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Taking Control of Cognition: An Instance Perspective on Acts of Control

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Cognitive control is often viewed as an ability or as an interaction between higher and lower level systems. This article takes an instance perspective, articulating the view that cognitive control is accomplished by a multiplicity of specific acts of control tailored to accomplish specific adjustments to the cognitive system in specific circumstances. Acts of control take states of the cognitive system and states of the world as inputs, perform computations, and produce changes in the state of the cognitive system as output. Acts of control take measurable time. They are voluntary and specific, and they can be learned. The article addresses acts of control for inhibiting responses, shifting attention, and switching tasks, describing how to measure their durations and assess whether they are voluntary and specific. It concludes by reconciling ability, interactive systems, and instance perspectives and considering implications for research and practice.

Keywords: control, executive function, automaticity, inhibition, attention

Control is a challenge from the day we are born until the day we die. We have to make our bodies, minds, and the world around us do what we want. Controlling other people and controlling ourselves around them is a major challenge. Mostly, we cope with these challenges well. We acquire control as children and maintain it for most of our lives. We learn the ways of the world and exploit them to our advantage. Some people are challenged more than others. Deficient control is common in psychiatric and neurological disorders, but control is a challenge for everyone. This article focuses on cognitive control, which mostly involves controlling our minds and interfacing with devices and the environment, describing how we take control of cognition.

Cognitive control has challenged psychology since its birth in the 19th century and continues to challenge it 150 years later. Cognitive control addresses core issues in basic and applied psychology, from free will and the nature of intention to practical strategies for improving our own control and treating deficient control in our clients. One approach to understanding control is to treat it as an *ability,* focusing on differences between individuals (Miyake et al., 2000). This approach has been very successful, making sense of the strong trends in life span development and construing disorders of control as extreme individual differences. Another approach is to treat control as a *system* that interacts with subordinates, focusing on differences between conditions within individuals. Control is viewed as hierarchical, with higher level processes controlling lower level ones (Logan & Crump, 2011; G. A. Miller, Galanter, & Pribram, 1960) or with the frontal lobes controlling the back of the brain (Badre, 2008; E. K. Miller & Cohen, 2001). This article promulgates an *instance* view, treating control as the result of deliberate *acts of control* that are designed to control something specific in some specific task (Logan, 1985, 1988; Verbruggen, McLaren, & Chambers, 2014). The instance view suggests that control is heuristic and opportunistic, providing many specific solutions instead of a general one, as if we control our minds with patches and hacks that get us through the task at hand. The control strategies we learn to master the guitar do not help us master our smartphones.

What Is Control?

Dennett (1984) offered a general definition of *control* as a relation between two systems, A and B: "A *controls* B if and only if the relation between A and B is such that A can *drive* B into whichever of B's normal range of states A *wants* B to be in" (Dennett, 1984, p. 52; emphasis in original). This definition addresses how we control the environment: A is a person and B is the physical world, a device, another person, or a group of people. The definition also addresses how we control our minds: A is the control

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Correspondence concerning this article should be addressed to Gordon D. Logan, Department of Psychology, Vanderbilt University, Nashville, TN 37240. E-mail: gordon.logan@vanderbilt.edu process, and B is the process it controls. A may exert control by changing B's parameters or setting its goals. The definition encompasses the three approaches to cognitive control, which emphasize different aspects of the control relation. The ability approach addresses differences in the effectiveness with which A controls B. The systems approach asks which process is in control and whether the control is structured hierarchically. The instance approach focuses on the acts of control that A engages to drive B into the states A wants. The three approaches are complementary, but the instance approach is fundamental. It addresses the mechanisms underlying single acts of control, providing the building blocks from which abilities and systems can be constructed (Verbruggen et al., 2014). The instance view provides learning mechanisms that can account for the acquisition and automatization of acts of control (Logan, 1988).

