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TARGET ARTICLE

The possibility of a pluralist cognitive science

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A case for a pluralistic approach to cognitive science is sketched. It is argued that cognitive scientists should take seriously the possibility that a single, unified framework for all of cognition is an unrealistic expectation for its diverse interdisciplinary goals and subject matter. A pluralistic approach instead seeks ways of integrating the multiple perspectives that have provided explanatory success in loosely interconnected sub-domains of cognitive phenomena. Research strategies recommended by this approach are discussed, with review of research currently carrying out such strategies and others that may hold promise for the future. The article ends with a discussion of seeking closer integration of the inquirer into consideration of which explanatory framework to choose. A systematic exploration of this transactional approach to cognitive science may grant coherence to pluralism even as it embraces diverse schemes of explanation.

Keywords: pluralism; cognitive science; complexity; dynamics; computation; pragmatism

1. Introduction

Newell (1973) famously fretted about an emerging strategy in cognitive science to identify points of dissent, and debate whether one or another perspective on these points is correct. He called this the 'construction of binary oppositions,' akin to playing a game of 20 questions with nature. This form is still a common, familiar one: Is the mind dynamic or computational? Is it serial or parallel, continuous or discrete, mostly innate or mostly learned, mostly conscious or non-conscious, representational or non-representational? Such extreme dichotomies are poles *between* which most researchers live theoretically, so this characterisation has a quality of caricature (which Newell acknowledged). Nevertheless, there may be bimodality in our distribution between these poles, with crowding nearer one or the other. These binary oppositions thus also serve as defining features of broader theoretical perspectives. For example, three primary clusters of them are often recognised in the form of symbolic, connectionist, and dynamical systems frameworks (e.g. Eliasmith 1996, 2003; van Gelder 1998; Bechtel 1998) and in developmental cognitive science (as reviewed in Thelen and Bates 2003). James J. Gibson urged the psychologist to be radical in these theoretical commitments (cf. Shaw 2002), and this disciplinary dialectic may have brought the field to have a character of 'warring bands' (Leahey 2001; Edelman, in this issue).

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In the current article, I consider a different *kind* of position that may be described as somewhat 'radical.' It is not new. To some it may be obvious, and to others inevitably anathema. The goal of this article is to consider the possibility of a pluralistic approach to cognitive science. Such an approach suggests new ways of treating debate between apparently competing theories. It encourages embracing diversity in these theories by identifying their unique usefulness in choice sub-domains of cognitive phenomena. It may also recommend integrating these competing theories in meta-theoretical frameworks that would sustain their co-existence. This possibility of pluralism may seem obvious to many, considering the range and complexity of cognitive science's subject matter. This 'super-discipline' is already plural in the sense that there are many domains of inquiry, and many competing and co-existing theories in these diverse domains. Nevertheless, in a very large number of cognitive scientists, there is a tendency to practice cognitive science in a way that opposes pluralism. I believe, for many, there is a strong sentiment that there exists some single overarching theory or framework that will eventually explain all of human brain and behaviour. The overall goal of this article is to consider the possibility that this will not happen, and what cognitive scientists should do about it.

There is an important distinction between scientific pluralism and scientific plurality. Pluralism goes beyond the mere recognition of plurality. Science exhibits the latter, but the former is a stronger position. Kellert, Longino and Waters (2006) introduce their edited volume on pluralism and philosophy of science by noting the distinction between these two notions. One may recognise the plurality of explanatory schemes in science without advocating pluralism for science. They offer a general description of pluralism as the recognition that plural perspectives are probably the norm across the sciences – an 'ineliminable character of scientific inquiry and knowledge' (p. ix) – perhaps even as a rule long into the future, if not indefinitely. The various already-existing pluralistic approaches to science, of which Kellert et al.'s is one, are nuanced, but this simple definition gives a general outline of this meta-theoretical position. Supplying some detail to this position for cognitive science is another purpose of this article.

Pluralism can also be defined by contrast with fundamentalism. As described above, this is the perspective that there will be some ultimate victor in competing scientific theories, and all theories are either approximations or derivations of it (Cartwright 1999). Many prominent philosophers of science have recently challenged this sentiment. For example, Cartwright (1999; see also Cartwright 1983) offers her own vision of a 'dappled world,' where nature exhibits numerous disparate regularities in unique and diverse domains that have their own set of entities and lawful relations. Hers and the approach of Kellert et al. (2006) are two of several proposals in the philosophy of science for pluralism, applied to a diverse range of case studies across several scientific disciplines (e.g. Suppes 1981; Dupré 1993; Cartwright 1999; Mitchell 2003, 2004; Putnam 2004; Giere 2006; Kellert et al. 2006; Longino 2006; Godfrey-Smith in press). In cognitive science, there have already been some proposals for moving beyond conventional 'paradigm debate' that has been ongoing for a number of decades (e.g. McCauley and Bechtel 2001; Looren de Jong 2002; Eliasmith and Anderson 2003; Dale and Spivey 2005; Sun, Coward and Zenzen 2005; Abrahamsen and Bechtel 2006; Kelso and Engstrøm 2006; Smolensky and Legendre 2006; Weiskopf, in press).

This article, therefore, has substantial and recent precedent, both in broader philosophy of science and some existing proposals in cognitive science and psychology (e.g. Slife 2000). It is a presentation of many already-existing (and some new) facts and ideas, organised in a manner that I hope persuades the reader to take seriously the possibility of pluralism, and what it might mean for broader theories of the mind. I myself do not find the perspective so obvious, and with colleagues am engaged in strands of research that demonstrate the importance of one particular framework in explaining cognition (e.g. Spivey and Dale 2004, 2006; Dale, Kehoe and Spivey 2007; Dale, Roche, Snyder, and McCall 2008; McKinstry, Dale, and Spivey 2008). For a similar reason, many may hesitate to consider seriously the idea that across our diverse domains of cognitive research – such as differing subject matters, methodologies, goals, etc. – cognitive scientists ought to practice (or at least entertain) the usage of diverse theoretical frameworks to help explain and predict brain and behaviour. We should find ways of integrating these frameworks when they are individually useful, but not immediately mutually intelligible. Pluralism recommends other meta-theoretical strategies as well, and I consider more below.

