Action control and the sense of agency

Bernhard Hommel

Leiden University, Cognitive Psychology Unit & Leiden Institute for Brain and Cognition

Abstract and Keywords
This chapter discusses the relationship between the sense of agency and human action control. Experimental analyses of agency have been mainly motivated by four theoretical frameworks, which differ in emphasis and explanatory goals: associative learning, ideomotor action control, comparator models of action control, and the theory of apparent mental causation. The chapter discusses whether, how, and in which sense they are functionally equivalent with respect to their agency-relevant assumptions. The chapter concludes with considerations how the existing theoretical ideas can be integrated into one single model that can provide a solid basis for understanding the relationship between action control and the sense of agency.

Action control; associative learning; illusion of control; ideomotor action; action effect; outcome prediction; action selection; conscious will

Introduction: The sense of agency

People's behavior is often impossible to predict and to understand based on the stimulus condition and the environment in which the behavior occurs. We can carry out very different actions in response to the same stimuli, and respond to very different stimuli by means of the same action, if we only have reasons to do so (to refer to the personal level of description) or a goal that has motivated and is satisfied by that action (to refer to the functional level of description). Therefore, people are commonly assumed to be in control of their actions, so that their actions often reflect their intentions—which again allows some degree of "mind reading" in social encounters (e.g., Heider & Simmel, 1944).

Planning and executing goal-directed behavior requires knowledge about means-ends relationships (i.e., about which goals can be reached by means of which actions/movements). That is, the goal-directed agent needs to have knowledge about which goals can be reached by him-/herself and which can't. In the literature, this kind of knowledge has been assumed to emerge from a so-called "sense of agency". Unfortunately, the term is rather ill-defined and used differently by different authors (for recent overviews, see Gallagher, 2012; Haggard & Tsakiris, 2009). This has created considerable confusion with respect to at least three different, relatively orthogonal dimensions.

First, authors tend to confuse *objective* agency, the question whether a given individual was actually producing a particular action, with *subjective* (or "perceived") agency, that is, with the question whether the agent or non-agent is actually sensing, experiencing, or reporting to have some sort of authorship. For instance, Haggard and Tsakiris (2009) discuss three empirical observations that provide strong evidence that *objective* agency matters (e.g., objectively self-produced events are perceived to be closer to one's action; see Haggard, Clark & Kalogeras, 2002) and take that to speak to the issue of *subjective* agency (which actually is not assessed). In the following, I will mainly restrict myself to the discussion of how objective agency operates (i.e., how self-performed actions are cognitively controlled) and which aspects of these operations are likely to inform subjective/perceived agency—without attempting to provide a full-fledged account for the latter.

Second, in discussions of the "sense of agency" it often remains unclear what the concept of "sense" is actually referring to. On the one hand, the term may be used the same way it applies to vision, audition, and other sensory systems. These "senses" can be defined as "physiological capacities of organisms that provide data for perception" (Wikipedia). According to this definition, having a "sense" need not imply its proper use. For instance, one can easily imagine that one's visual sensory system provides complete information about particular states of affairs (e.g., that one is facing fresh powder snow rather than packed powder or crud) while the perceiver makes very little use of that information (and simply perceives "snow"). From this perspective, investigating the "sense of agency" should focus on the origin and availability of information about whether it was the agent or someone else who carried out a particular action—irrespective of whether that information is actually picked up and used appropriately by that agent (Synofzik, Vosgerau & Neven, 2008). On the other hand, however, everyday use of language often takes the term "sense" to imply some degree of "sensing", so that having a "sense of agency" would imply that an agent engages in some sort of perception related to his or her agenthood. Indeed, some authors relate the term to "the experience of controlling one's own actions" (Chambon & Haggard, 2013), which goes way beyond the mere availability of information but implies its active and appropriate use for creating particular mind states. In the following, I will restrict myself mainly to the first use of the term and focus on the origin and availability of agency information. One reason for that choice is that I will be discussing findings from infant research suggesting that the availability of information about agency precedes the use of this information for action control. This implies that requiring appropriate use of agency information, as in studies asking for agency judgments, tends to underestimate the actual availability of agency-relevant information. Another reason is that multiple sources for agency judgments are likely to exist (Synofzik et al., 2008) and it makes sense to assume that people differ both intra- and inter-individually with respect to which sources of information are considered and how the different sources are weighted in making an agency judgment (Synofzik et al., this volume).

