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Sense of Agency

Patrick Haggard[1]

[1]University College London

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Sense of agency refers to the subjective experience of controlling one's own actions and, through them, events in the outside world. The subjective *sense* of agency should be distinguished from the objective *facts* of agency (i.e., who did what) and from propositional *judgments* about those facts. This distinction is required because a sense of agency can be mistaken with false positive errors (one feels one has done something that one has not) and false negative errors (one does something but fails to feel responsible for the outcome). A simple "ideal observer" model might propose that agent P performs action Q (fact of agency) and thereby experiences a sense of control over an outcome O (sense of agency). This experience might then form the basis of *judgments* and reasoning about their responsibility for O (judgment of agency). Sense of agency can therefore be considered as a specific experience whose principal content is a relation between a particular action event and an outcome event. This experience can be studied using experimental methods such as psychophysics and neuroimaging and by investigating changes in this experience in persons with neurological or psychiatric conditions.

History

The sense of agency is intertwined with the concepts of voluntary control and conscious thought. The voluntary agent who translates their thoughts and desires into actions and thus transforms the environment around them has been a core element of many philosophical systems, from Plato to Descartes to Marx.

The term "sense of agency" is relatively recent, although the core idea of attributing outcomes to agents can be traced back to prehistory. The first discussion of a specific experience of agency appears to be by Maine de Biran (de Biran, 1932). Many 19th century philosophical discussions of "the will" in fact revolve substantially around sense of agency, without necessarily using the term. More recently, neuropsychological studies of patient deficits have been important in identifying a specific experience of sense of agency. Patients with *anarchic hand syndrome* (also sometimes termed *alien hand syndrome*) following medial frontal lesions make movements in response to objects in their immediate environment while experiencing these movements as involuntary and not self-generated (Della Sala et al., 1991). Patients with psychosis (Frith, 2015) also sometimes show abnormal sense of agency, either experiencing their own thoughts and actions as caused by some external influence or (more rarely) experiencing that they can control, through their thoughts and actions, events that they do not in fact influence.

Based on these findings, the modern understanding of sense of agency has progressed from metaphysical notions of individual will towards a computational concept of attributing sensory systems either to one's own action or to some other agent or cause. The core computation is thus a form of causal inference.

An early insight into this computational problem came from Hermann von Helmholtz's investigations of how the visual world remains stable, even though eye movements imply an ever-changing retinal input. Helmholtz argued that the oculomotor command to move the eyes can be used to predict a corresponding retinal motion. This is then subtracted from (or *canceled against*) the actual visual input prior to

awareness. Thus, retinal motion due to eye movements is not actually perceived as motion because it is predictable.

Core concepts

Motor command and prediction

Sense of agency implies an agent who makes an action. This in turn implies a *voluntary motor command*, that is, a signal sent from specific cortical areas of the agent's brain directly or indirectly to the motor neurons that drive skeletal muscle. These commands reflect the agent's choices or intentions: in this manner, sense of agency is fundamentally linked to individuals' conscious thoughts and choices.

Agents normally have *goals* that they aim to achieve through their actions. For example, someone might open a window in order to cool down. Their voluntary motor command also affords a *prediction*; I predict I will soon feel cooler because I have just made the action of opening the window.

Comparator models

The comparator model formalizes the role of prediction in sense of agency. If an afferent signal matches the prediction made from a voluntary motor command, then one experiences a sense of agency with respect to the corresponding external event. A specific neurophysiologic and computational process is associated with the matching process. An efference copy of the voluntary motor command is sent to an internal model of the motor system in question (e.g., the eye, limb, or machine as appropriate) in parallel to being sent to the motor system itself. The internal predictive model makes an estimate of the likely consequences of the motor command, for example, the arm will move following a particular trajectory. The resulting estimate is then compared with sensory reafferent information about the actual trajectory of the arm by subtracting the sensory information from the prediction. If the result of this subtraction is zero, then the actual movement of the arm is exactly as intended, and the agent will feel a sense of agency with respect to the movement—they will attribute it to themselves.

Measuring the sense of agency

When watching a newborn infant, it is difficult to believe that the random, jerky movements of their limbs represent goal-directed actions. Sense of agency seems to be learned rather slowly, along with the capacity to generate voluntary actions that efficiently achieve one's desired goals. In normal development, the sense of agency becomes so routine that the sense of agency is sometimes treated as an enabler or accompaniment to normal mental life rather than the result of any specific computation.

