained to use a rake to draw food toward themselves (Iriki, Tanaka, & Iwamura, 1996). Posttraining, the receptive fields of bimodal neurons in these macaques that responded to visual information around the macaque's hand had expanded to include the length of the tool. Interestingly, this receptive field plasticity was only observed when the macaques used the rake and not when they only held the rake in their hands, suggesting that active manipulation was crucial to the incorporation of the rake into the body schema, emphasizing the importance of goal directed action in this extension of the sense of one's own body.

However, distinctions have been made between the ideas of body extension and body incorporation. One claim is that that tools act as body extensions—they modify how the body responds to the environment but they do not become part of the body-model and do not change elicit a feeling of body ownership in the way that prostheses do (De Preester & Tsakiris, 2009). Rather, tools appear to be temporary extensions that extend the sense of the acting body in pursuit of a specific goal. Thus, it seems unlikely that the TOJ evidence of attentional prioritization we observed for self-owned objects is due to incorporation of visual images of objects into a body schema. Rather, we will suggest that it may be due in part to their availability for action by the first-person, agentic self.

The prominence of action as a key influence on attention and perception was first pioneered by Gibson (1979). He argued that affordances, which are motor possibilities offered by an object in the environment, directly impact and constrain the visual information gleaned from the environment. Since then, research stemming from the notion that action biases attention has revealed that affordances (specifically, evoked grip types) affect neuronal firing in V6A cells as early as 250 msec (Breveglieri, Galletti, Bosco, Gamberini, & Fattori, 2015) or in some cases even earlier (Humphreys et al., 2010). It has further revealed that the differential affordances of tools over nontool objects are electrophysiologically distinguishable. This effect is found even when differentiating tools from nontools is orthogonal to task demands (Proverbio, Adorni, & D'Aniello, 2011). Morevoer, it can be disentangled from the conceptually related Simon effect (Riggio et al., 2008), a phenomenon in which responses to stimuli are faster when the stimuli are in the same relative location as the response. Importantly, affordances have been used to explain action selection with one theory proposing that potential actions compete against each other for selection until sufficient information accumulates to bias one action over the others (Cisek, 2007). With respect to how affordances may interact with the self, attention to objects in peripersonal space is affected by affordances. For example, Costantini, Ambrosini, Tieri, Sinigaglia, and Committeri (2010) observed faster responses to mug handles when they were on the same side as the responding hand but only when the mugs were in actable/reachable peripersonal space and not merely visible peripersonal space. Considering that affordances are dependent on an action-capable agentic self and that they bias the attentional landscape, it is imperative to include to take them into account when modeling how the self affects attention to objects.

As mentioned previously, a longstanding explanation of the potency of ownership effects is that possessions contribute to and reflect one's identity (Belk, 1988). This characterization of the self-object link operationalizes self as object. However, these classic theories of ownership also identify control as a link between self and owned objects (Belk, 1988; Prelinger, 1959). This characterization views self-owned objects as extensions of self that can be controlled much as one's limbs can be controlled. Not only does this framing of the self–object link anticipate findings related to tool use reviewed above, it refers to the concept of self as subject—an embodied agent that engages in perception and action. When construed as control or as a permission to act, ownership is therefore a transformative process that generates affordances for objects. There is thus a tight relationship between being able to act on an item and owning an item. Moreover, work arising from developmental research indicates that children as young as 3 years give priority to ownership when judging who should use an object (Neary & Friedman, 2014). Specifically, when there is a dispute between someone who owns an object and someone who currently using said object, children side with the owner. This suggests that the connection between ownership and action is made at a very early age. We propose that it is just such permission to act that serves to as a foundation for attentional prioritization we have observed for self-owned objects.

Consistent with this claim, ownership has been found to influence how people act on objects, even for otherwise completely equivalent objects. A study by Constable, Kritikos, and Bayliss (2011; later replicated in Constable, Kritikos, Lipp, & Bayliss, 2014) found that when participants moved mugs that were theirs (given to them by the experimenters), they moved their own mugs closer to their body and did so with more force than with mugs that were not their own. An additional experiment demonstrated that a stimulus–response compatibility effect (i.e., faster responses during trials where the mug handles were facing in the same direction as the response location), observed when participants responded to their own mugs, was abolished when the mug belonged to the experimenter. The authors suggest that the permission to act endowed by ownership alters the availability of certain affordances—"as if the action system is blind to the potential for action toward another person's property" (Constable et al., 2011). Future research can directly test the hypothesis that permission to act is responsible for effects of ownership on early action selection and selective attention.