Third, even though most authors seem to share some implicit agreement that it is individual agents that are the attributional targets of the experience or the judgment of agency, this is likely to reflect but a widely shared cultural bias. Indeed, most articles on agency restrict their analysis to an "I-perspective", on whether and how a single individual agent is able to perceive him- or herself as being in control of his or her self-performed action. However, even though this seems to be the obvious perspective for most readers with a Western background, members of Eastern cultures tend to have a more extended perspective that includes family, peers, and colleagues in the perception of agency (Marcus & Kitayama, 2003). This is likely to be a consequence of the wider definition of the "self" in Eastern as compared to Western cultures: while in Westerners the borders of the perceived self coincide more or less with one's skin, Easterners often have a more socially extended self-concept (Marcus & Kitayama, 1991). Accordingly, while the former commonly perceive some sort of individual agency, the latter will often experience what Marcus and Kitayama (2003, 2010) have called "conjoint agency". If one assumes that culture operates on cognition mainly by providing selective reward for a particular cognitive style (Hommel & Colzato, 2010), one would expect that other kinds of social systems that operate similarly can exert comparable effects. Indeed, there is evidence that Buddhists (i.e., members of a religion that emphasizes social concern and deemphasizes self-other distinction) spontaneously relate their own action to the action of a co-actor more strongly than culture-matched atheists do (Colzato et al., 2012). Interestingly, neither cultural background nor religion seem to create fixed, "hard-wired" agency models but rather implement default biases towards one or the other alternative model—which leaves room for short-term adaptation: For instance, participants are more likely to relate their own action to someone else's action after having circled relational pronouns in a text (such as "we," "our," or "us") then after having circled pronouns emphasizing social independence (such as "I", "my", or "me"; Colzato, de Bruijn & Hommel, 2012). These and other demonstrations of considerable inter- and intra-individual variability in distinguishing between oneself and other agents (e.g., Hommel, Colzato & van den Wildenberg, 2009; Kuhbandner, Pekrun & Maier, 2010); Kühnen & Oyserman, 2002) provide a substantial theoretical challenge for agency models—in which the identity of the agent is taken as a given. While I will not attempt to provide a comprehensive account for variability in self-other discrimination (see Hommel & Colzato, 2010), I will briefly get back to its implications below.

Approaches to agency

Theoretical treatments of the sense of agency commonly focus on the predictability of the perceivable outcomes of actions. Carrying out a goal-directed action implies knowledge about the expected outcome of the action, and this knowledge must play some role in judging whether it is oneself or another person who actually created this outcome. Experimental analyses of agency have been mainly motivated by four theoretical frameworks, which differ in emphasis and explanatory goals (i.e., most were actually not developed to account for agency) but which can nevertheless be considered functionally equivalent with respect to their agency-relevant assumptions. In the following, I will briefly discuss these four frameworks in turn and then explain where and in which sense they are functionally equivalent. Next, I will discuss how they can be integrated into one single model that might provide a solid basis for understanding the relationship between action control and the sense of agency.

Associative learning models

Associative learning approaches to action control have focused on three concepts: the stimulus, which is commonly assumed to trigger associated responses (after sufficient stimulus-response learning), the response, which might be triggered by a stimulus or by the expectation of reward, and the response outcome (e.g., Mackintosh, 1974). From this perspective, perceiving oneself to be the agent of a given action should be a function of acquired response-outcome associations: if performing a particular response has often produced a particular outcome, one would be likely to perform that action again in order to create that outcome (if wanted) and to perceive oneself to be the agent responsible for that outcome. This hypothesis has been confirmed in various studies, which for instance show that the causality agents perceive between their actions and related outcomes increases with degree of contiguity (i.e., temporal and spatial proximity) and contingency (i.e., constant co-variation) between action and outcome (for overviews, see Shanks & Dickinson, 1987; Wasserman, 1990; Young, 1995). Interestingly, these are the same factors that determine the degree of action-outcome learning in higher and lower animals as well (e.g., Meck, 1985; Rescorla, 1992; Urcuioli & DeMarse, 1996), which suggests that the mechanisms providing the information underlying the sensing of action-effect causality are cognitively rather undemanding.