Acts of Control

Cognitive psychologists characterize mental processes by their inputs and outputs and by the changes caused by their outputs. Canonical reaction time (RT) tasks take inputs from the environment and require external responses, like key presses. A participant is shown a picture and asked to report whether it represents a dog or a cat. Acts of control can also be characterized by their inputs and outputs and the changes they effect. Their inputs are states of the external or internal environment, and their outputs are changes in the internal environment (see Figure 1). A stop signal triggers inhibition of internal motor commands (Boucher, Palmeri, Logan, & Schall, 2007). A peripheral cue triggers a covert shift of attention (Logan, 1995). A brief instruction triggers a shift in task set (Schneider & Logan, 2005). Acts of control and canonical RT tasks can both be described as processing stages, as stimulus–response associations or connections or as IF–THEN production rules. The structure is the same, but the content is different. Inputs and outputs are external in RT tasks. Inputs may be external, but outputs are always internal in acts of control.

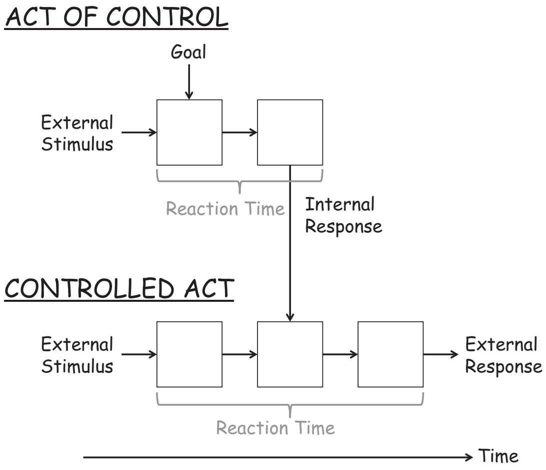

Figure 1. An *act of control* and the *controlled act* it controls. The boxes represent elementary processes like detection, selection, and execution, and the arrows represent the flow of information. Acts of control are built of the same constituents as are controlled acts but respond internally rather than externally. Acts of control take time; measuring reaction time usually requires a model. Acts of control are voluntary because they require a goal as input. Acts of control may be specific or general.

Theories of RT tasks are grounded in the physiology and psychophysics of the stimulus and in the physiology and kinematics of the response. Acts of control are grounded more abstractly in the states of the processes they control (Logan, 1985; Logan & Gordon, 2001). Their inputs are often states of the controlled processes, and their outputs are always changes in those states. A theory of an act of control must be grounded in a theory of the controlled processes. It is only as solid as the ground that supports it. Solid grounding is possible in mathematical or computational theories, in which some parameters are determined by the stimulus and the participant's history with it whereas others are determined by the participant's goals, values, and motives. The latter parameters are targets for acts of control (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Gilbert & Shallice, 2002; Logan & Gordon, 2001).

Acts of Control Take Time

The most fundamental property of acts of control is that they take time. Acts of control are mental processes, and all mental processes have durations that are measurable in principle. From Donders (1868/1969) to Sternberg (1969) to modern times, much of cognitive psychology is built on the idea that durations of mental processes can be measured and manipulated experimentally. Theories of control can be built by applying theories and methods of mental chronometry that have developed over the last 150 years—including the more recent extensions to electrophysiology and brain imaging—to studies of acts of control (Algom, Eidels, Hawkins, Jefferson, & Townsend, 2015; Anderson, Zhang, Borst, & Walsh, 2016; Ratcliff, Smith, Brown, & McKoon, 2016). The application is difficult because acts of control generally do not produce overt behavior (see Figure 1). The time at which they finish (their RT) must be estimated with a model.

Acts of Control Are Voluntary

Acts of control are the instruments of volition, triggered by goals and intentions as much as the environment. They are the means by which control processes get what they want. The input must include a goal as well as other triggering conditions, so the act is carried out only when it is intended (see Figure 1). This makes acts of control voluntary: Setting a goal enables an act, and deleting the goal disables it. It may be possible to trigger acts of control entirely voluntarily, with no input but intention. More often, intentions may enable acts of control, which are then triggered by external stimuli. Those are certainly easier to study.