Our own recent research examined the relation between self-as-subject and cognitive prioritization related to ownership by testing the influence of action on ownership biases in recognition memory (Truong, Chapman, Chisholm, Enns, & Handy, 2015). To investigate whether object-directed actions contributed to cognitive biases for self-owned objects, we had participants move images of everyday objects on a touch-interactive table. We combined image projection and motion tracking technology such that participants were able to view and move images of (arbitrarily assigned) self-owned and other-owned objects on a table surface using a motion-tracking marker attached to their index fingers. For half of the trials, self-owned objects were moved to a location close to the participant's body, whereas other-owned objects were moved to a location farther away from the participant's body. This configuration was reversed for the remaining half of trials. In a subsequent recognition memory task, objects that were self-owned and moved to the nearby location were significantly more likely to be recognized than self-owned objects moved to the far location and other-owned objects moved to either location. In a second experiment, we sought to isolate the effect of peripersonal space by having participants use keyboard presses instead of actual arm/hand movements to move the objects to near and far locations. We found that, although there was still a main effect of ownership (self-owned objects were more likely to be recognized), the location to which the objects were moved did not affect recall. Last, a third experiment examined how the type of actions performed mattered by manipulating whether the objects were pulled or pushed into their respective locations. This experiment revealed that self-owned objects that were pulled were significantly more likely to be recognized than self-owned objects that were pushed or other-owned objects that were pushed or pulled. This interaction between action and ownership almost exactly mirrored that found in the first experiment, and we concluded that it was the process of moving a self-owned object toward the self—rather than simply moving it near the self—boosted object encoding (see Figure 3). More generally, we argued that physical, active self was critical to understanding how the body influences the effects of ownership on cognition. Although