The article is organised in the following way. First, I consider a series of relatively straightforward statements about science and cognitive science that motivate the perspective of pluralism. These structured observations provide two ways of taking pluralism seriously, one from the nature of cognitive science specifically, and the other from general epistemological concerns in science. Rather than forming arguments for pluralism, I make use of these observations to intuitively motivate the potential, and potential requirement, of pluralism. These facts will not 'prove' this position in the form of a series of premises leading to a conclusion of pluralism. Instead, this sequence of straightforward statements will serve as a crude 'intuition pump' (Dennett 1995) for pluralism.

Following this, I consider a range of consequences of pluralism, and the potential research strategies that may grow out of it. Among many possibilities, I consider how complex systems research recommends pluralism, how meta-theoretical frameworks may permit co-existence of apparently inconsistent theories, and ways of integrating theoretical approaches in methodological advances for ongoing problems in cognitive science.

In a concluding discussion, I consider a pragmatic perspective on pluralism by drawing from Putnam (2004) and Dewey and Bentley (1949). These thinkers, among other pragmatists, may provide a strong basis for taking pluralism seriously. The overall purpose of the article is to consider the possibility and potential for pluralism in cognitive science. The next section, therefore, begins by drawing one towards the position by considering some simple facts about 'cognitive science.'

2. Motivating pluralism

I start with a sequence of facts about cognitive science, and then science generally. Many of these points have been made elsewhere, while some have perhaps not been given such an explicit focus because they do seem so obvious. These six statements create two ways of taking seriously the need for pluralism. The first three statements, cognitive science is young, diverse, and not theoretical physics, suggest that there *should* be plural perspectives, and this should temper hubris towards any one particular theoretical framework. The next three statements, that human knowledge is limited, humans are complex, and all theories have limited scope, motivate the perspective that any theory can only capture a relatively restricted set of regularities in brain, behaviour, environment, and interactions among them. The result is some recognition of pluralism as a potentially long-standing status quo.

In these sections, review and discussion remain at the level of generic descriptions in an attempt to draw observations that encompass all kinds of theorising, whether more limited in scope, or more broad such as the three perspectives for cognition mentioned in the introduction. As a caveat, I bandy about such terms as *explain*, *describe*, *theory*, *framework*, *scheme*, etc. relatively freely. I do not think any of these terms can be given a clear and unanimous definition in cognitive science. I choose to use them casually, and hope this use is in accord with the reader's sensibilities.

2.1. *Three statements about 'cognitive science'*

Let us assume for a moment there are coherent disciplines called 'physics' and 'cognitive science.' Compared to physics and many other scientific disciplines, *cognitive science is young*. One could place a relatively conservative date on formalised physics of 1687 with Newton's *Principia*. This makes physics well over 300 years old. Cognitive science, on the other hand, is often associated with the year 1956, when a few interdisciplinary meetings occurred on the topic of information theory and artificial intelligence (Miller 2003). This makes cognitive science about 50 years old. Of course the growth of a science in our time is much faster given the abundant professionalisation of science, and information technology to create and disseminate literatures. But whatever your measure, cognitive science as a recognisable discipline is relatively younger than many sciences, including physics, chemistry and biology. It is also, as discussed below, at least equally diverse in its subject matter. All things being equal, cognitive science is relatively young. Whether it is still in a conception phase, or breaching the walls of puberty, may simply be a matter of personal conjecture beyond assessing relative 'raw' age. Using this very age metaphor, Bechtel, Abrahamsen and Graham (1998) provide a wonderful history of cognitive science that places it well into the pensive teenage years. Again using this metaphor here: Simon's (1992) more optimistic assertion that by 1991 'we know a great deal about human thinking' (p. 150) perhaps puts it into its first postgraduate career, while Fodor's (2001) note that he is 'not inclined to celebrate how much we have so far learned about how our minds work' (p. 5) could put it back into the womb. There is enough confusion about its successes (or lack thereof) to make it seem younger than its peers.

While cognitive science is young, its aspirations are rather grand in scope. As an identifiable discipline, cognitive science is often simply defined as the 'interdisciplinary study of mind' (e.g. in a prominent text on the topic: Thagard 2005). Though simple, this definition obviously invokes a wide diversity of concerns. The second fact about cognitive science is a simple expression of this characteristic: *Cognitive science is diverse*. This is easily evidenced by inspecting well-known textbooks and proceedings in the discipline. Wilson and Keil's (1999) award-winning encyclopedia of cognitive science has an impressive table of contents, with chapters that are merely 'selected topics.' In the psychology section alone one spans low- to high-level processes, from smell to metacognition. By inspecting published proceedings abstracts at the 2007 *Annual Meeting of the Cognitive Science Society*, representative of recent topics taken to the primary cognitive science meeting, one finds an equally diverse range of topics. A passing glance at these documents uncovers high-level cognitive models of navigating the Internet (Fu and Pirolli 2007), recovery from brain damage (Kiran 2007), and inhibiting beliefs (De Neys and Franssens 2007). But just as the age of a science cannot be easily quantified, there would be equal difficulty in quantifying diversity. Clearly, and as a consequence of its interdisciplinary definition, cognitive science is diverse. The range of spatial and temporal scales, measurement 'grain-size' (McCauley and Bechtel 2001), covered by its topics is dauntingly expansive, and bridging these scales is an important part of ongoing scientific activity in the field (e.g. Anderson 2002).