Ideomotor theory of action control

Whereas associative learning approaches tend to downplay cognitive factors, ideomotor theories have the explicit goal to account for a role of intentions (i.e., internal states that drive the body towards reaching particular goals) in action control. Ideomotor theorizing has a long and varied history (for extended reviews, see Prinz, 1987; Stock & Stock, 2004) but it is fair to say that the most systematic theoretical treatments were developed by Lotze (1852), Harless (1861), and James (1890). And yet, it took many decades of oblivion before the theory was revived (Greenwald, 1970) and updated, modern versions were suggested (Hommel, Müsseler, Aschersleben & Prinz, 2001a, 2001b). It is interesting to consider why this theoretical approach has suffered from such a bad press. As I will explain, it assumes that mental states become conditioned to patterns of the motor system, and that the resulting association is sufficient to explain voluntary action. On the one hand, the consideration that mental states play a role in action control must have provoked considerable resistance in the behaviorist movement dominating the research on action from the 1910s on. It is thus not surprising that influential theorists like Thorndike (1913, p. 113) considered ideomotor theorizing a "descendant … of, the crassest forms of imitative magic". On the other hand, the suggestion that something as central to human self-understanding as voluntary action should emerge from mere associations must have provoked fierce resistance in cognitive scientists. Indeed, the assumption that simple associations may suffice to create voluntary action seemed so absurd to Miller, Galanter, and Pribram (1960) that they caricatured the intellectual contribution of ideomotor thinking as merely inventing the (sometimes used) hyphen between the words "ideo" and "motor". This difficult start notwithstanding, ideomotor theorizing has received ample empirical support and it has certainly benefited from the great interest in mirror neurons and other neural mechanisms linking perception and action. In fact, computational models that were developed to capture the way mirror systems operate in humans (as that by Keysers & Perrett, 2004) can be considered highly instructive reinventions of the ideomotor principle.

The basic problem the first ideomotor theorists aimed to tackle might be coined the riddle of "executive ignorance" (to borrow the term from Turvey, 1977). We can carry out all sorts of voluntary action whenever we want, and yet we know nothing at all about how we actually achieve this. Indeed, asking an agent to describe how she carried out a particular action commonly triggers one of two strategies: either she carries out the action on the spot and describes her perceptions while doing it (suggesting the use of re-afferent information) or she tries to recall an earlier occasion on which she carried out that action and tries to remember the re-afferent information available back then (a strategy that is very close to Lotze's particular consideration). In other words, agents do not seem to have any sort of privileged access to their motoric means to execute actions but rather refer to perceptual knowledge that any other attentive observer might have collected as well (apart from interoceptive simulation, that only the agent herself could perceive). How can it be that this executive ignorance nevertheless allows us to orchestrate all the motor processes necessary to carry out the action?

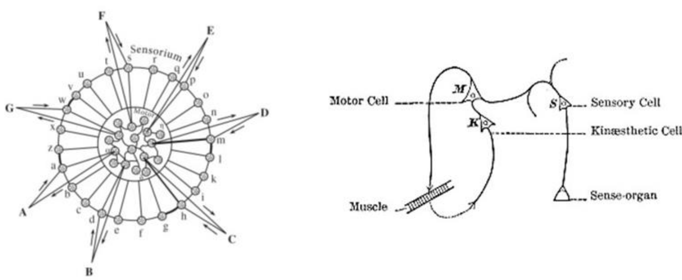

Figure 1. Harleß' (1861) and James' (1890) models of the ideomotor mechanism (left and right, respectively). Reproduced from Harleß (1861) and James (1890), respectively (in the public domain).

Figure 1 sketches the basic mechanism that according to ideomotor theories underlies voluntary action control. They take as a given that activating particular motor patterns ("Motor" codes in Harleß' model and the "M" neuron in James') leads to the execution of overt movements, which again creates re-afferent stimulation (activation of codes of the "Sensorium" in Harleß' model and the kinesthetic "K" neuron in James'). Frequent overlap of activation of motor neurons/codes and re-afferent neurons/codes induces an association between the two—an early example of what is now known as Hebbian learning. Importantly, this association can include any kind of motor and sensory code, and it is bidirectional, so that the sensory code becomes a "mental cue" (James, 1890) of the action. All the agent needs to do to activate an action pattern would thus consist in reactivating the representation of the sensory action outcome; this would prime the corresponding action pattern and (ceteris paribus) drive it to execution. In other words, voluntary actions are carried out by anticipating their sensory consequences.