The ubiquitous, default aspect of agency makes the experimental measurement of sense of agency difficult. The simplest approach to measuring sense of agency would seem to involve asking people to make explicit agency judgments: "Did you do that?" This approach has high face validity, but the question may seem bizarre in a normal case in which there is no obvious alternative agent nor any ambiguity over the facts of agency. It is difficult to find a convincing control condition with which agency can be

compared. Explicit judgments of agency are rather rare, outside of law courts. Accordingly, various implicit measures of sense of agency have been proposed. Some rely on the fact that predictable consequences of self-generated actions are perceptually attenuated—so perceiving a reduced magnitude for a given event can be taken as evidence that one is an agent with respect to that event (Blakemore et al., 1998).

A second implicit measure is based on a distortion of time perception linked to voluntary motor commands [see Time Perception]. Participants made voluntary keypress actions while watching a rotating clock hand. The action caused a tone to occur 250 ms later. Thus, the tone was the outcome of the action, and one might expect people to experience a sense of agency over the tone (as well as over the keypress action). The clock continued briefly to rotate and stopped in a random location. Participants judged either the clock hand position at which they pressed the key or the clock time at which they heard the tone, in separate blocks of trials. These estimates were compared against control trials, in which participants pressed the key without causing any tone or merely heard the tone occurring without making any keypress. These events were time matched to the participant's own voluntary keypresses from a previous block. Participants perceived their keypress actions as shifted slightly later in time in agency blocks in which their voluntary action caused the tone to occur compared to control blocks in which their voluntary actions did not cause any tone. Further, they perceived the tone to occur slightly earlier in agency blocks in which it was caused by their own keypress action compared to control blocks in which it was not. The implication of these action-binding and outcome-binding effects was that the interval between action and tone was perceived as shorter than it really was. Thus, the fact that the participant caused the tone through their own voluntary action led them to perceive the action and outcome as bound together in time and temporally compressed. This could provide a useful implicit proxy of the sense of agency (Haggard et al., 2002; Zhao et al., 2025). Interestingly, this compression was absent when outcomes were paired with passive movements rather than voluntary actions. The difference in temporal compression between voluntary and passive conditions has therefore been termed the *intentional binding effect*.

Questions, controversies, and new developments

Limits of comparator models

The key role of prediction in sense of agency is broadly accepted. Comparator models provide a clear, mechanistic account of how sense of agency arises, for specific events, and based on specific signals which could potentially be identified in neurophysiological studies. However, two key difficulties remain.

First, it remains unclear how such models can produce a positive experience of agency with respect to external events given that the core computation of the comparator involves canceling or attenuating the inputs that signal those events. In agency situations, the events that occur are those predicted to occur given a voluntary action. The comparator compares what occurs with what is predicted to occur and outputs the difference between these signals—a quantity known as prediction error. In agency situations,

the prediction error is zero. How would the *absence* of any signal at the output of the comparator node produce a positive experience given the general assumption conscious experience is associated with the *presence* of a neural signal? Yet, we regularly experience the results of our own actions. Indeed, experiences of outcomes are often the reason for acting in the first place; if someone decides to cook a soufflé, they will experience, and perhaps even celebrate, the taste experiences that they thereby produce instead of canceling them.

Second, sense of agency seems to depend on processes of post hoc reconstruction as well as prediction. One may infer after the fact that one has done something, without necessarily knowing it in advance. A domain-general cognitive process of sense making and causal attribution may be applied to one's own actions as it is to other events. That is, one might conclude, "I did that," not because of any privileged internal signal within the voluntary motor system but by the same cognitive processes that one applies to other events. This kind of reconstructive process has been emphasized in modern theories of consciousness (Dennett & Kinsbourne, 1992) and in social psychology accounts of agency (Wegner, 2003). Some studies have compared contexts in which the occurrence of a tone given an action—p(T/A)—is more or less probable (Moore & Haggard, 2008). In contexts in which p(T/A) is high, action binding was found even on trials without any tone, implying prediction. In contexts in which p(T/A) was lower, action binding was found only on trials in which a tone occurred, clearly implying reconstruction of the perception of the action by the tone.

The role of action selection

Most experimental studies of sense of agency have told participants more or less explicitly what action to make and then investigated the experience of the outcome of the action. Yet, outside the laboratory, humans have a wide behavioral repertoire. The human sense of agency could be described as *pluripotent* because an agent may experience agency over so many actions and outcomes. The capacity to choose between alternative actions, including the possibility of not acting at all, seems central to the concepts of agency and responsibility. Some studies have used intentional binding to distinguish one component of sense of agency related to voluntary movement from a second component related to the choice between alternative actions (Borhani et al., 2017). The importance of choice has been confirmed by studies showing reduced intentional binding under conditions of social coercion (Caspar et al., 2016).