It is also important to note that the diversity of subject matter accompanies a diversity of explanatory goals and methods. The various fields making up cognitive science invoke a diversity of research strategies, from cognitive architecture building (e.g. Newell 1990), to conceptual analyses of consciousness (e.g. Dennett 1991). These not only invoke differing subject matters and theoretical constructs or ideas, they also invoke entirely different research methodologies.

This youth and diversity contribute partly to a third characteristic of cognitive science: *Cognitive science is not theoretical physics*. This (admittedly tongue-in-cheek) statement points to substantial differences in the goals of a young science with diverse subject matter, and the goals of a fundamental physical theory in which broad general laws are sought. For example, the search for a grand unified theory in theoretical physics is famous. There is an outstanding problem of unifying general relativity and quantum mechanics, and it still generates broad public and professional interest (e.g. Lisi 2007). Some cognitive scientists are wont to align their endeavours with those of theoretical physicists (e.g. 'unified theories of cognition'; Newell 1990). As mentioned in the introduction, some recognise three primary approaches available to explain cognition (e.g. Eliasmith 1996, 2003): symbol systems (Newell, Shaw, and Simon 1958; Fodor 1975; Marcus 2001), parallel-distributed processing (Rumelhart and McClelland 1986; Elman et al. 1996), and more recently dynamical systems (e.g. Thelen and Smith 1994; Kelso 1995; Port and van Gelder 1995; van Gelder 1998; Van Orden, Holden and Turvey 2003; Spivey 2006). These frameworks are often contrasted as competing 'grand theories,' each supposedly having underlying assumptions that inherently exclude the assumptions of the other two (recently there has been a move towards reconciling the latter two: e.g. Thelen and Spencer 2003; Spencer, Thomas and McClelland, in press).

There is a problem with the perspective that any one of these approaches captures the full (or even representatively large) range of the diversity noted in the previous fact: they simply, at present, do not have such comprehensiveness. Any one of the theories actually has choice regions of concern. For example, the symbolic approach is still the primary means of explaining high-level cognition, such as reasoning and problem solving. While there may be exciting echoes of dynamical qualities during the unfolding of these processes (e.g. McKinstry et al. 2008), these echoes admittedly cannot yet supply an explanatory framework for the overall patterns of complex behaviour observed in high-level cognition. Each framework, in other words, exhibits a characteristic territoriality in the diverse subject matters of cognitive science. Where there is overlap in these territories, there are those characteristic battles that are considered to be dichotomising points of dissent (e.g. the past-tense debate; Pinker and Ullman 2002; McClelland and Patterson 2002). The theories are thus somewhat grand, and somewhat unified, but typically with respect to some sub-domain of concern.

There are other important reasons why cognitive science is not theoretical physics. First, as Bechtel (1998) notes, cognitive scientists are concerned not just with mathematical laws of explanation (such as in physics), but also with discovering the structures or mechanisms underlying those laws (as in 'cognitive architectures'). This suggests some strong similarities between cognitive science and biology, in which there is articulation of structural entities of a wide range of scale (from cell biology, to organism anatomy).

As biologists examine the structural characteristics of biological entities, many cognitive scientists study the structure of cognitive mechanisms, whether more abstract or neurophysiological in description.

A second reason cognitive science is not theoretical physics is a consequence of accepting this relationship between biology and cognitive science. The biological sciences have for some time recognised the diversity of domains and explanatory schemes. Some have even argued that there will be no such thing as a truly general law in the biological sciences (Schaffner 1993). Recently, Looren de Jong (2002) has noted that psychology (and cognitive science, by implication) ought to face up to the biological complexity of its subject matter. Because biological entities are inherently historical and 'contingent' in nature, it is unlikely that they can supply a true 'time eternal' law. For example, while natural selection may hold as a general process of biological change, its governance over biological forms is entirely subject to historical context: 'The apparent generalisations of functional biology are really spatio-temporally restricted statements.' (Looren de Jong 2002, p. 453; see however Rosen 1999, for an example framework that seeks generalisations.)

These initial three observations consider the nature of current practice in cognitive science. It is young, and by implication likely has much to discover (especially if you believe Fodor 2001). It is, however, diverse, and these discoveries will inevitably take place in a variety of corners that span quite a range of temporal and spatial scales, methodologies and explanatory goals. Finally, those discoveries will not likely come with unified, mathematical laws. They will instead have distinct characteristics, sometimes seemingly quite disparate or even inconsistent when compared across domains. This suggests that plurality may be a characterising feature of cognitive science. A pluralistic approach, in which we embrace and manage that plurality, may help forge new paths of discovery and integration. This is a challenge, and a viable and perhaps necessary option compared to the current standard of choosing one scheme, and asserting comprehensiveness.

2.2. *Three statements about humans and science*

The previous three statements are about cognitive science specifically. While there may be some dispute about the details provided above, it seems difficult to disagree with the notions that cognitive science is relatively youthful, that it has a wide diversity of domains, theories, and goals, and that these differ from those of a theorist in the physical sciences. They form a first sequence of ideas motivating pluralism. This next intuitive path towards pluralism is based on three relatively straightforward statements about humans and science more generally.

The first of these is that *human knowledge is inherently limited*. Despite the occasional (and arguable) assertions about the 'mere' task of filling out the rest of theoretical physics and science, (e.g. Horgan 1997), there likely remains a vast amount to figure out in the sciences, the focus of which lies between the smallest and largest things we can measure. The way that complex entities, of many interacting components, give way to systematic behaviour at middle scales ('mesoscopic' scales; Laughlin, Pines, Schmalian, Stojkovic and Wolynes 2000), holds some potential for new discoveries even in relatively low-level physical systems (see Laughlin et al. 2000, for some examples; see also Section 4.1 below). This first general statement about scientific knowledge is simply the observation that, given the vast complexity of human beings, and their interaction with a complex environment, it is unlikely that we could ever 'know everything' about cognition. The very findings of cognitive science itself reveal deep limitations in our natural ability to reason about and represent the world (Keil 2003). Given these limitations, it seems cognitive science must be content with partial answers in sub-domains of brain, behaviour and environment.