Acts of Control Are Specific

In principle, acts of control could be very general, solving similar computational problems in a broad range of contexts. Alternatively, acts of control could be very specific, tailored to the nuances of particular contexts. General acts would conserve memory—fewer would have to be remembered—but would require online processing to adapt to specific circumstances, binding input and output variables to the values for the task at hand. Specific acts use more memory, because each specific act must be stored separately, but specific acts save on processing, because they are already adapted to specific circumstances and need only to be retrieved. Memory is cheap, and processing is expensive, so many specific acts of control may be more desirable than is a single general one (cf. Logan, 1988).

What Is at Stake?

The instance perspective is one of three approaches to understanding control. What is at stake in taking this approach instead of the others? Measuring the duration of an act of control and determining whether it is voluntary invite a mechanistic analysis of elementary processes. Individual difference and systems approaches can only benefit from this more detailed knowledge. Whether acts of control are specific or general is more controversial. The instance perspective predicts specificity, and an instance account of a particular act of control would be falsified if specificity effects could not be found. The instance perspective predicts learning effects, and an instance account of a particular act of control would be falsified if the learning effects could not be found. These failures would encourage the development of more general theories.

The remainder of this article focuses on three exemplary acts of control—inhibiting an ongoing response, shifting attention, and switching tasks—that are engaged the following scenario: You are reading this article on your computer. The phone rings, and you glance at the clock to see whether it's time for your daughter to call. You notice it isn't, so you expect a stranger. You inhibit reading, shift attention to the clock, and switch task sets to prepare for the stranger. There are many other acts of control in a person's repertoire, but these are prominent in current research. Evidence on their duration, voluntariness, and specificity is reviewed and evaluated.

Response Inhibition: Taking Control of Action

Stopping as an Act of Control

The ability to inhibit action is a basic component of cognitive control. We need to disengage the current course of action when the environment changes, our current goal becomes irrelevant, or we make errors. You stop reading when the phone rings. This ability is often studied in the *stop signal paradigm* (Logan & Cowan, 1984), in which people who are engaged in a *go task* that requires them to make a speeded response to a stimulus are instructed to withhold their response if a stop signal occurs (e.g., the phone's ring). Performance is well described by a model in which the go process races against the stop process (Boucher et al., 2007; Logan & Cowan, 1984; Logan, Van Zandt, Verbruggen, & Wagenmakers, 2014; Logan, Yamaguchi, Schall, & Palmeri, 2015). If the stop process wins, the go response is inhibited. If the go process wins, inhibition fails and the go response is executed.

The stop process is a clear example of an act of control. It is a response by the control system that is intended to bring behavior in line with goals and intentions. Its input is the intention to stop and the presentation of the stop signal. Its output is a change in the state of the go process, either inhibiting the growth of activation in the go process or removing the input that drives the go process (Logan & Cowan, 1984; Logan et al., 2015).

Stopping Takes Time

The stop process has a duration that cannot be measured directly. If the stop process wins the race, there is no overt behavior—no response—whose latency can be measured. Stop-signal RT (SSRT) has to be measured with a model. Fortunately, models provide several converging methods for measuring SSRT (Logan & Cowan, 1984; Logan et al., 2014; Matzke, Dolan, Logan, Brown, & Wagenmakers, 2013). In young adults, SSRT is usually 200–250 ms (Debey, De Schryver, Logan, Suchotzki, & Verschuere, 2015). The simplest method for estimating SSRT involves a tracking procedure that adjusts the delay between the go signal and the stop signal (stop-signal delay [SSD]) so that participants inhibit 50% of the time. At that SSD, the race is tied, so Go RT = SSD + SSRT. Stop-signal RT can be estimated simply by subtracting the observed mean SSD from the observed mean go RT (Logan, Schachar, & Tannock, 1997). Verbruggen, Chambers, and Logan (2013) urged caution in using this estimate, however, because it is susceptible to differences in skew.

