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Action-Oriented Cognition and Its Implications

Contextualizing the New Science of Mind

Tony J. Prescott and Paul F. M. J. Verschure

Abstract

The action-oriented paradigm in cognitive science is emerging alongside a broader movement toward a more contextualized, pragmatic, and socially distributed science. This synergy between the view of the mind as practice and the practice of the science of mind bodes well for the development of a new, robust, and socially useful understanding of human experience through which scientific insights can connect with broader intellectual traditions and refocus on societal impact as opposed to impact factors. Through its emphasis on action, the paradigm is well-suited to address real-world problems while advancing fundamental understanding. This chapter explores promising domains in which applications of the action-oriented view are being pursued, including biomimetics, enactive approaches to design, and immersive technologies. Research that has real-world impacts entails social risk; therefore, to be ethical, research in action-oriented cognition should be performed openly and in dialogue with the wider public.

Introduction

This Forum was convened to consider the possibility of a "paradigm shift" in brain and behavioral sciences: one aimed at a more action-oriented view of cognition. In this chapter we consider the notion of paradigm shift within the wider context of how current science is practiced and supported. We argue that, within a societal and international context, science is increasingly judged by its ability to advance solutions to real-world problems. Moreover, this is not necessarily a bad thing: a focus on societal challenges can promote understanding and resolve the false dichotomy between pure and applied science. A strong test of the action-oriented view, then, is whether it is able to produce artifacts that can act effectively in the real world. This is the notion of the "pragmatic

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turn" applied, not just to how we understand brains and minds, but also to how we *do* our science. While it is beyond the scope of this contribution to review the practical impacts of the action-oriented approach fully, we will try to point to some areas where we think such impacts are happening, or where they might happen with some additional effort. Finally, we will argue that scientists can no longer afford to ignore, if they ever could, consideration of the potential negative impacts of their research. To pursue science in an ethical way obliges us, therefore, to think carefully about where our science and technology might lead, and engage in an open and public debate about our goals.

Paradigm Shifts and the Social and Political Context of Science

Our discussion begins with a consideration of the broader scientific context within which the action-oriented paradigm is being pursued and with which we see interesting parallels.

When Thomas Kuhn (1962/1970) developed the notion of a "paradigm shift," he did so in the context of a post-positivist philosophy of science that had hitherto focused more on methodology (e.g., Popper 1935/2005) and on the role of the individual scientist (e.g., Polanyi 1958). Kuhn's thesis, by contrast, recognized that the "scientific view," the dominant paradigm at any given point in time, is determined by a consensus within the community of research scientists and he sought to analyze specifically the dynamics of how this consensus can change. His approach brought a sociological perspective to the understanding of science, emphasizing how science *is* practiced rather than how, in some ideal decontextualized way, science *should* progress.

Kuhn remained convinced that science advances to a better understanding of nature over time, but it is easy to find support in his thesis for a more relativistic view. For instance, Kuhn's notion of *incommensurability*[1] asserted that competing paradigms rely on incompatible conceptual frameworks, such that measurement (how we obtain data), epistemic standards (the rules we apply when reasoning about data), and meaning (the semantics of the concepts we use to interpret and explain data) can each differ between paradigms. As a consequence, the truth of statements conceived within one paradigm cannot easily be assessed within another. Figure 19.1, reproduced from Froese et al. (2012), illustrates that there may be a degree of incommensurability between the action-oriented view and other approaches in cognitive and brain science. However, if truth depends on your scientific framework then the preference for one view over another can become a matter of taste. Following in the wake of Kuhn, Feyerabend (1975/2010) developed epistemological anarchism, the view that there is no such thing as the scientific method, which led him to later

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[1] Kuhn's version of incommensurability is probably the best known, but the idea was also central to Feyerabend's philosophy of science, and its roots can be traced to the earlier writings of physicists, such as Einstein and Bohr, and Gestaltists such as Köhler.