As reviewed elsewhere (Hommel, 2009; Shin, Proctor & Capaldi, 2010), the ideomotor approach has received ample empirical support, but it was not developed to address perceived agency. In fact, James (1890) explicitly denies conscious access to outflowing (efferent) information, thus leaving no direct information from action production about action production. The only information that could be used to arrive at agency-related judgments arises from a comparison between expected and actual outcome—like in the basic cybernetic control loop (Wiener, 1948) or, as we will see below, in comparator models of action control. In terms of Harleß' model: if action "A" is selected by anticipating (i.e., activating the internal code of) the sensory action effect "a" but for some reason produces effect "b", anticipation and outcome would differ, which could be expected to create internal conflict. Such a conflict could provide important information for the perception of agency. Indeed, after being exposed to regularities between actions and sensory action effects, irregular (i.e., experience-incongruent) action effects induce surprise (Verschoor, Spapé, Biro & Hommel, in press) and a decreased sense of agency (Spengler, von Cramon & Brass, 2009), accompanied by electrophysiological indicators of internal conflict (a so-called feedback-related negativity, N_{FB}, which is commonly observed if agents are informed to have committed an error: Band, van Steenbergen, Ridderinkhof, Falkenstein & Hommel, 2009).

Comparator models of action control

Comparator models seek to use cybernetic control principles to provide a computationally transparent account of action control. Particularly influential in the discussion of agency is the model presented by Frith, Blakemore, and Wolpert (2000; Blakemore, Wolpert & Frith, 2002) shown in Figure 2. It translates the representation of a wanted outcome (a "desired state") into motor commands (which may be fine-tuned online through environmental information: "affordances"). The re-afferent information produced by the action is compared to outcome expectations, which can be improved in the case of a mismatch, and to the desired state. This latter comparison is essential for the perception of agency: the greater the mismatch the less agency is perceived.

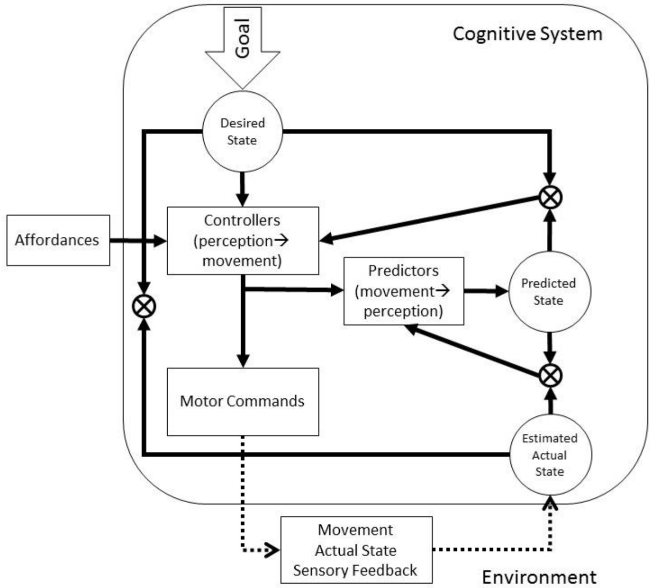

Figure 2. Frith, Blakemore and Wolpert's (2000) comparator model of voluntary action. Redrawn (modified) from Frith et al. (2000).

Like with ideomotor theory, the original motivation for the comparator framework was not to address agency but, rather, to provide a general processing model for action control. In contrast to ideomotor theory, however, the comparator framework targets processes rather than the cognitive structures these processes operate on, and it emphasizes the evaluation of the action rather than its selection—the main focus of idemotor theory. Considering these differences in design, ideomotor and comparator approaches can be considered complementary: the ideomotor approach provides a cognitive architecture that implies the processes that the comparator approach explicitly suggests, and the comparator approach suggests operations that imply a cognitive architecture similar to that suggested by the ideomotor approach. Considering this relationship, the two approaches can be considered to be more or less identical (cf., Chambon & Haggard, 2013): the desired state corresponds to the activation of the intended action effect (e.g., of K in James' model); the translation into motor commands to the spreading of activation from action-effect representations to the associated motor patterns (from K to M in James' model); the estimated actual state to the registration of the actual sensory action effects (the muscle-produced activation of K in James' model); and the comparison between the estimated actual state to the desired state the matching of, or competition between the representations of the anticipated action effect and the actually registered action effect (an aspect that the original version of ideomotor theory did not devote much attention to). Accordingly, the comparator approach can be considered a translation of the ideomotor control model into processing terms—a translation that also highlights the role of action evaluation.

Apparent mental causation model

The main question that is driving the apparent mental causation model suggested by Wegner (2003) relates to the connection between the experience of conscious will and action. While, according to Wegner, human agents have the experience that their thought of a particular action is causally responsible for its execution (a process that ideomotor theories try to explain), this connection should be considered an illusion. Wegner claims that voluntary actions are actually driven by not further specified unconscious processes (the "actual causal path" in his model), which also trigger conscious thoughts of the action in a direct or indirect fashion. Given that performing an action takes time, the conscious thought will often precede the action in time, which creates the illusion that it was the thought that created the action.