Degrees of agency

Sense of agency clearly is not binary and clearly comes by degrees. One may feel more or less in control of a machine, of a horse, of one's own life. In the *button press + tone* paradigms that have dominated experimental research on sense of agency, the participant's action is the sole and exclusive cause of the outcome. Only a few studies have investigated more complex agency scenarios. These studies typically find that sense of agency increases with the degree of correlation between action and outcome (Wen & Haggard, 2020).

Another important dimension of sense of agency relates to the complexity of goal-directed actions (Koechlin & Summerfield, 2007). Individuals regularly make a simple movement in order to achieve a complex goal; for example, one may click on a button on a travel website to organize an overseas trip. In such cases, proximal control over the manual movement is linked to control over the distal goal of making the trip. Such informational hierarchies are well accepted in models of intentional action (Pacherie, 2008) and intelligent problem-solving behaviors guided by executive function (Duncan et al., 2020). Few experimental studies of sense of agency have engaged with this hierarchical quality of action. However, the *experience* of agency may draw on multiple levels of representation, including motor, proximal, and distal elements of agency (Pacherie, 2008). These elements span from the sensorimotor experience of one's body actually moving, through conscious deliberative choice regarding which action to make, up to a metacognitive reflection on one's own action capacities. This final aspect of subjective sense of agency, *what I could potentially achieve*, forms a useful link to concepts such as self-efficacy in social psychology and empowerment as conceived by the social sciences more broadly. Future experimental studies could usefully focus on capturing the range of different agency experiences that span these multiple levels.

Other agents

The sense of agency is, fundamentally, a first-person experience of one's own action and its consequences. The two key physiological signals that underpin sense of agency—that is, the efference copy of the voluntary motor command and the somatosensory reafference associated with limb movements—are fundamentally private. Accordingly, the experience of one's own is quite different from the purely exteroceptive experience one has of actions made by other agents, particularly by other people. Nevertheless, there is enduring interest in whether agency representations may be "shared," with some common element between one's own actions and those of others. One philosophical view posits a level of action representation that is common or agent independent. In that case, a secondary *who-system* would then be needed to attribute the action to oneself or another person [see Mirror Neurons]. Efferent motor signals (Tsakiris et al., 2005) or proprioceptive signals would form the key element of the putative who-system. Implicit measures such as intentional binding allow the experiences of action–outcome linkage to be compared directly between actions one makes oneself and actions one observes others making. Interestingly, one meta-analysis showed that a binding effect is present for the observed actions of another person but is significantly smaller than the binding effect for one's own voluntary movements (Zapparoli et al., 2022).

Another approach to common action representations has focused on joint agency or *we-agency* (Sebanz et al., 2006). Humans, like many other social animals, often cooperate to achieve a common goal. Those who have played in a team sport may recognize the strong experience that this can generate. Cooperation can be symmetric (e.g., a corps de ballet moving in unison) or asymmetric (e.g., a pas de deux, in which two dancers may take markedly different roles). In this field, the key cognitive question has been how an individual can appear to experience a sense of agency for shared actions that are defined at the

superordinate level of the group rather than the individual level. Social psychology theories often suggest that the presence of other agents tends to *dilute* individual sense of agency through the *bystander effect*. On the other hand, experimental data suggests that agents who cooperate can experience an augmented sense of agency compared to a control condition involving solo action. This contrast recalls a distinction made by Jean-Paul Sartre (1985) between a *série* (a set of individuals whose actions happen to be similar but who do not share or interact) and a *groupe en fusion* (a class of agents working together for a common goal, for example, against a common enemy). The nature of we-agency remains controversial (Le Besnerais et al., 2024).

Broader connections

Sense of agency has clear links with decision-making; individual agents decide for themselves among options and express their decision through a voluntary action that delivers the chosen option. Sense of agency also has clear links with volition. As intentional binding studies confirm, people experience a sense of agency over the outcomes of their voluntary actions but not over the consequences of passive or involuntary movements.

Sense of agency also has an obvious connection to ethical and legal ideas of responsibility. Legal systems often assume that human actions are voluntary by default, that agents experience a sense of agency with respect to the predicted outcomes of those actions, and that individuals plead guilty or not guilty based on whether they experienced a sense of agency with respect to a given event or not. A legal finding of guilty/not guilty is effectively a third-person judgment of agency. This judgment may be based on first-person reports of sense of agency but can also contradict these (for example, a defendant pleading not guilty may nevertheless be found guilty by the court).

An interesting but largely unexplored connection exists between sense of agency and the basic architecture of language (Bornkessel et al., 2005) [see Language]. Languages with subject–verb–object syntax implicitly rely on a core notion of agents whose actions impact or change the external objects on which they act—a situation close to the experience of agency.

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