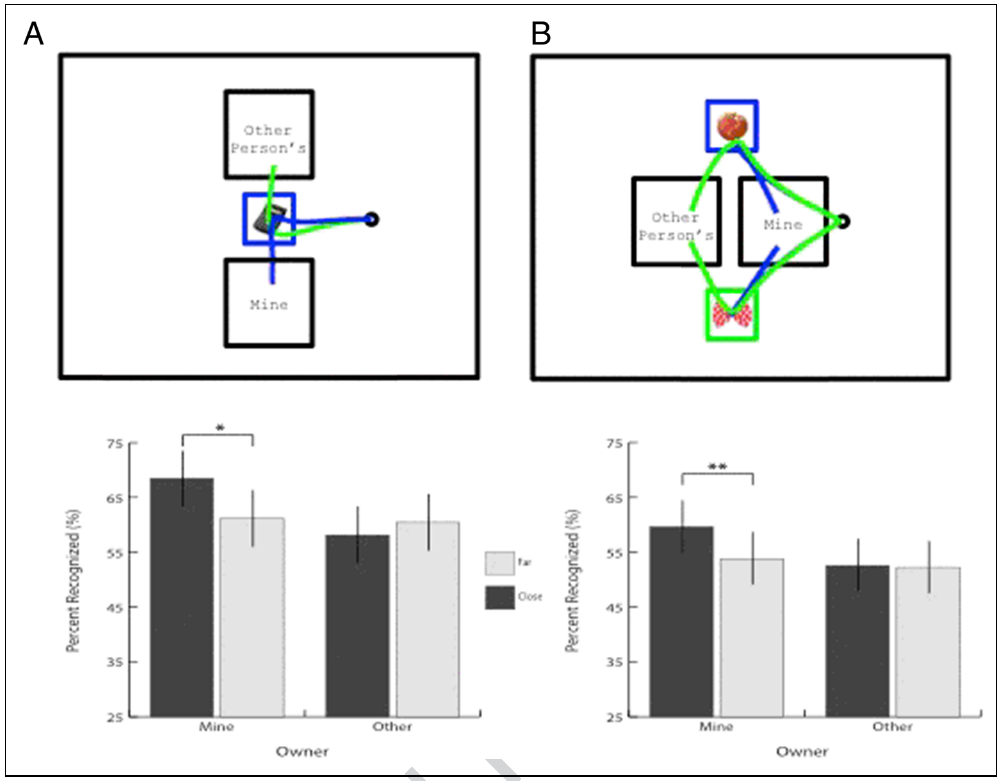

Figure 3. (A) Top: Layout and average trajectories for mine-close/other-far configuration of sorting task in the first experiment of Truong et al. (2015). In this experiment, participants actively "sorted" images to target locations closer to or farther away from their bodies based on the ownership status of each object. Object owner was denoted by a colored border around the object image. For half of trials, self-owned objects were moved to the close location and other-owned objects were moved to the far location. For the remainder of trials, the target locations were swapped (i.e., mine-far/other-close). Bottom: Mean percent recognition scores as function of ownership and target location for the first experiment. Participants were significantly more likely to recognize self-owned objects that were moved close relative to all other owner-location combinations. (B) Top: Layout and average trajectories for mine-left/other-right configuration of sorting task in third experiment in which participants actively "sorted" images by pushing or pulling the objects into target locations. Objects were sorted by reaching out to the object and either "pulling" the object into the target location (blue-bordered/upper object) or "pushing" the object into the target location (green-bordered/lower object). Action type (push vs. pull) was fully crossed with owner (self vs. other) within participants. Bottom: Mean percent recognition scores as function of ownership and action type for the third experiment. Participants were significantly more likely to recognize self-owned objects that were pulled toward the body relative to all other owner–action combinations. Figure adapted from Truong et al. (2015).

in this study we did not measure attention directly, we hypothesize that the enhanced recognition memory we observed was the result of enhancement of attention by a specific action associated with acquisition of an object. Notably, our study had participants overtly and intentionally do what participants in Constable et al.'s (2011) study did automatically—move a self-owned object toward their own bodies. Had Constable and colleagues somehow measured attention toward those self-owned objects, we would predict relatively higher attention for them compared to objects that were not moved closer to the body. Future research can test this hypothesis as well as examine underlying neurocognitive systems linking specific actions to prioritized attention. If this is true, it is consistent with the notion that a potent way to establish an attentional set is through availability for action by an agentic first-person self.

SELF AS OWNERSHIP IN ATTENTIONAL PRIORITIZATION

In the SOAP framework, we propose that ownership increases the salience of a given stimulus via both self as object and self as subject (Figure 4). As reviewed above, our own possessions can attain a measure of self-relevance arising from the object's association with personal experiences and/or representativeness of identity. By this route, ownership can exert an influence on one's perspective on self-as-object, which in turn can tune attention and generate prioritization effects. Such effects can operate either over the long term or be rapidly acquired. At the level of brain systems, these effects may be to a large extent mediated by the SAN system (Humphreys & Sui, 2015), with VMPFC activation tracking reward value gained by viewing (or visualizing) an object associated with the self.

Yet as our TOJ study reviewed above (Truong et al., in press) suggests, effects on the third-person construal of self likely does not account for all effects of attentional prioritization. We propose that some of the potency of rapidly acquired ownership may be because ownership fundamentally changes the salience of a given object—arguably increasing its value by altering the set of potential actions the object affords. The agentic self that perceives and acts on the environment wields a distinct impact on attention, adding increased salience to items that can be acted upon (e.g., Handy, Grafton, Shroff, Ketay, & Gazzaniga, 2003). In this way, ownership acts as to stratify the salience of objects that have otherwise equal action affordances. To this end, the self as subject can impact attention to the immediate environment ("What can I act on now?") and more broadly across contexts ("What can I act on in general?").

With respect to the concept of shifting hierarchical goals, ownership through permission to act may serve to constrain action selection to specific actions that meet short-term goals. If it is mine I can eat it or drink it for survival and/or pleasure, I can wear it for warmth and to attract love and attention, or I can use it as a tool for any number of short-term goals in the service of motivational goals of surviving and thriving. To the extent that the agentic self-as subject influences attention in service of these goals, greater modulation of the visual system by networks associated with self as subject, including premotor and somatosensory cortices and TPJ, should be observed—possibly operating via the mediating role of dopamine or norepinephrine systems (e.g., Sara, 2009). As with executive attentional processes, such modulation may improve the signal-to-noise ratio of neurons tuned to features of my possessions by inhibiting responses to those tuned to competing features (Manunta & Edeline, 2004). Signals from regions mediating self-as-subject could also increase gain in populations of neurons sensitive to features of my things without corresponding suppression of competing features, as in biases without competition observed for affective attention (Wieser, McTeague, & Keil, 2011). A third potential mechanism could be modification of neuronal gating such that previously silent neurons become responsive to the features of my possessions (Sara, 2009). One hypothesis that can be tested by future research is that the VMPFC is an important node in modulating the value of an object endowed with permission to act. Objects one is permitted to act on should elicit greater VMPFC activation linked to subjective valuation of the objects than unpermitted objects, and this should in turn tune visual attention via communication between VMPFC and visual cortex activity (increased coherence or synchrony in key frequency bands)—directly and/or via the LC system.