The apparent mental causation model suggests that the degree of agency that agents perceive depends on the match between pre-actional thought and the actually produced action effects. Indeed, Wegner and Wheatley (1999) observed that people experienced more agency for the appearance of an object on a screen if they were presented with a word describing that object about half a second before the appearance. Hence, correctly "anticipating" action effects (i.e., thinking of them before they appear) makes one believe that one has produced these effects oneself.

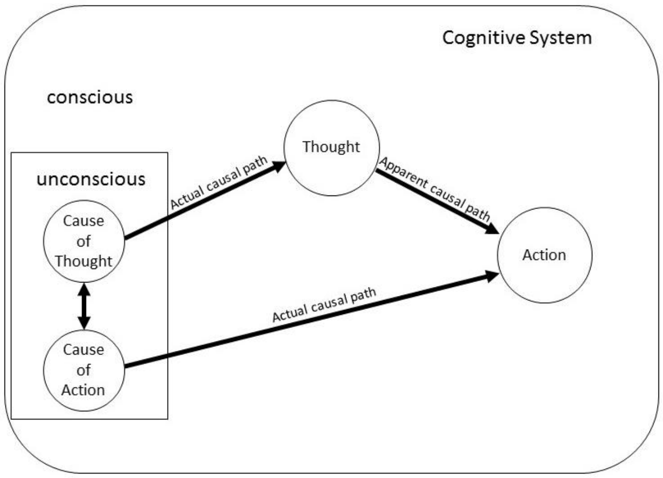

Figure 3. Wegner's (2003) model of apparent mental causation. Redrawn (modified) from Wegner (2003).

Theoretical integration

The four approaches to agency I have discussed so far overlap to a substantial degree, especially with respect to the crucial assumption that perceived agency is, or at least can be informed by relating representations of expected action effects to representations of actual action effects. Even the many assumptions that go beyond the issue of agency seem to be compatible, suggesting that these four approaches merely highlight different aspects and implications of the underlying cognitive machinery. And yet, there are a few assumptions and implications of these approaches that are somewhat more difficult to reconcile, and it is these details, so I will argue, that are informative and helpful for building a more comprehensive model of action control in general and the sense of agency in particular. I will discuss the most important of these discrepancies in turn.

How specific are action-effect representations?

While associative-learning approaches are notoriously silent with respect to internal representations and the apparent mental causation model is not overly specific with respect to the original cause of both thoughts and actions, ideomotor theory and the comparator approach both assume that voluntary action begins with a representation of the wanted effect. According to ideomotor theory, an agent creates some sort of active representation of the intended outcome, such as a visual image or a verbal description of the wanted effect. Effect representations become associated with the motor patterns that have created the corresponding effects in the past, which renders these effect representations retrieval cues of the motor part of the action. If we assume that wanted effects are represented in the same format as the effects of actions in the agent's repertoire (Hommel et al., 2001a; Prinz, 1990), the identification of intention-compatible actions boils down to a feature-matching process. As a result of this process, action representations are primed (pre-selected or pre-activated) to the degree that their expected outcome corresponds to the wanted outcome (i.e., to the degree that their features overlap). Hence, provided sufficient practice and experience of the agent, the ideomotor principle provides a computationally transparent and undemanding, but highly effective means to prepare a relevance-ranked repertoire of suitable actions for every given intention.

Ideomotor approaches are not particularly specific with respect to the amount of detail that action-effect representations are likely to have. As they assume that action-effect knowledge is created through association, driven by repeated experience, the amount of detail is unlikely to be high. No two actions or action-effect experiences are identical, as they depend on, and are modulated by the context, the current body posture, etc., suggesting that the information integrated into action-effect representations is confined to the most relevant, invariant features of an action. Interestingly, this is also implied by the comparator model of Blakemore et al. (2002). Note that the action outcome is determined by two factors: the desired state (corresponding to the wanted action effect) and so-called affordances, that is, context-specific environmental information necessary to fine-tune an action. Indeed, there is ample evidence that cognitive action planning considers intention-relevant features only, such as the bottle to be grasped in order to drink, but not the situational specifics, such as the precise landing position or the kinematics of the approaching movement—these specifics are likely to be added online through fast-acting but consciously inaccessible sensorimotor loops (Hommel, 2010; Milner & Goodale, 1995). However, the comparator model assumes that this dually determined action outcome is compared against the wanted outcome, which again is not informed by affordances. Accordingly, the comparison would always result in some degree of mismatch, which should tend to reduce perceived agency. To make the model realistic, one would thus need to assume that the comparison is not precise enough to consider the modification of the action through affordances. In other words, the comparison must relate relatively abstract representations of wanted and actual effect, just as implied by the ideomotor approach. Indeed, pointing movements have been shown to immediately adjust to small and unnoticed changes of the goal location (Prablanc & Pélisson, 1990), suggesting that goal states do not contain high-resolution spatial information.