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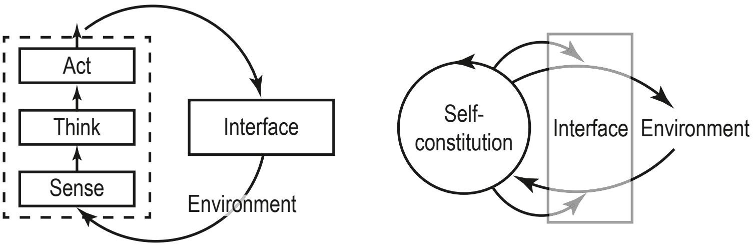

Figure 19.1 Contrast of a cognitivist (left) and an enactivist (right) view of a sensory augmentation technology (Froese et al. 2012). The cognitive view is characterized by an agent implementing a classical sense–think–act loop mediated by the interface device which comes between the agent and the environment. The enactive view sees the agent as an autonomous system engaged in an activity called "sense-making," which is an emergent property of the agent-environment interaction. The interface device alters the dynamics of this interaction resulting in "augmented sense-making" such that the device itself may be "experientially transparent." The diagram illustrates that because the cognitivist and enactivist paradigms employ quite different semantics and conceptual frameworks, they may be incommensurable in the Kuhnian sense. (Figure from Froese et al. 2012; reprinted with permission from IEEE Transactions on Haptics.)

endorse a relativist understanding of the history of science. For the wider postmodern movement, it became possible to characterize scientific knowledge as the belief system of an intellectual elite, a view that still has resonance in popular culture and which questions the authority that has been assigned to science traditionally. We believe that the pragmatic turn in the study of mind and brain must also address the question of how this paradigm shift and its practical consequences can be assimilated by society and induce positive change.

Research into the societal, political, and cultural context of science has expanded in recent decades, giving rise to the field of *science and technology studies*, and has come to have a significant impact on science policy, especially in Europe. In particular, the view of science as a process of discovery, pursued by dispassionate researchers who are neutral with respect to the broader context, already criticized by Polanyi and Kuhn, has been further challenged. In a series of influential books and articles, Nowotny and colleagues have contrasted this classical idea of science, characterized as mode-1, with a view of science, as practiced at the end of the twentieth and beginning of the twenty-first centuries, as "socially distributed," denoted as mode-2 (Gibbons et al. 1994; Nowotny 1999; Nowotny et al. 2001, 2005).

Mode-2 science is said to have several key characteristics. First, the traditional distinction between pure and applied research is modified by the contextualizing of even basic science relative to identified application domains: societal, economic, or technological. Second, rather than operating within traditional disciplines, research happens within transdisciplinary groupings which emerge to address identified priorities, then dissolve as trends or opportunities move elsewhere. This mixing of transient research cultures can, dependent on

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the incentive structures, provoke new forms of scientific creativity or opportunistic exploitation of resources. However, the temporary nature of such consortia rarely leads to lasting structures, such as the formation of new disciplines. Finally, science is pursued by increasingly diverse actors involving a broad set of stakeholders. Universities and government-funded research centers are still key players, but companies, large and small, get in on the act, as do nongovernmental organizations such as user groups, charities, and think tanks. There is little space for the individual researcher independent of their brilliance.

This changing climate for research is thought to be reflected in a number of identifiable trends including the top-down steering of research priorities, the commercialization of research, and the increase in scientific accountability (the "audit explosion"; Power 1997). Furthermore, the rise of open access publishing as well as the increasing role of social media in promoting and evaluating scientific ideas has served to democratize science as well as to dilute scientific authority—a commentator with many Twitter followers, or a popular blog, can be more influential than a scientist with a high H-factor.