Third, we propose that over the long term the two aspects of self (subject and object) have a bidirectional relationship in which one aspect of self can influence how the other orients itself to objects in the world. For example, it may be that repeated interactions with an unowned object leads to increased feelings of ownership over the object and increased identification of said object with one's concept of self-as-object. Finally, we propose that the two aspects of self elicited by ownership are not equally represented or equally influential in all situations. Situations in which action-oriented cognitive processing is emphasized may lean more heavily on self as subject than self as object. Future research can test these proposals directly.

In summary, we suggest that our own things have potent claims on attention because of the actions they afford, our experience with them, and their higher reward value. Yet all things that are affectively or motivationally salient are only so in relation to the self, which is the primary locus of the resulting pleasure or pain. Thus, our senses of self as subject and object can be seen as constituting a superordinate category of salience that encompasses all of the others. Just as a threat or reward that is immediate is prioritized over one that is distant, things explicitly associated with the self may also have heightened salience through proximity to this ground zero.

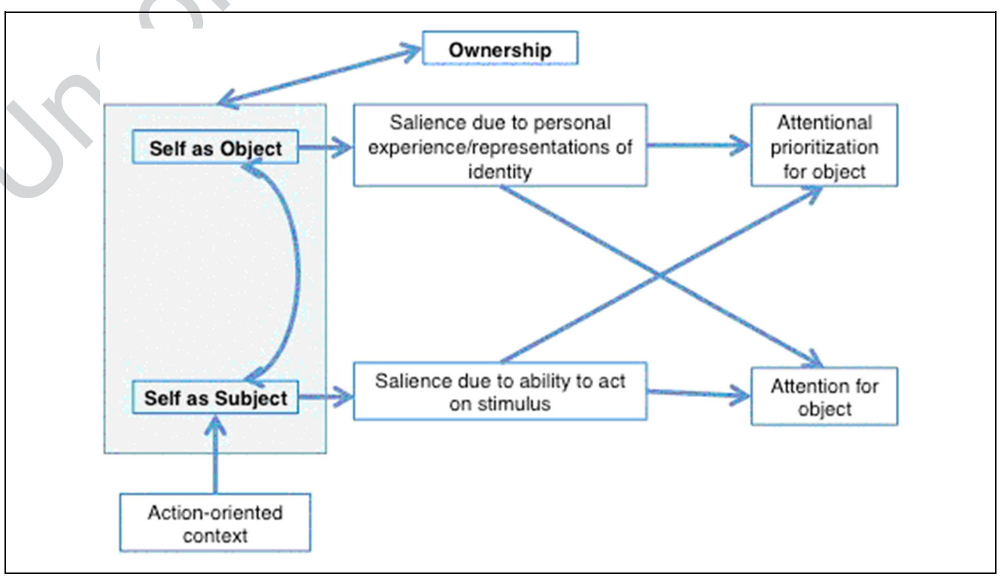

Figure 4. The SOAP framework. Increased salience due to ownership arises from two sources of prioritization, self as subject and self as object. Through self-as-object, ownership increases the salience of objects via links to personal experience and representations of identity. Through self-as-subject, ownership increases the salience of objects through a permission to act on given objects, a path that is weighted more heavily in action-oriented context. Both paths contribute to attention for self-owned objects in the short and long term. The SAN framework proposed by Humphreys and Sui (2015) describes several plausible neural paths through which self-related information (mainly through representations of self) can capture attention in a manner consistent with the self as object branch of the SOAP. We further propose that the VMPFC, through its role in valuation processes, may serve as a common hub linking networks modulating visual cortex activity for self as construed as both subject and object. We propose that such networks partly overlap with networks mediating affective and motivational modulation of attention and functions in a similar fashion. These multiple networks mediating implicit attentional sets in turn interact with the well-established dorsal and ventral systems to influence attentional states for prioritization of the most relevant stimuli depending on context.