Stopping Is Voluntary

The act of control in the stop-signal paradigm is clearly voluntary. Experimenters choose stop signals arbitrarily. There is nothing inherent in them that demands stopping. Participants can treat the same stimulus as a go signal or a stop signal depending on instructions (Logan & Burkell, 1986; Welford, 1952). Participants can ignore stop signals when instructed to do so but then stop in response to them when the instruction changes (Verbruggen & Logan, 2009). Participants can deploy the stop process strategically in response to cues and contingencies (Bissett & Logan, 2012). To accommodate this theoretically, the stop process must take two inputs: the intention to stop and the stop signal. In stop signal experiments, the intention is in place before the stop signal is presented. Outside the laboratory, stop signals themselves may retrieve the intention to inhibit, as when an opponent suddenly changes direction or we notice an error.

Stopping Is Specific

The act of control that underlies stopping may be general. It loads on a general inhibition factor in individual-difference studies of executive function (Friedman & Miyake, 2004; Miyake et al., 2000). It relies on a fronto-basal-ganglia circuit that is recruited in a broad range of stop tasks (Aron et al., 2007; Wessel & Aron, 2017). Stop-signal RT is about the same for different tasks and different modalities of stop signals and responses (Logan & Cowan, 1984; Xue, Aron, & Poldrack, 2008), suggesting a general process, although SSRT is shorter for eye movements than for key presses (Logan & Irwin, 2000).

There has been mounting evidence that the act of control underlying stopping is specific. It is shaped by learning and adapted to specific circumstances. People associate stopping with specific stimuli, and that affects subsequent performance. RT is longer if people stopped their response to the stimulus on a previous exposure than if they responded to it (Bowditch, Verbruggen, & McLaren, 2016; Verbruggen & Logan, 2008a, 2008b).

The specificity of the acts of control underlying stopping has implications for treating clinical problems. Consistent pairing of stopping and food-related pictures in stop-signal and go/no-go paradigms reduces subsequent food consumption (Houben & Jansen, 2011; Lawrence, Verbruggen, Morrison, Adams, & Chambers, 2015). Such training can reduce impulsive choices of unhealthy foods (Veling, Aarts, & Stroebe, 2013), alcohol consumption (Jones & Field, 2013), and risky choices in gambling (Verbruggen, Adams, & Chambers, 2012). Much work will be required to turn these studies into treatments, but the results are promising. We may be able to train specific acts of control to deal with specific problems.

Attention: Taking Control of Perception

Shifting Attention as an Act of Control

William James (1890) said, “Everyone knows what attention is” (p. 403), but everyone has a different idea. Everyone seems to agree that attention is an internal determining factor that frees us from sensory dominance (Hebb, 1949) and that *selectivity* and *capacity limitations* are fundamental properties. They all agree that we control what we select, whether to use capacity efficiently (Broadbent, 1957; Kahneman, 1973; Posner & Boies, 1971), think conceptually (Logan & Zbrodoff, 1999), or act coherently on the environment (Allport, 1987). The idea that selection is voluntary implies that we can shift attention from one moment to the next. You shift your eyes from the computer to the clock. Voluntary shifts of attention are acts of control. They begin with a cue and an intention to shift, compute an end point for the shift, and end with a shift to the new location. The input is a cue and an intention, and the output is a change in the state of the cognitive system, altering its sensitivity in the new location. There are many formal models of attention with top-down parameters that can be adjusted by acts of control (Bundesen, 1990; Logan, 2002; Lu & Dosher, 2008; Smith & Sewell, 2013; Sperling & Weichselgartner, 1995).