This limitation is more compelling when we consider it in light of a second observation: *Humans are, like many objects of scientific interest, extraordinarily complex*. This is not to say that it is impossible to find domains in which apparently 'simplistic' behaviours can occur (e.g. biases and heuristics in judgment and decision-making; Gilovich, Griffin and Kahneman 2002). Despite such *description* of simplistic behaviour patterns, the range of possible avenues to *explain* that simplistic behaviour is complex: patterns of learning in a person's lifespan, evolutionary considerations, discoveries through social cognitive neuroscience (Gilbert 2002), and even interaction with cultural background (Yates, Lee, Sieck, Choi, and Price 2002). In other words, even when we find behaviours in humans that can appear simple at first blush, they necessarily invoke many dimensions of explanation, spanning multiple spatial and temporal scales, and methods and goals of inquiry. The very existence of stable, systematic behaviour at varying scales is definitive of 'complex' systems science, with that word more technically construed (see Section 4.2). The recent and exciting interest in more thoroughly integrating brain, body and environment into a fuller description of the underlying causes of behaviour, along with the scales of concern in our diverse subject matter and methods, should underscore the notion that our subject matter is vastly complex.

Across the sciences, any theory can be seen as a model or 'representation' of the part world that it is supposed to account for (Rosen 1999; Giere 2004, 2006; Kellert et al. 2006). As described in Section 2, representations can come in such forms as mechanistic schematics for the structure of a physical or abstract entity ('minds'), or as 'covering laws' (Bechtel 1998) in the form of mathematical descriptions. No matter the theory, this final observation is one that expresses an inherent and perhaps *desired* characteristic that each theory has: *All theories are limited in their scope of application*. Kellert et al. (2006) succinctly describe this fact: '[A]ll representations are partial in that any representation must select a limited number of aspects of a phenomenon (else it would not represent, but duplicate).' (p. xv) Those aspects of the world the scientific representation captures (or explains, predicts, etc.) are the scope of the scientific theory, and they all winnow the world into those parts to which it can apply. Newton's laws are about medium- to large-sized objects moving at a relatively slow speed. They can describe the relative path of a human if launched through the air in a particular way and under particular circumstances – but they do not have anything to say about the *words* this human will use to describe the experience. A theory whose worldly parts are relevant to this level of description is obviously needed.

An important part of the philosophy and history of science is determining how scientists choose the scope of their theory, the form these scopes take, and what the consequences are for the development of scientific theories. According to Cartwright (1999), bodies of scientific knowledge are achieved by carefully arranging the world, and noting the consequences of these limited scopes. These careful arrangements, the boundary conditions of a scientific theory, are the contexts in which observations are made, and laws derived. Cartwright dubs these contexts and practices 'nomological machines' – law-making machines – and these are the systems for reliably generating certain systematic outcomes. Laws and other scientific regularities are discovered through these 'machines' by rigidly controlling worldly circumstances, and accounting for the regularity seen in them. She gives a variety of examples, such as the design of Stanford's Gravity Probe, the materials of which were carefully selected so as to fit with known conditions to generate lawful behaviour (she also offers the example of the orbiting planets, their regularity being a kind of nomological machine permitting the derivation of Kepler's laws by Newton).

Based on nomological machines, and case studies in physics and economics, Cartwright (1999) contends that science gives us a patchwork of theories and laws that uncover the *natures* of the universe. She argues that even the most successful fundamental physical theories cannot help us in situations whose conditions are drastically detached from the nomological machines which commonly support those fundamental theories. In one of her illustrations taken from Otto Neurath, she considers letting a thousand-dollar bill get taken by the wind in an open area. Fundamental laws of mechanics cannot predict this complex scenario – they are of 'limited serviceability' (p. 27). Rather, the problem may get shunted into the realm of fluid dynamics, which may 'provide a practicable model' (p. 27).

This second sequence of observations perhaps recommends a stronger form of pluralism. Given the complexity of cognitive science's subject matter, and the inherent limited scope of all scientific theories, any theory in cognitive science will compartmentalise, and carve out its own 'nomological machines,' where assumptions and careful experimental arrangements generate corners of regularity in interactions among human brain, behaviour and environment. As an example of this, Longino (2006) provides a careful analysis of the domains carved by competing accounts of behaviour: behavioural genetics, socio-environmental investigations, neurobiology and developmental systems theory. She argues that these modes of inquiry are relatively complementary in the discoveries they offer, each functioning in temporal and spatial scales of particular subject matter. Such carving of empirical niches is endemic to scientific inquiry, and results in perhaps a more general and persistent recognition of pluralism, as it may already characterise broader realms of scientific knowledge well beyond cognitive science.

3. The possibility of pluralism

The foregoing observations, I contend, provide two motivating paths towards the perspective of pluralism. I hesitated to call these 'arguments' because they are intended to draw the reader's intuition towards pluralism. This will not keep those in disagreement from treating them as having an underlying argument format. To accommodate this sentiment, I offer a translation of the above observations as a condensed argument for the possibility of pluralism. The statements could form the following kind of argument, derived from these paths.

Premise 1: No theory in cognitive science yet has actual comprehensiveness in application.

One may accept this premise from the statements regarding the youth and diversity of cognitive science. The statement about limited scopes of scientific theories also motivates it: it is not a matter of time until there will be some grand theory emerging from the diversity of perspectives. Instead, humans are sufficiently complex that limited theories and their carved domains may contract and expand to some extent, but always remain circumscribed according to the limits scientific theories naturally face (and embrace) given such complexity.