PATHOLOGICAL ATTENTIONAL EFFECTS OF OWNERSHIP IN HOARDING

The mechanisms we have proposed in our theoretical framework of modulation of attentional prioritization by ownership can be explored through their potential malfunctioning in neurocognitive pathologies. One plausible test case is hoarding. Compulsive hoarding is a mental illness characterized by the excessive accumulation of possessions (Greenberg, Witztum, & Levy, 1990) and the clutter arising from hoarding can pose significant health and safety risks as well as psychological distress and stigma (Tolin, Frost, Steketee, & Fitch, 2008). Existing research on hoarding suggests that hoarders show intense emotional attachment to objects they own (Frost, Hartl, Christian, & Williams, 1995), but little is known about what elicits and maintains this attachment. We speculate that atypically high and sustained attention to the different aspects of self through ownership may be implicated. Research in the 1970s explored the nature of ownership through interviews with a large cross-cultural sample of children and adults (Furby, 1978). Content analysis of the interviews revealed that self-owned objects were high in sense of self, perceived control (i.e., control over use or permission to allow other to use), and instrumental value (i.e., the ability to perform tasks). These themes consistently parallel the functions of ownership that we have highlighted in this review. Thus, it may be that compulsive hoarding involves hyperresponsiveness to these object-related properties. Although there may be multiple etiologies contributing to hoarding behavior, abnormal patterns of ownership-mediated attention are consistent with two specific hoarding findings.

First, our framework proposes that ownership taps into the self as object and increases the salience of objects that reflect one's self-concept or identity. Previous research suggests that self-ambivalence is positively correlated with compulsive hoarding (Frost, Kyrios, McCarthy, & Matthews, 2007). As defined by Guidano and Liotti (1983), self-ambivalence manifests as vigilant searching for signs in the environment that can reveal one's self-worth. This particular characterization of hoarding as related to vigilance suggests a maladaptive attentional set for representations of self-identity. From this perspective, objects that would otherwise go unnoticed by persons not exhibiting compulsive hoarding would now possess abnormally high salience. In particular, our model would predict attentional prioritization to self-relevant objects in the environment to the extent they could inform the self-concept. The act of hoarding such objects could temporarily reduce levels of self-ambivalence and allow for attentional disengagement from the objects. Subsequent returns to the original maladaptive attentional patterns would result in the gradual accumulation of objects to potentially pathological levels.

Second, our framework proposes that the action-oriented contexts tap into the self as subject and increase the salience of objects that can be acted upon. One facet of compulsive hoarding is the finding that hoarders tend to accumulate items that are seen by others as having little to no value such old newspapers and damaged items (Frost & Gross, 1993). Despite the low utility of the hoarded items, persons with hoarding disorder sometimes cite potential uses for them items as reasons not to discard them (Frost & Steketee, 2010). If the salience of an object were abnormally high due to prioritization via systems mediating self as subject, it would be unsurprising to observe contorted conscious action-related rationalizations for keeping the object. For example, a bucket with a large rip or hole in its side is unlikely to retain most of its original uses and affordances: It can no longer be used to hold and transport substances and might not even be able to be picked up depending on the type of damage. To a person without hoarding symptoms, the bucket has lost much of its self-as-subject forms of salience and fails to draw attention. However, a person with compulsive hoarding might still observe many of the original affordances of the bucket (even though they are no longer valid) and thus attend to it much more and perhaps for much longer than a typical person. When later probed about the failure to discard the bucket, a hoarder may make an affordance-based argument by insisting that there are multiple potential ways of acting on or using it.

CONCLUSIONS

In the present article, we first reviewed current models of attentional prioritization proposing multiple sources of salience that tune attention to implicit and explicit contextually modulated goals, with a focus on the role of motivational and affective salience. We next reported recent evidence indicating that ownership, as an instantiation of self-relevance, also functions as a source of prioritization and sought to contextualize these findings within current frameworks of attention sources and their neural substrates. We suggested that understanding how ownership affects attention necessitates operationalizing the self as both object and subject. Whereas self-as-object has been widely studied and its effects on attention has been debated and modeled, self-as-subject, in which the self is active and agentic, has received less focus as a potential contributor to attentional biasing. In light of our own and others' research showing the active self as an influence on attention, we proposed the "self as ownership in attentional prioritization" (SOAP) framework as a way of understanding the development of attentional sets for self-owned objects when considering self as subject as well as self as object and discussed hoarding a test case. Ultimately, we argue that ownership activates the self as subject by providing contextual permission to act on items in the environment. As with affective and motivational salience, such action-oriented salience may tune us to proximal goals shaped by and embedded within implicit long-term goals of surviving and thriving. Future studies can use behavioral and neuroimaging methods to test the hypothesis that the permission to act contributes to the salience of objects we own, as well as the relatively greater role played by self construed as subject in action-oriented contexts. It can also test the various paths described in SOAP framework by using brain imaging to test models of putative bidirectional relationships between neural systems subserving self as subject and the self-as-object in modulating activity of visual cortex.

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