Shifting Attention Takes Time

Shifts of attention are usually studied by presenting cues that indicate a target’s location followed at various delays by a display containing a target to be reported. The time it takes to shift attention is inferred from a *time-course function,* which plots performance as a function of the delay between the cue and the target. Performance improves as cue delay increases, reaching its asymptote 100–300 ms before the target display (Eriksen & Collins, 1969; Eriksen & Hoffman, 1972). Researchers have often interpreted the cue delay at which performance reaches its asymptote as the time it takes to shift attention, but that may overestimate shifting time. Sperling and Weichselgartner (1995) argued that shifting time is variable and that the time course function reflects the probability that attention has shifted at each point in time. The asymptote of the time course function reflects the upper tail of the shifting time distribution. Logan (2005) assumed the distribution of shifting times was exponential and found mean shift times of 75–100 ms in a simple cuing task.

Another way to assess switching time is to cue targets invalidly, presenting a cue that suggests the target will appear in one location but presenting the target elsewhere (Posner, 1980). Reaction time is 50–100 ms slower when the cue is invalid than when it is valid and the target appears in the expected location. The extra time includes the time to disengage attention from the cued location and move it to the target location.

Shifts of attention also occur in dual-task situations like the *psychological refractory period procedure,* in which participants must make separate responses to each of two stimuli that occur in rapid succession (Welford, 1952). Participants focus on one task at a time, switching to the second when the first is finished (Pashler & Johnston, 1989). The time to switch can be estimated with computational models (Logan & Gordon, 2001; Meyer & Kieras, 1997).

Shifting Attention Is Voluntary

Attention researchers generally believe attention is voluntary. You chose to look at the clock, you weren't obliged to. There has been much interest in cases of involuntary attention, where attention seems to be drawn to a target against a person's will (Corbetta & Shulman, 2002; Posner, 1980; Theeuwes, 2010). Sudden onsets (Yantis & Jonides, 1984) and salient singletons (Theeuwes, 1991) draw attention, shortening RT when they are relevant and lengthening it when they are irrelevant. Involuntary or *exogenous* attention is often contrasted with voluntary or *endogenous* attention, which is typically studied with cues that do not draw attention directly to the target. Endogenous cues are often arrows in the center of the display, symbolic cues like numbers that refer to positions, and cues that require computing spatial relations like selecting the target opposite the cue (Eriksen & Collins, 1969; Logan, 1995). Endogenous cues are effective but take longer to process than do exogenous cues (Müller & Rabbitt, 1989). Endogenous cues engage an act of control. They must be detected, the cued location must be calculated, and the shift must be executed (Logan, 1995; Verbruggen et al., 2014). Exogenous cues may also engage an act of control but with much less processing required to calculate the cued location.

Shifting Attention Is Specific

There is a long tradition of thinking of attention as unitary, stemming perhaps from James's (1890) identification of attention with consciousness. Consciousness seems unitary, so attention should be unitary. This tradition was echoed in early theories of attention that tried to capture all the phenomena of attention with a single mechanism, like a processing bottleneck (Broadbent, 1957) or a source of allocatable processing capacity (Kahneman, 1973; Posner & Boies, 1971). Treisman's (1969) idea that there are several kinds of attention engaged in different kinds of selection presaged the modern era, inspired by neuroscience, in which few people endorse a unitary view (Chun, Golomb, & Turk-Browne, 2011). Today, many researchers would accept the idea of different acts of control for different kinds of attention. Shifting visual attention may be different from shifting auditory attention. Shifting between spatial locations may be different from shifting between perceptual attributes. Shifting between tasks may be different from shifting between percepts. There is evidence that the acts of control underlying the shifts are even more specific.

The act of control that shifts attention to a location in a display can become specific to targets and contexts. Our friends draw our attention in a room full of strangers, especially if they are sitting in their "usual" places. Training with consistent targets and contexts reduces RT substantially (Chun & Jiang, 1998; Shiffrin & Schneider, 1977). The act of control that divides attention can also become specific to targets and contexts. Stroop effects can be modulated by varying the proportion of incongruent items within blocks and within items (Jacoby, Lindsay, & Hessels, 2003; Logan & Zbrodoff, 1979).