For example, symbolic theories are still the dominant paradigm in high-level cognition. Still, some recent evidence from ours and other laboratories suggests that dynamical description may yet be relevant to high-level cognitive processes, such as decision-making (e.g. McKinstry et al. 2008; see also Stephen, Dixon and Isenhower submitted), but these findings are not yet an application of dynamical descriptions to the typical problems in that domain (but see Townsend and Busemeyer 1989, for a rare counterexample). They do demonstrate the value of continuous, dynamical description in important high-level cognitive contexts (information granularity in action dynamics), but do not yet serve as an 'explanation' of certain high-level cognitive regularities *per se*. Do such continuous descriptions promise to 'take over' this domain of concern? Such statements can only be promissory at present. The issue is whether the overall framework can contact the problems and situations that psychologists who study high-level cognition have framed. Besides some rare examples, this is unattained at present. This fact motivates a second premise:

> Premise 2: It is possible that cognitive theories do not have the representational wherewithal to contact explanatory needs in all contexts of inquiry.

The statement that cognitive science has goals unlike theoretical physics, in which general covering laws make sense, inspires this premise. Rather than identifying theories that span a generalised range of brain, behaviour and environment, cognitive science is in the business of rather more circumscribed theories. In addition, the diversity and complexity of our subject matter, described in both previous sections above, recommend this premise. For example, it may simply not be possible to use some theories in a domain that others are in the habit of explaining. Sharply discrete symbolic descriptions have now been thoroughly discarded as explanations of gait and posture; instead, formalisms from dynamical systems have clearly more relevance and application in that domain (e.g. Kelso and Jeka 1992). Conversely, understanding transitions from equation to equation in a complex algebraic problem in a high-school student is currently more thoroughly explored by these symbolic systems (e.g. Nathan, Kintsch and Young 1992). Both are valid and important problems in cognitive science, but may require different explanatory schemes. Thus, given the statement that scientific theories are inherently, deliberately limited in their scope, urging comprehensiveness may be pressing their limits of representation (in the sense of Giere 2004).

> Conclusion: It is therefore possible that cognitive scientists face theoretical diversity to have comprehensive coverage of their problem domains.

No theory has comprehensive coverage of the problem domains of cognitive science (premise 1). In fact, it is *possible* that theories will be inherently limited in the problems they will have tools to explain (premise 2). It is, therefore, *possible* that comprehensive coverage of our diverse subject matter can only come from combining disparate theories. This article considers this possibility of pluralism, and this conclusion follows upon that modality expressed in premise 2: it is *possible* that cognitive science will have to deal with plural theoretical schemes. The position thus turns on one's acceptance of this second premise. This premise does not insist on indefinite limitations of certain perspectives into the future, but only the possibility that these perspectives may be limited in their contact to the diversity and complexity of cognitive science's concerns.

This second premise could be changed into a statement regarding fundamentalism: that it is possible one theoretical scheme will be identified in the future. This would motivate a conclusion that cognitive science faces the puzzle of achieving comprehensiveness, and that it is therefore possible. Of course, this route is already the more common one for theoretical debates in cognitive science. The avenue of pluralism is much less explored. If one accepts its possibility, or even its probability (exchanging 'possible' with 'probable' in premise 2 and the conclusion may be acceptable to some), then its consequences should be considered seriously by anyone who wants to see progress in cognitive science's attainment of explanatory success.

We are left with a problem of plurality (at least, as a serious and lesser-entertained possibility). Devising a systematic scheme for integrating these plural theories, domains, goals, etc. is thus a potential challenge that is not as widely recognised as one might hope. As noted in the introduction, some may see this as obvious. Others may find its result can only be a messier cognitive science. The thesis, however, is not meant to be a negative one. Accepting the potential for pluralism recommends an array of meta-theoretical activities that may help manage theoretical diversity, and as Kellert et al. (2006) note, avoid prolonging debates that may otherwise be reconciled. It may also recommend richer representational perspectives on language and other cognitive phenomena, accepting the place of multiple kinds of mental representations and processes rather than urging just one (e.g. Louwerse in press; Weiskopf in press). I consider these programmes of research systematically in the next section.

4. Possibilities for a pluralist cognitive science

These pluralist recommendations so far may appear as a form of relativism, a 'complacent family' approach to cognitive science, in which there is broad acceptance and admonition against open dispute. The recommendations could also be interpreted as advocating a nihilistic stance towards generalised theories in cognitive science – a sorry retreat from the idealistic but compelling strategy of maximal generalisation and unification in science (see Weiskopf in press, who argues against theoretical nihilism). Such immediate interpretations are too extreme, and one could argue that they exemplify the tendency towards binary oppositions described in the introduction. Rather than having just these two options (fight for frameworks vs. relativism/nihilism), the possibilities pluralism presents are much more detailed. I argue in this section that pluralism can be regarded as a positive thesis for cognitive science, and can recommend a variety of research strands. Some of these strands are already being carried out, while others I hope hold some promise for the future.

Embracing a diversity of subject matter and the corresponding diversity of methods available to investigate it offers an epistemological framework similar to that recommended a half-century ago by Dewey and Bentley (1949). Dewey and Bentley's system for organising scientific knowledge emphasises *cooperative* and *transactional* inquiry. Dewey and Bentley refer to *cooperative* inquiry as commonly construed, as 'integral with communication' amongst scientists (p. 97). Their idea of *transactional* inquiry is subtler. It involves the recognition that the object of inquiry and its environment are part of one system whose parts transact. Shaw and Turvey (1999) note the significance of this perspective for theories of cognition in organism–environment transactions. Dewey and Bentley intended the term to go beyond simply recognising the organism–environment as an integrated system, however. They also meant to include the person doing the 'knowing' in this frame – both the knowing and the known. In other words, they recommended a programme of contextualising inquiry by attending to the very situations and problems that the knower herself faces (something Shaw and Turvey 1981, take as a central idea; see also Van Orden, Kello, and Holden in press). I will elaborate on this perspective in later sections of this article, and tie this in with a variety of pragmatic perspectives that make strong recommendations for theoretical pluralism.