If the main contribution of action control to the sense of agency refers to relatively abstract information, this must create quite some degree of uncertainty with respect to agency—at least in the absence of other, control-unrelated information (Synofzik et al., 2008). This explains why agents can be fooled so easily when it comes to agency judgments, so that they compensate for movement errors of limbs that are actually not their own (Nielsen, 1963) and claim authorship for anticipated but objectively random events on a screen (Wegner & Wheatley, 1999).

Is outcome prediction derived from action selection?

Comparator models assume that the representation of wanted action effects is translated into two states, resulting in the activation of the motor program that is needed to produce the wanted effect and in the representation of the expected outcome. In particular, the latter is assumed to derive from the former: agents are claimed to first specify the appropriate motor program and translate that back, as it were, into a sensory expectation. As ideomotor theory is more interested in the role of action effects in selecting an action than in the monitoring of its outcomes, it does not say much about how action effects are used to evaluate action outcomes. One possible scenario could be just like the one suggested by the comparator approach: matching the image of the wanted effect against previously acquired action-effect codes would lead to the selection of an appropriate action-effect/motor pattern compound, and the action-effect part of this compound could be used as a reference to evaluate actually produced effects. Even the apparent mental causation model could be interpreted along these lines: the actual cause of the action (the motor program or action pattern) could inform the actual cause of the thought (the action-effect expectation), which could then become conscious.

Unfortunately, however, there are reasons to assume that the actual mechanism is more complex. For instance, Elsner and Hommel (2004) presented participants with keypressing-contingent auditory action effects. After an extended practice phase, participants were presented with a new task that required keypressing responses to auditory stimuli that were the same as the previous action effects. As reported before (Elsner & Hommel, 2001), participants were faster if the new tone-key mapping heeded the previous key-tone mapping; that is, people were faster pressing a key to a tone that they had previously produced by pressing that key. The size of this mapping effect was modulated by temporal contiguity (largest effect with zero delay between keypress and tone in the practice phase) and contingency (largest effect with high correlations between keypress and tone and/or high probability of tone in the practice phase). In the contingency experiment, Elsner and Hommel also assessed the participants' perceived agency, the degree to which they felt that they produced the tones by means of their keypressing. The outcome mirrored the mapping-effect profile, with strongest perceived agency is the keypress-tone contingency and/or told probability was high. However, correlation analyses did not reveal any relationship between these measures, suggesting that they reflected different processes.

A similar conclusion is suggested by a recent infant study of Verschoor et al. (in press). The study investigated oculomotor action-effect learning by presenting 7- and 12-months olds (in addition to adults) with tones that were contingent on the direction of horizontal saccades. In a test phase, participants were again to make saccades to left or right while task-irrelevant tones (the previous action effects) were presented. Replicating the findings from manual studies, reaction times were slower if the eye was moved into a direction that did not match the direction of the saccades that had produced the current tone in the practice phase. This suggests that participants had acquired bidirectional associations between saccades directions and the particular tones, as predicted by ideomotor theory. Being presented with a tone would then tend to reactivate the previously associated saccade, which would compete with the tendency to perform a saccade into the opposite direction. Only 12-months-olds and adults showed this effect but 7-months olds did not, again replicating findings from manual tasks (Verschoor, Weidema, Biro & Hommel, 2010).

Importantly, Verschoor et al. (in press) also measured task-evoked pupillary responses as an index of surprise—prediction failure that is. All three age groups showed evidence of surprise when moving their eyes to a tone-incompatible location. That is, even though the 7-months olds had not yet acquired reliable associations between actions and action-effect representations, they did make accurate predictions of action outcomes. This dissociation between action-effect representation for action selection on the one hand and action-effect anticipation on the other suggests that these two processes are independent and develop at different rates. And if we take the ability to correctly predict action outcomes to be at the basis of, or at least provide strong input to the conscious perception of agency, it suggests that perceived agency is rather independent of the causal connection between actions and the sensory outcomes they produce. In other words, the degree of perceived agency seems to depend more on the accuracy of our prediction than on our actual authorship for a given action. If so, this provides strong support for Wegner's (2003) claim that agency judgments are rather unrelated to actual action production and do not provide privileged access to action-control operations.