Shifting attention between tasks is item-specific. Dual-task interference decreases with consistent practice on tasks. Part of the decrease is specific to the combinations of stimuli that were experienced during training, because changing the combination can disrupt performance (Logan & Etherton, 1994). Shifting attention between tasks is specific to task order. Participants are faster when the order of the tasks repeats from one trial to the next (A–B then A–B) than when they alternate (A–B then B–A; De Jong, 1995; Luria & Meiran, 2003).

Switching Tasks: Taking Control of Cognition

Switching Tasks as an Act of Control

Multitasking is part of the fabric of modern life. We all do it. You read this article while preparing for a phone call. We think we are good at multitasking despite strong evidence to the contrary (Strayer & Johnston, 2001). Multitasking is often operationalized in task-switching experiments, in which participants repeat or alternate between simple tasks like reporting the shape or the color of a geometric figure (Allport, Styles, & Hsieh, 1994; Jersild, 1927; Meiran, 1996; Rogers & Monsell, 1995). Task-switching experiments consistently produce robust switch costs: RT is longer when tasks alternate than when they repeat. There is widespread agreement that task switching requires an act of control but little consensus on what it is and how it produces switch costs. Switch costs have been interpreted as the time required to establish a task set (Meiran, 1996; Rogers & Monsell, 1995); the time required to suppress the previous task set (Allport et al., 1994); or conversely, as the benefit of repeating cue-encoding and retrieval processes from the previous trial (Altmann & Gray, 2008; Logan & Bundesen, 2003; Schneider & Logan, 2005). There is some merit in each account. A theory that encompasses all of them would be an important advance.

Switching Tasks Takes Time

Many researchers interpret switch costs as measures of the time it takes to switch tasks. Alternation RT includes repetition RT plus the time to switch tasks, so switching time can be obtained by subtraction. However, this is questionable because the act of control that enables switching may be engaged on repetition trials (Altmann & Gray, 2008; Gopher, Armony, & Greenshpan, 2000; Logan & Bundesen, 2003; Schneider & Logan, 2005). Switch costs may reflect the difference in the time it takes to engage a task set on repetition versus alternation trials.

Switching time can also be estimated from analysis of time-course functions, which plot RT on repetition and alternation trials as a function of the delay between the cue and the target. RT for both repetitions and alternations decreases as cue–target delay increases, as does the difference between them. Some people interpret the asymptotic cue–target delay as a measure of task-switching time. It is measured better with a model (Sperling & Weichselgartner, 1995). Logan and Bundesen (2003) developed models of the time-course function that measure both cue-encoding and task-switching times and found longer intervals for cue encoding than for task switching.

Switching Tasks Is Voluntary

We assume that people engage in tasks voluntarily in that they can choose whether to perform a task. You may decide not to talk to the stranger. This is the basis of informed consent. We assume more specifically that participants choose to engage in the tasks they perform on each trial of an experiment. In most cases, their choice amounts to consenting to follow instructions and letting the cues choose the task for them. Arrington and Logan (2004) gave participants the choice of tasks in a voluntary task-switching procedure, presenting them with a single digit on each trial and asking them to choose whether to classify it as odd or even or greater or less than five. Voluntary task switches produced longer RT than did voluntary task repetitions, much like cued switches and repetitions (Arrington & Logan, 2005). Subsequent research has shown that the choice may be influenced by aspects of the tasks and stimuli, but voluntary choices produce reliable switch costs (Arrington, Reiman, & Weaver, 2014).

Switching Tasks Is Specific

It is likely that several different acts of control underlie task switching. The concept of task set is muddy (Gibson, 1941; Schneider & Logan, 2014), but there is general agreement that it consists of many things. A nonexhaustive list includes settings for attention (stimulus locations and dimensions), memory retrieval (recognition vs. recall), decisions (criteria and thresholds), effectors (hands vs. eyes), and responses (up vs. down), as well as rules for mapping stimuli onto decisions and decisions onto responses. In principle, a separate act of control may be required to change each of these settings (Logan & Gordon, 2001). Task-switching experiments typically manipulate only a few settings, focusing on processes of interest. The acts of control required may differ considerably between experiments. There may be many acts of control in a person's repertoire.