In Suppes' (1981) now-classic picture of pluralism, he offers stark statements about the growing heterogeneity of scientific inquiry, and encouraging the pragmatic perspective that 'scientific activity is perpetual problem solving. No area of experience is totally and completely settled by providing a set of basic truths; but rather, we are continually confronted with new situations and new problems, and we bring to these problems and situations a potpourri of scientific methods, techniques, and concepts.' (p. 14). Before resigning cognitive science's diverse accounts to the status of a 'potpourri,' the following sections consider some integrative strategies in a pluralistic cognitive science. The first section considers how accounts apparently in dispute may take emergentism and complex systems seriously by embracing diverse regularities that emerge out of organising principles. This permits co-existence of theories, and encourages ways of identifying their relationship. The second section presents a variety of proposals for achieving theoretical integration. These meta-theoretical strategies may again permit apparently competing theories to co-exist, and establish means of relating them and identifying where they apply (and where not). The third section considers two kinds of methodological integration, in hybrid systems that generate intelligent or interesting behaviours, and in the analysis of complex, multi-dimensional data.

4.1. *Emergentism and mesoscopy*

Complex systems and the notion of emergent properties are thoroughly entrenched across several disciplines, including physics, biology and philosophy. A complex system is one with many interacting units whose joint behaviour generates some collective properties of the overall system that those individual units do not possess (Anderson 1972). More detailed definitions of both 'complex' and 'system' are diverse and disputed (see, e.g. Edmonds 1999, for connotations of 'complex'). Nevertheless, all such definitions seek to characterise a context in which emergent properties can be described by laws that look quite different from those that govern the system's constituents. Such systems display order through self-organisation. A classic example is the convection rolls found in oil that is heated in a pan, described eloquently by Kelso (1995). When conditions are just so, the oil forms coherent patterns of behaviour in the form of dynamic undulating rolls. The emergent behaviour thus invites new vocabulary and mathematics that characterise it over and above the units that compose the oil. Another example is mathematician John Conway's Game of Life, used recently by Dennett (1991) to argue that collective action even under simple rules can generate regularity at the system level that demands novel descriptive schemes seemingly independent of the lower-level entities that interact. This 'game' is based on very simple update rules for a spatially organised grid of pixels (thus being a cellular automaton; see also Wolfram 2002, for many examples). Depending on the initial configuration of the grid, elaborate and dynamically moving 'higher-level' sets of pixels move about the terrain in ways that seem to demand new, emergent descriptions. There are innumerable other examples of emergence in the physical and life sciences (e.g. see Kauffman 1995).

Recently, Laughlin et al. (2000; see also Laughlin and Pines 2000) have proposed that novel organising principles may hold at a diversity of scales between quantum effects and macroscopic physics. In these middle scales, at spatial and temporal scales between these extremes (in some cases referred to as the 'mesoscopic' scale), there may be self-organising properties that require new laws to describe their behaviour. An example that has generated much interest recently is the behaviour of complex bio-molecular structures, such as folding proteins. They note that two clearly delineated classes, some complex proteins that fold and others that do not, emerge out of large assemblies of amino acid sequences. Such regularities may be the subject of mesoscopic laws at the level of complex biological structures. More recently Laughlin (2005) has laid out a broad consideration of these issues – fundamental laws and organising principles – arguing for the important role of emergent, collective properties at diverse scales as a fundamental basis for much of our scientific knowledge.

There are indeed consistent emergent patterns across different complex systems and scales. Much of the excitement for emergentism derives from the observation that, in very distinct systems, similar organising principles are found. One prominent example is fractal scaling, in which certain system fluctuations can be characterised in the same way mathematically independent of the spatial or temporal scale of measurement (e.g. different lengths of ordered reaction-time measures; Van Orden et al. 2003). This scaling principle also seems to hold across a vast range of different systems (from highway traffic to economic fluctuations; see Li 2002). Recently, Jacobson and Wilensky (2006) and Goldstone (2006) recommend the use of these consistent principles to improve learning and transfer in students of the sciences. Nevertheless, despite the existence of some crucial consistent emergent principles, it is also true that there are disparate principles in different systems – not all emergent properties are universal.

Some have argued that complex systems research in fact supports a particular theoretical perspective over others (e.g. van Gelder 1998). However, when looking for such emergent properties, if 'simplistic reductionism' (Shaw and Turvey 1999, p. 111) is to be avoided, then it cannot be urged *a priori* what kind of organising principles will be useful in describing certain characteristics at differing scales. The very acceptance of emergentism in complex systems argues for this. From selection of scale or 'grain' (Bar-Yam 2004; Shalizi 2004) to selection of a measurement framework (Crutchfield 1994; see also Van Orden et al. in press), there may be differing but equally valid emergent principles for these measurement and scale contexts. As we further consider below, there are mathematical frameworks such as symbolic and computational dynamics that may permit more 'classical' symbolic descriptions to serve as analyses of dynamical systems. Which analysis you choose depends on how you choose to carve up the system under study.

There are a variety of issues associated with emergent properties I will not discuss here, but point to them for the reader. Some suggest that emergent properties carry their own causal forces in the complex system, thus revealing a kind of 'downward' causation (Campbell 1974). In addition, others argue that the entities or constructs identified at the higher temporal scale enjoy a kind of 'autonomy' epistemologically or ontologically. Fodor (1975) and other functionalists famously argued for this autonomy of mental descriptions, using multiple realisability as a primary premise. I do not wish to espouse any of these theses for the purpose of pluralism. I point out that at least epistemologically – with respect to the task of explaining and predicting a complex system – organising principles emerge richly over lower-level interacting entities.