What is the functional role of conscious will?

Common sense has it that voluntary actions are initiated and accompanied by a conscious representation of its goal (Hommel, 2007). Scientific investigations did not provide much evidence for this apparently too optimistic scenario, however, which led Wegner (2003) to conceptualize conscious will as a functionally irrelevant by-product of intentional action control. Ideomotor theory originally presumed the conscious representation of the wanted outcome to be the trigger of voluntary action; after all, it was developed to understand how this representation can get muscles moving. However, more modern versions have dropped this implicit assumption and did not leave any particular functional role for conscious experience (Hommel et al., 2001). Similarly, Frith et al. (2000; Blakemore et al., 2002) consider which action-related information might be consciously accessible but their comparator model does not require any particular contribution of conscious representations.

Irrespective of this widespread disenchantment with consciousness, it is interesting to consider which aspects of voluntary action control might be available to consciousness. The most obvious candidate would be the representation of the wanted action effect, an assumption that James (1890) would share. Indeed, the consciousness theory of Baars (1988) suggests that action goals would be a prime candidate for conscious representation. The standard counterargument against this possibility is based on findings in the tradition of Libet, Wright, and Gleason (1982), who reported physiological indicators of action preparation to produce measurable effects some hundreds of milliseconds before the agent even feels the urge to act. It is this finding that motivated Wegner (2003) to distinguish between the true cause of voluntary actions (which would produce the physiological markers observed by Libet et al.) and its conscious representation. And yet, this argument is by no means watertight. Tasks in the tradition of Libet and colleagues require participants to perform tens or hundreds of equivalent actions in a row. Actions of that sort have been suspected to be automatized ahead of time by authors as early as Exner (1879), and more recent studies have indeed revealed that task instructions are automatically translated into mental sets that, in turn, enable more or less automatic performance (Bargh, 1989; Hommel, 2000). If conscious action representations would play a role in Libet-type experiments, they would be expected to occur while participants prepare for the task but not while carrying it out. There is thus little reason to search for functionally relevant conscious representations a few hundred milliseconds before the actual action is carried out, and it is difficult to understand why Libet's findings have played such a dominant role in discussions of the role of conscious action representations and free will (e.g., Klemm, 2010).

Given the lack of evidence that humans can consciously access internal processes (rather than the states they produce) directly, it is not very likely that the translation of action-effect representations into motor activation is a reasonable candidate for conscious representation, and the absence of suitable receptors for activity within the motor cortex makes that activity an unlikely candidate as well. This leaves the perception of self-produced action effects. There is some evidence that the representations of expected action-effects are attenuated in the process of planning and executing the action (Blakemore, Wolpert & Frith, 1998). This suggests that the expected action effects are more difficult to consciously perceive than non-expected stimuli, and there is indeed evidence supporting this prediction, such as the you-can't-tickle-yourself effect (Blakemore et al., 1998). Similar effects have been obtained for other modalities as well (Weiss, Herwig & Schütz-Bosbach, 2011), even though more research on this issue is needed.

Taken together, the available, very preliminary observations suggest that, if conscious experience is related to action control in some systematic fashion at all, it most likely refers to the anticipatory (i.e., pre-actional) representation of the wanted action effect. Even if that would be correct, it would not necessarily mean that conscious experience plays a causal role in the sense that preventing conscious experience would make voluntary actions impossible. And yet, it may well be that under normal circumstances the wanted action effect is always available for conscious consideration, a kind of standard companion. As pointed out by Hommel (2013), consciousness is commonly operationalized as communicability of the represented information. While communicability does not seem to have much use for the online control of action, it does allow informing other people about one's intended actions, instructing others to carry out particular actions, or discussing the pros and cons of alternative actions. Hence, communicability allows one to explain one's action to others and to relate it to theirs, thus providing the opportunity for self-reflection and social impression management. As important as these functions are, they do not seem to reflect immediate causation in action control. Thus, there seem to be good reasons to consider the possibility that consciousness is more important for the "social communication" of one's action rather than for their actual performance (Masicampo & Baumeister, 2013).