Several results are consistent with specific acts of control. Allport et al. (1994) reported asymmetrical switch costs between easy and hard tasks. It was easier to switch from an easy task to a hard one than from a hard one to an easy one. Switch costs depend on the transparency with which the cue indicates the task. Cues that name the task or the response alternatives ("parity," "odd–even") yield smaller costs than do arbitrary cues ("d" and "v" for the odd–even task; Logan & Bundesen, 2004), suggesting that participants may learn specific acts of control for specific cues (see Logan & Schneider, 2006). Task repetitions are faster when the cue repeats than when it changes ("magnitude" → "magnitude" vs. "magnitude" → "large–small"; Logan & Bundesen, 2003; Mayr & Kliegl, 2003; Schneider, 2016; Schneider & Logan, 2005), suggesting that task repetition benefits are specific to particular cues.

Discussion

The goal of this article was to make a case for the instance perspective on cognitive control, arguing that acts of control are the agents of cognition, drawn from a bag of tricks to solve specific problems. The case was based on three exemplary acts of control involved in stopping reading this article to answer a phone call—inhibiting responses, shifting attention, and switching tasks. The article showed that these acts of control take time, are voluntary, and may be specialized, replacing the general acts with a host of specific ones.

Common Ground for Different Perspectives

The instance perspective is compatible with ability (Miyake et al., 2000) and systems perspectives on control (Badre, 2008; Logan & Crump, 2011; E. K. Miller & Cohen, 2001; G. A. Miller et al., 1960). The structure of the abilities may derive from the similarity structure of the acts of control engaged by the tasks that define the constructs. Acts of control require *detection* of the control signal, *selection* of an appropriate act, and *execution* of the act (Verbruggen et al., 2014). Correlations among tasks may reflect shared components. Tasks that require inhibition load on a common factor, whereas tasks that require shifting load on another (Miyake et al., 2000). The evidence that acts of control can be learned suggests that some individual differences in control may be based on experience rather than ability. We expect much better control in skilled performers than in novices. Skills are often very specific, so the acts of control that guide them must be specific as well (Logan, 1988; Palmeri, 1997).

From a systems perspective, acts of control may be the means by which higher level frontal systems communicate with lower level posterior systems, with specific acts modulating specific computations. This idea is implicit in the strategy of building control systems for existing cognitive models. The Botvinick et al. (2001) and Gilbert and Shallice (2002) models control the Cohen, Dunbar, and McClelland (1990) model of the Stroop task. Logan and Gordon's (2001) model controls Bundesen's (1990) theory of visual attention. Botvinick et al. close the loop, specifying the higher level computations that determine how lower level processes are adjusted. Acts of control leave some elbow room for the homunculus. The input includes a goal, and the processes that determine the goal are unspecified. The loop can be closed, but we can learn something useful without having to close it (Attneave, 1961).

The instance perspective is compatible with ability and systems perspectives, with acts of control as the common ground. However, the instance perspective does not require abilities or systems. It would be appropriate to analyze elementary acts of control even if there are no consistent correlations between individual acts, even if control is not hierarchical. The instance view is compatible with heterarchical control, in which no system consistently dominates any other. This justifies studying single acts of control for their own sake, leaving questions about similarities and larger structures aside, while learning the details of the single act. This approach has advanced our understanding of response inhibition, attention shifting, and task switching. Of course questions about similarities and larger structures are important and are currently topics of intense investigation.