What does emergentism recommend for cognitive science? On the one hand, it suggests that debating perspectives may be misguided by neglecting levels of analysis – the assumptions, goals, and scales of measurement (see Edelman, this issue). Instead, descriptions at different scales may be linked by identifying how emergent properties derive from lower-level interactions. McCauley and Bechtel (2001), for example, propose a heuristic identity theory that recommends a linking of concepts across theories not only to explore possibilities for reduction (or elimination), but also to have theories mutually inform each other at varying levels (which, they argue, is the norm in scientific practice and progress). Bechtel and Mundale (1999) challenge the multiple realisability premise by suggesting that rich interconnections between high- and low-level approaches can further our understanding of cognition. According to Bechtel (2001) the localisation and decomposition of mental function into neural substrate can also fit with dynamical analyses that are sometimes considered to gainsay such a mechanistic strategy.

In the specific case of language structure, for example, the computational approach of Tabor (2001, 2002) may open new avenues of identification across symbolic and neurocomputational explanatory schemes as accounts of linguistic structure. Another exciting possibility is found in Kloos and Van Orden (in press), who argue that self-organisation in highly interactive systems permits the emergence soft-assembled mechanisms (see also Smith and Breazeal 2007). Soft-assembly describes how system components fluidly coalesce under particular functional constraints, such as performing separate tasks. The brain-body system, under given task constraints, may soft-assemble into a 'mechanism' appropriate for relevant cognition and action, such as in reaching behaviours, or even perhaps higher cognitive task performance. Such a line of research may contribute to understanding how the emergence of differing behaviours look the way they do in such diverse contexts. This approach could also contribute to explaining the plurality of conceptual representations that humans exhibit under varying task constraints (Weiskopf in press).

Importantly, collective characteristics of complex systems enhance the recognition that handling multifaceted, multileveled explanatory principles is likely the norm in a system as complex as human beings (and their complex context). Emergentism suggests that theoretical co-existence may be a necessary consequence of the diverse schemes of measurement for that complex system of the human brain, body, environment and their interaction. Importantly, this does not imply autonomy of these schemes. The lines of research described in the previous two paragraphs suggest instead that linking across these co-existing schemes, across goals and levels, may be an extremely productive avenue. The next section considers further such examples.

4.2. *Theoretical integration*

The previous section considered embracing potential diversity in the emergent properties of a complex system. The upshot may be the identification of which explanatory schemes are suitable for particular domains of measurement of that system. I argued briefly that it is nevertheless important to link these frameworks, and provided a brief review of avenues that are currently being pursued. In this section, I consider broader frameworks that show how apparently divergent schemes of explanation are in fact intimately related or even equivalent under particular conditions. These frameworks provide integrative theoretical contexts permitting not just the embracing of diverse modes of explanation, but showing that they may be at root intimately related in a way that permits a 'rapprochement' (Mitchell 1998).

One prominent theoretical distinction drawn amongst existing accounts of cognition is based on the spatial and temporal characteristics of the proposed underlying states and processes (Dale and Spivey 2005). In one family of accounts, theories may be classed as 'continuous-distributed' in that they see cognition as a continuously changing parallel process. These are typically modelled in the form of neural network models that often approximate continuous time using iterative functions, or systems of differential equations as urged by van Gelder (1998). In another family of accounts, many theories can be described as 'discrete-symbolic,' in that states transition discretely in time, and instantiate temporally and spatially discrete symbols upon which operations are applied. Such models are the progeny of the 'classic' physical symbol system hypothesis and associated models (Newell, Shaw, and Simon 1958). These two theoretical families are often pitted as fundamentally distinct, each having assumptions that radically violate those of the other.

While the approaches do appear vastly different, and as described in previous sections, are applied to quite different subject matter, the fundamental temporal and spatial assumptions can in some cases be shown to be dependent only on choice of measurement for a system under study. Through a now-prominent mathematical framework dubbed 'symbolic dynamics', both systems of measurement can be shown to have important qualities of equivalence in the limit (see Edelman, this issue; Dale and Spivey 2005). A conceptual description of this is rather straightforward to convey (for more detail see Dale and Spivey 2005): carve up a dynamical system's state space, assign symbols to different regions of that space, and output a sequence of symbols as the system assumes a trajectory through those regions. Well-established theorems now show that certain characteristics of the original dynamical system (e.g. chaos) can be shown to hold in the (often assumed infinite) symbol sequence. In other words, discrete and continuous characterisations have equivalence relations through symbolic dynamics.

Even in real-world contexts, discrete symbol sequences can be extracted from a semi-continuous time series from natural systems. The symbol sequences can then be subjected to a wide variety of analyses to characterise both its dynamic and computational features. Crutchfield (1994) shows that the resultant symbol sequence can be given a description based on traditional-looking notions from machine learning and computation (through an overall framework he dubs 'computational mechanics'; Crutchfield 1994). Mitchell (1998) offers an elegant demonstration of cellular automata whose functioning requires both dynamical and computational formalisms – but each perspective is individually useful depending on epistemological goals, and only together provide a comprehensive understanding of these complex systems. These along with other pursuits (e.g. discretising EEG signals; beim Graben, Frisch, Fink, Saddy, and Kurths 2005) show that the apparent difference based on these spatiotemporal assumptions may be more a matter of measurement choice, and their divergent aspects could be integrated in a mathematical framework.

Symbolic dynamics may hold promise for integrating continuous and discrete descriptions, but it remains largely outside the domain of cognitive science. Recently, Smolensky and Legendre (2006; see also Smolensky 1995) have already provided an overarching theoretical framework for accomplishing just that. Their integrated connectionist/symbolic (ICS) architecture is based on the very idea that different analytic strategies may be carried out over a system. A symbolic account based on rules and discrete constraints can actually be derived from low-level neurocomputational descriptions. While the ICS architecture has detractors (see, e.g. Fodor 1997 for a critique), the impressive volumes of Smolensky and Legendre (2006) demonstrate the potential for an integrated account of classical and connectionist frameworks. Despite a focus that is primarily on language, the authors recommend in numerous places (e.g. Smolensky and Legendre 2006, Chap. 3) that the ICS architecture may serve to integrate disparate frameworks in other cognitive subject matter.