The weakening of the traditional scientific hegemony, the legacy of relativist views in the philosophy of science, the growing coupling of research to innovation, and the emergence of alternative actors and of new forms of knowledge exchange have undermined the authority of the scientific view. To reestablish its validity, proponents of mode-2 science suggest that it is no longer sufficient for knowledge to be "reliable" in the sense of reflecting a consensus among "competent, well-informed scientists" (Ziman 1978). As Nowotny (1999:253) states:

> A 21st century view of science must not only embrace the wider societal context, but be prepared for the context to begin to talk back. Reliable knowledge will no longer suffice, at least in those cases, where the consensuality reached within the scientific community will fail to impress those outside. In a 21st century view of science, more will be demanded from science: a decisive shift toward a more extended notion of scientific knowledge, namely a shift toward socially robust or context-sensitive knowledge.

Social robustness thus implies the inclusion of nontraditional players in efforts to build consensus around a scientific view. This implies that science communication and dissemination becomes as important as the process of discovery and its results. As a paradigm that looks to develop a scientific understanding of human experience, the action-oriented view has many external audiences with whom common ground can be sought: engineering, the humanities, the creative arts, health, and spiritual traditions concerned with mindfulness. This possibility was also very much in the minds of some of the originators of the field (Varela et al. 1992). With the notion of socially distributed science coming more to the fore in science policy, the action-oriented view thus seems well-placed to build a science of human experience that is contextualized,

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robust, and connects to these wider intellectual traditions through its intrinsic commitment to the real-world relevance of knowledge.

Building Artifacts That Solve Real-World Problems As a Strategy for Research in Action-Oriented Cognition

Mode-2 science has been presented as a modern phenomenon; however, science has always been exposed to societal pressures and, in the past, has looked to push back. In 1850, in a presidential address to the American Association for the Advancement of Science (AAAS), Joseph Henry, the first Secretary of the Smithsonian Institute, sought to defend pure science from the intrusion of applied concerns:

> The incessant call in this country for practical results and the confounding of mechanical inventions with scientific discoveries has a very prejudicial influence on science....A single scientific principle may include a thousand applications and is therefore, though if not of immediate use, of vastly more importance even in a practical view (Rothenberg 1998:101–102).

A generation later, Henry Rowland (1883), first president of the American Physical Society, asserted in his speech to the AAAS that "to have the application of science, the science itself must exist"(Rowland 1883:242). Both of these leading figures of nineteenth century science considered it important to dissociate pure from applied research and to assert that the flow of ideas goes from discovery to innovation, not vice versa. Indeed, for Rowland, there was something morally admirable about the self-sacrificing nature of the scientist who avoided applied topics (similar in spirit to Henry V, when Shakespeare wrote of "the few, the very few, who, in spite of all difficulties, have kept their eyes fixed on the goal"). The notion of a pure science base as "scientific capital" that would allow technological innovation to flourish, and economic and societal benefits to flow, was later placed at the center of an influential report from the U.S. Office for Scientific Research and Development (Bush 1945); this led to the establishment of the National Science Foundation. Indeed, a key aim of that report was to protect basic science from potential erosion by excess focus on societal need, echoing the assumption of Henry and Rowland that applied research would pay for itself by generating revenue whereas pure science was too long-term and high-risk to be left to market forces. (For an assessment of the impact and legacy of the Bush report fifty years later, see Cole et al. 1994.)

Today, the dichotomy between pure and applied as well as the notion of a one-way flow of causality appears oversimplistic and may be holding back science (Brooks 1967; Stokes 1992; Nowotny et al. 2001). Further, the characterization of basic science as disconnected from application may have contributed to the perception of science as detached from, and thus insufficiently

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concerned with, the human condition. It may also have led to an unhelpful devaluing of mission-led scientific research that addresses societal needs that are not commercial (e.g., Sarewitz 2012). The history of science contradicts the notion that good research cannot serve both basic and applied goals. Pasteur, for instance, spent most of his life working on practical problems (e.g., sugar fermentation and the diseases of domestic animals), yet his research led to fundamental discoveries concerning the germ theory of disease as well as to the birth of a new research field (microbiology). Consideration of such examples led Brooks (1967) to propose a spectrum of research from pure to applied and Stokes (1992) to describe "Pasteur's quadrant," a two-dimensional conceptual plane where research efforts can emphasize fundamental understanding, societal use, or some productive blend of the two.