The instance perspective invites its own form of computational modeling, which grounds theories of control more firmly in theories of perception, attention, and memory. Computational modeling provides a bridge between behavior and physiology, guiding the search for neural mechanisms that implement the computations and providing quantitative accounts of behavior and neural activity (Boucher et al., 2007; Purcell et al., 2010).

Acts of Control and Controlled Acts Revisited

Controlled acts may also be viewed as acts of control directed toward the environment. Our responses are intended to change the state of the world, some device, or some person, so they fit Dennett's (1984) definition of control. Controlled acts are voluntary. They require goals and external stimuli as input just as acts of control do. Participants often play a passive role in psychology experiments, responding as instructed to whatever stimuli we present, but the instructions set goals that participants adopt voluntarily. Outside the lab, the same acts would seem purposeful and intended. If someone said "dog" in the presence of a dog, you would know what he or she meant.

Controlled acts are like acts of control directed externally. They also take time, are specific, and are made of the same elementary constituents (processing stages, IF–THEN rules; see Figure 1). Thus, it may be more appropriate to distinguish between *acts of internal control* that we have been discussing and *acts of external control* that underlie the controlled acts on which the internal acts operate. This would be more consistent with views of humans as active agents. When focusing on a single act of control, however, it may be simpler to talk about acts of control and controlled acts with a mental footnote that controlled acts may be acts of external control.

Taking Control

The instance perspective has implications for taking control of our own cognition. We can initiate acts of control by playing the role of the homunculus and setting the goal in the input. How we come up with goals is beyond the reach of today's science, but we manage to do it anyway. Despite Wegner's (2002) suggestion that control is an illusion, we manage to do what we intend and not do what we intend not to do most of the time. Control may not be perfect, but it is good enough for most purposes. We rely on it every moment of every day. However we come up with our goals, acts of control provide us with means to make ourselves attain them.

The idea that acts of control are multiple and specific should encourage us about the possibility of gaining control and recovering from deficiencies. The research reviewed here indicates that acts of control can be learned and tailored to specific circumstances (also see Verbruggen et al., 2014). This is ground for optimism: Our ability to control is not fixed. It grows with experience. We can improve control just by learning a simple trick or adapting an existing one to new conditions. That is much less daunting than trying to change a fixed ability or improve an entire control system. Changing one thing is easier than changing everything. The idea that control grows with experience should encourage us and our clients to try to change (Dweck, 2006).

What's Missing?

Of course, control is more than a bag of tricks. The focus on elementary acts of control draws attention away from larger control structures, like plans and routines (Logan & Zbrodoff, 1999; G. A. Miller et al., 1960); broader distinctions, like proactive and reactive control (Braver, 2012; Verbruggen & Logan, 2009); and broader concerns, like the role of learning and development in cognitive control (Verbruggen et al., 2014). Perhaps these structures can be modeled as collections of acts of control and the distinctions can be based on properties of acts of control. Proactive control might be triggered by feedback, whereas reactive control might be triggered by a target stimulus. Development might occur by learning and adapting acts of control.

The focus on cognitive control ignores the driving force of value and emotion (Higgins, 2000; Huntsinger, Isbell, & Clore, 2014). They shape our intentions and choices of goals and strategies. In extreme cases, they limit our control and challenge us to maintain it. Value and emotion must be central components in a complete theory of cognitive control. Perhaps they can be understood in terms of acts of control, grounded in computational models and differing in content but not in form. Maybe the tricks we use to control cognition can give some insight into the tricks we use to control emotion.

Who's in Control?

Cognitive psychologists are eager to banish the homunculus from explanations of control, replacing an omniscient, omnipotent executive with an army of idiots (Attneave, 1961; Monsell & Driver, 2000). The instance approach epitomizes this perspective, replacing general acts of control with ones tailored to specific circumstances. We must be careful in banishing the little people in the head not to banish the big person. Our personal, social, cultural, and legal institutions depend on the idea that people are autonomous agents in control of their actions. The person should be explained, not banished. Ultimately, we must explain how a person arises from a collection of control processes, memories, and percepts.

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