Conclusion

As I have argued, action control provides information about agency, not by providing copies of any outcome of the action-selection process (as comparator model claim) but mainly by specifying the expected perceptual consequences of a given action—a process that has been neglected by ideomotor theories but focused on by comparator approaches and predictive-coding accounts (Friston, 2012). This comparison between anticipated and actual action outcomes are likely to provide input for judgments of agency, as indicated in Figure 4. Wanted action effects are likely to be familiar because they were something similar have been previously experienced (otherwise they could not be expected). This would imply that the feeling of familiarity provides a cue for agency or that the feeling of unfamiliarity provides a cue for non-agency. Indeed, the observation that the perception of an expected action effect is attenuated (Blakemore et al., 1998) suggests that the expected effects are effectively "nullified" by subtracting the expected from actual effects. If so, unexpected effects would attract quite some attention and "surprise" the agent—a cue for non-agency.

These considerations do not exclude that there are other cues as well, as the Figure indicates. For instance, Chambon and Haggard (2013) have argued that the fluency of action selection might provide information about agency, which fits with Wenke, Fleming, and Haggard's (2010) observation that facilitating action selection through subliminal response-compatible cues produced a heightened sense of control over the action effects that their responses generated. Under other circumstances, perceived agency might be suspected to increase with the effort the agent is exerting: agents are likely to perceive more agency when climbing the Mount Everest instead of passing a bump on the street, and when making a difficult rather than a simple and obvious decision. That is, it will often be the *lack* of fluency that informs us about agency. Indeed, participants perceive the temporal distance between their action and an auditory action-contingent effect to be shorter if they judge this relationship while performing an effort-demanding task (Demanet, Muhle-Karbe, Lynn, Blotenberg & Brass, 2013). And there are likely to be more sources for agency judgments, such as contextual plausibility, past experience, and the agent-specific typicality of the action. Hence, action control provides some input to agency judgments but certainly not all and sometimes perhaps not even the most important one (Synofzik et al., 2008).

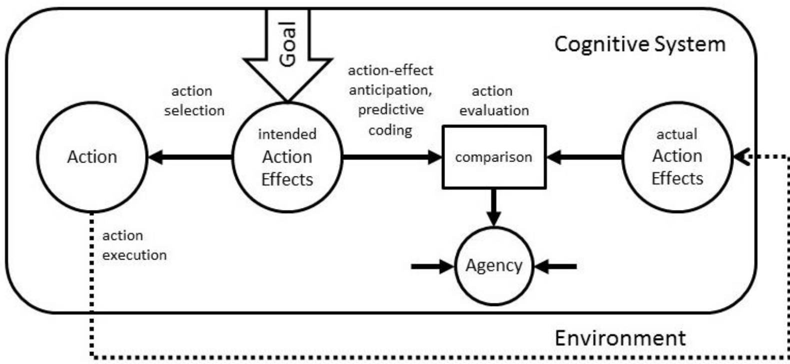

Figure 4. An integrative model combining ideomotor action selection, predictive coding of anticipated action outcomes, and action evaluation driven by comparing predicted and actual action outcomes. Note that agency is informed by only one of the two main control operations (action evaluation but not action selection) and that it does not feed back directly to action control. Also note that the outcome of action evaluation provides just part of the information agency perception relies on.

It is also interesting to consider that none of the action-control models I have discussed leaves any functional role for the perception or representation of agency—which is why in the Figure agency judgments do not feed back directly to action control. And indeed, if everything goes as expected and if the agent gets what he or she wants, it does not seem to be particularly important whether it is him or her who was actually responsible or someone else instead. Moreover, there are interesting cultural differences with respect to what counts as agent and as oneself. While Western authors commonly refer to individual agents, often even without justifying this theoretical choice, Easterners seem to carve the world in different ways. Indeed, what counts as an agent and as a causal factor is open to interpretation. If, for instance, a speed runner beats the world record, one can argue whether it is her who was the responsible agent or an entire team including support staff, family members, and friends—the people Eastern sportsmen indeed tend to refer to when attributing responsibility for individual performance (Marcus & Kitayama, 2003). Considering this kind of conjoint agency (Marcus & Kitayama, 2003) has considerable impact on our theoretical conception of perceived agency and the kind of information it is likely to reflect. And yet, this is unlikely to affect the internal organization of action control, as in the end it is the individual runner's brain and muscles that must realize the record-beating run. Accordingly, it makes a lot of sense that action control proper is independent of perceived agency and the cultural context it is woven into.

Author Notes

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