To locate the sweet spot in Pasteur's quadrant, for the domain of action-oriented cognition, we can also look for inspiration to the eighteenth century Neapolitan philosopher Giambattista Vico, who famously proposed that we can only understand that which we create: *Verum et factum reciprocantur seu convertuntur* (Verschure 2016). Vico's dictum can be viewed as an instruction to apply a synthetic approach, that is to build models, as well as to create technologies that validate and make practical use of scientific ideas. Following Vico, we can adapt the notion of the "pragmatic turn" to a methodological use—applied research as embodied proof-of-principle, or to turn it around the other way, "the theory as a machine" (Verschure 2013). Below we consider specific application domains where research in action-oriented cognition is using (or could take) this approach and where there is potential for bidirectional (fundamental understanding *and* societal use) impact.

Application Domains for Action-Oriented Cognition

As put forth by Engel et al. in the introduction to this volume, key principles of the action-oriented paradigm that can be exploited to develop applications include:

- Understanding cognition as the capacity to generate structure by action
- The immersion of the cognitive agent in its task domain
- The significance of the body and the possibility to export some aspects of the problem of generating appropriate actions to the body or to the environment
- The dynamic, context-sensitive, and adaptive nature of behavior-generating systems
- The ability to extend cognitive tasks into the environment

Here we discuss a number of key domains where these principles can or are being usefully applied. We do not attempt to be exhaustive but rather focus

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on domains where we have some experience and interest. Further discussion of possible application domains is provided by Dominey et al. (this volume).

Biomimetics

Biomimetics is the development of novel technologies through the distillation of principles from the study of biological systems (Bar-Cohen 2005). Biomimetic research operates in three directions (Prescott et al. 2014):

1. It promotes a flow of ideas from the biological sciences into engineering.
2. It provides physical models of biological counterparts that can serve as experimental platforms to understand them (Rosenblueth and Wiener 1945).
3. It creates a new class of technologies that can then be advanced toward innovation and direct application.

Since the action-oriented approach stems from the study of biological cognition, it seems natural that biomimetic artifacts are developed to embody and evaluate these principles.

Within biomimetics, one example domain where the action-oriented paradigm has been particularly influential is in the control of locomotion in biomimetic robots. The importance of embodiment in generating coordinated movement is beautifully illustrated in passive walking machines that exploit the natural dynamics of their parts for periodic motion. For example, bipedal walking machines, with no control system whatsoever, can generate a stable walking gait on a suitably sloped surface by relying on the passive dynamics of suitably configured mechanical parts (Collins et al. 2005). Animals provide control through their nervous systems in a manner that complements their natural body dynamics (Chiel and Beer 1997; Ijspeert 2014). In walking or running, for example, many-legged animals exploit the pendulum-like natural motion of jointed limbs to help generate a suitable cyclic pattern. By relinquishing some aspects of control to the body, they also benefit from the energy-recycling capability of elastic tissues. Muscles and tendons, for instance, convert kinetic energy to potential energy as the foot hits the ground, providing a store of energy to be released in the next step cycle. Designing controllers modeled on animal locomotion pattern generators that exploit these principles provides a very promising path for building efficient legged robots (Ijspeert 2014). Such controllers can be simpler (e.g., have fewer control parameters) than more traditional forms of continuous robot control, and will entrain themselves to the dynamics of the body, making them highly adaptable. Prosthetic limbs are being developed which similarly reduce the need for control through well-designed natural dynamics (Carrozza et al. 2005). Similar principles—extending cognition into the body and exploiting natural dynamics to simplify control—have been applied to a range of other motor tasks in robotics including reach

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and grasp, as well as to the control of hyper-redundant soft robots (Pfeifer and Bongard 2006; Trivedi et al. 2008).

Enactive Approaches to Design

One of the most productive domains for the application of action-oriented principles appears to be in the design of artifacts that are used in close conjunction with the body, such as sensory substitution or augmentation devices. Examples include the Enactive Torch (Froese et al. 2012), the Feelspace Belt (Nagel et al. 2005), and the vOICe (Auvray et al. 2007). A key design aim is to make the device "experientially transparent" (see Figure 19.1) such that the goal-directed behavior of the user naturally incorporates properties of the artifact, including its capacity to transform from one sensory modality to another. Design can benefit from an understanding of the sensorimotor contingencies (O'Regan and Noë 2001) to which sensing in a given modality is attuned. Applications include assistive technologies for people with sensory impairments and sensory augmentation systems for use in safety services, construction, and defense. Commercial devices such as the *Nintendo Wii* controller also take advantage of some of the principles identified by the enactive approach.

Immersive Technologies

With the development of next generation virtual reality and telepresence technologies, experiencing the world from a point-of-view other than that from behind our own eyes is becoming a possibility for all of us (Sanchez-Vives and Slater 2005). Psychologists have long-known that our conceptions of our physical selves are very flexible; however, recent advances in immersive technology now allow us directly to examine and test our expectations about the limits of the self concept along different dimensions such as the physical, temporal, and social (Blanke 2012; Prescott 2015). Theoretical constructs emanating from the action-oriented perspective are helping to understand the experience of immersion and the capacity of the brain to adapt to a virtual or remote body (Stoffregen et al. 2006). Enactive principles can also improve the design of immersive technologies to increase the feeling of presence. For example, studies suggest that the immersive experience is more compelling when actions in a virtual environment result in expected sensorimotor contingencies of objects (e.g., bending down to see the underside of a horizontal surface) and agents, and so modulate presence (Inderbitzin et al. 2013).

The technology for immersive virtual reality is advancing very rapidly, largely due to its importance to the entertainment and games industries. In addition to leisure, however, there are also important applications of immersive technologies in civil and commercial domains: teleoperation of remote equipment in hazardous environments; telepresence for delivering health care or conducting business; and augmented reality for applications in areas such as

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design, tourism, and retail. In health care, studies are demonstrating the potential for the use of virtual reality in reducing pain (Hoffman et al. 2001), treating eating disorders (Riva 2011), and in assisting recovery from stroke (Jack et al. 2001; Cameirão et al. 2012) and posttraumatic stress disorder (Difede and Hoffman 2002). With an aging population in developed countries, ever greater burdens are being placed on health care systems, and new tools for deployment in both the hospital and home are required to maintain healthy aging. Telehealth is emerging as an important element of health service plans to streamline and improve services, and a key element of this is the use of telepresence technologies for health workers and carers to interact remotely with patients or those in care (Riva 2000). Immersive technologies are also growing in importance as technologies through which people interact with family and friends, and could offer an important means for reducing psychological stress.

The above examples show that an action-oriented paradigm not only holds promise in advancing our understanding of mind and brain but also provides a prime example of twenty-first century science. These examples also illustrate that the action-oriented approach must promise to establish a closer synergy between basic and applied science beyond Pasteur's quadrant. We can view the application in health care, for instance, as a direct validation of basic science hypotheses. Hence, by following a more deductive approach toward applications, they in turn become experiments that can advance theory. This has also been called Vico's loop (Verschure 2016). Pursuing this model, however, implies that scientists themselves must also be aware of the implications of applied research, including ethics.

Ethical Issues

Mode-2 science has heralded a more critical shift in evaluating the motivations for scientific research and the potential societal impacts of its consequences. Research in the action-oriented domain should recognize that although scientific knowledge is neither good nor bad, the use of knowledge is not ethically neutral. Thus, scientists have a responsibility to think about how the results of their research might be deployed.

Expectations about the positive societal benefits of advanced technologies, derived from research in cognitive systems, vary from the unconditionally positive (Roco and Bainbridge 2003) to more guarded and cautious (Nordmann 2004; Kjølberg et al. 2008). The guarded perspective worries that benefits will be for the few, not the many—and contribute to a more unequal society—or that we risk dehumanizing ourselves by advancing too far down a path of self-modification and enhancement. This broad debate is set to continue and become even more pressing as applications move from science fiction toward technological fact.

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It is known that the public is generally well-disposed toward science but that unease is often greatest at the intersection between science and technology, where advances are often disruptive and therefore perceived to entail risk (Wynne 2007).

Our view is that assessment of societal risk is an undertaking far too important for those engaged in the research not to be involved. This may mean that researchers need to take a different approach, away from the more traditional approach in science, which ensures that research plans conform with established codes (which govern, e.g., research involving animals and humans) but leaves consideration of the broader and longer-term risks to others, such as professional ethicists. The issue for science is this: if researchers do not get involved, they may find that lines of enquiry are shut down on the basis of "future scoping" activities undertaken by people who are less than fully informed. Because research in action-oriented cognition is often at the intersection of science and technology, it is both relevant and important, but also potentially hazardous. We advocate that the research plans of the community involved in action-oriented research should therefore integrate the analysis, understanding, and management of risk from an early stage.

A general approach to a risk-based science ethics is illustrated in Figure 19.2. Here, ethics in research is positioned along two complementary dimensions. The societal impact dimension (vertical) is concerned with the effects of technology on individuals and on society, projected along the dimension of time from the short-term to very long-term. Equally important, however,

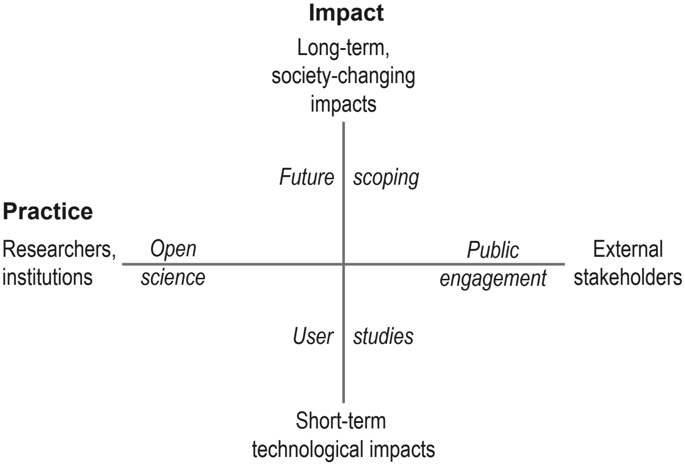

Figure 19.2 Ethics in research. The "Ethics Cross" divides the challenge of addressing ethical issues in research along two dimensions: investigating potential societal impacts (vertical) and pursuing research practices that foster a meaningful exchange, an analysis of research risks, through dialogue with the wider society (horizontal). The cross is based on Buchanan's (1985) analysis of product design as reinterpreted by Illah Nourbakhsh.

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is the dimension of research practice (the horizontal axis in Figure 19.2) projected between researchers, and their institutions, and external stakeholders, including the general public. The proposal here is that the research community engage in a broad dialogue with potential stakeholders continually presenting its goals, methods, and achievements. Key mechanisms include adopting an open science strategy—including free dissemination of results, a willingness to conduct research in public view, and public engagement—proactively looking to disseminate ideas and outcomes. Engagement should be bidirectional and include a willingness to adapt research aims to address concerns that are well founded, and potentially to abandon lines of research that are identified as being too high risk.

Conclusion

These are exciting times for action-oriented cognitive science, as this volume demonstrates. However, because science is a human activity, its pursuit is subject to societal and political constraints, and in recent times, the value of science for its own sake is increasingly being questioned. The number of potential questions that can be asked of science is infinite. For publicly funded research, it is reasonable to require research to address important questions whose answers have the potential for substantial societal benefit. Our research field is fortunate because its core questions concern the human condition, and advances should lead to insights as to how to improve it. Taking Pasteur and Vico as our role models, we can better understand ourselves through action-oriented cognition, and through this "pragmatic turn" also do science that makes a difference.

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