At an even broader scope of consideration, Kelso and Engstrøm (2006) discuss the tendency for both scientists and non-scientists to organise the universe into dichotomies. They lament the oft-adopted strategy of choosing one side of the dichotomy at the intended and entire expense of the other. They argue instead that the two sides of many dichotomies ought to be regarded as complementarities in a condition of mutual dependence. A now-common example of this strategy is the wave-particle duality that quantum phenomena exhibit. Kelso and Engstrøm note that most physicists have accepted this as a complementarity in that the two frameworks co-exist, and depend only on the mode of inquiry for showing that one or the other characteristic of quanta hold. The authors actually derive the tendency to dichotomise – both as tendencies in human epistemology and the human brain's physical dynamics itself – from self-organising patterns of coordinative dynamics. This is, therefore, ultimately rooted in dynamical systems notions of coordination, but their framework is intended to 'free us from the antagonism of opposites, the either/or mind-set that has dominated Western thinking throughout the ages.' (p. 76) Even if this is indeed the grandest of those reviewed in this section, such an integrated framework, like that of symbolic dynamics or the ICS architecture, may perhaps permit a moving beyond about some of the binary oppositions in cognitive theorising.

4.3. *Methodological integration*

The previous two sections suggest some elegant solutions to the problem of pluralism. In emergentism, we can seek out properties and principles that emerge out of the complex human-environment system. This may encourage diversity, but through complex systems science provide strategies of inter-linking frameworks. In the related strategy of theoretical integration, a bringing-together of apparently disparate accounts may be achieved through meta-theoretical frameworks that permit derivation of multiple accounts. In this section, I consider two concrete but important reasons pluralism may be needed to make valuable contributions to cognitive science. Both again relate to the deep complexity of its subject matter. The first is the need to devise systems that show the kind of behaviour most often associated with 'cognition': intelligent problem solving and decision-making. The only way this can be accomplished at present is by permitting apparently divergent models of cognition to act in combination in hybrid systems that explore how such systems hang together to exhibit complex behaviour. The second reason is the richness of behavioural data now filling vast digital repositories. Diverse multi-dimensional behavioural data collected during such tasks as conversation may involve such measures as physiological data, eye-movement patterns, word selection, and topic choice as conversation unfolds (e.g. Louwerse, Jeuniaux, Hoque, Wu, and Lewis 2006; Roy et al. 2006). These data sets span multiple timescales, and imply descriptions that may inhabit both fine- and coarse-grained regions of these timescales. It is important to employ integrated methodologies to characterise the interplay among these multi-scale measures.

In the first case, hybrid systems are virtually the sole artificial systems that produce anything akin to high-level cognitive processes. A prominent example is SOAR (Laird, Newell, and Rosenbloom 1987). While traditionally a fully symbolic model, Laird and colleagues have integrated a diverse set of representational schemes to accomplish a growing set of complex tasks in simulated agents. For example, Wintermute and Laird (2007) integrate quantitative spatial representations of a task environment (violating the assumption of purely disembodied informational structures traditional in symbolic architectures) with symbolic predicate representations to help simulated agents avoid obstacles in a real-time strategy game (see also Lathrop and Laird 2007). This architecture and others are perhaps not 'unified theories' as commonly understood, but rather 'pluralist architectures' that help us understand how particular structures and processes hang together to produce interesting and complex behaviours. There are other prominent examples found in Sun (1997), Anderson and Lebiere (1998), Franklin and Patterson (2006) and of course Jilk, Lebiere, O'Reilly, and Anderson (this issue). Whether one attributes 'theory-hood' to these systems, or refers to them as a sort of 'engineering hybridism,' it is nevertheless an important enterprise to integrate multiple schemes of explaining behaviour to solve the problems these researchers pose. Some artificial intelligence researchers have recommended moving away from complex representational schemes (e.g. Brooks 1991), but the results of pure instantiations of this approach so far are primarily existence proofs of rather low-level processes (e.g. locomotion; Brooks 1989). Though these are very impressive as existence proofs, it remains a relevant, real problem to generate systems that function intelligently. Plural systems are currently the rule.

In the second case for the methodological need of pluralism, cognitive scientists are now faced with vast repositories of multi-dimensional behavioural data. It will likely be an important avenue of methodological development to find ways of reconciling diverse descriptions to integrate them in investigating the coordination among these many dimensions of behavioural data. I offer one example from my laboratory on integrating high-level linguistic descriptions based on statistical characterisation of meaning (latent semantic analysis; Laudauer and Dumais 1997) and a method rooted in the analysis of complex, noisy dynamical systems (cross-recurrence quantification analysis; Shockley, Santana, and Fowler 2003; see the collection in Riley and Van Orden 2005, for an excellent introduction to these methods). This is ongoing research that aims to quantify the semantic interplay between conversation partners using dynamical methods (Dale and Duran in preparation).

To use the word-semantic framework, we are taking transcripts of words used in conversation and representing them as high-dimensional vectors that serve as approximations of word meaning derived from distributional information of these words in texts (calculated from very large databases of text). Each word thus has a high-dimensional vector in semantic space, and stands in that metric space as close to or distant from words that are similar or different in meaning, respectively (often, a cosine measure is used to compare these vectors).

By extracting the sequence of words used by conversation partners, we then have a time series of these vectors, and subject them to an analytic framework that allows the quantification of trends of recurrent word or word-pattern usages. We are therefore able to quantify the extent to which two persons are coordinated in their meaning – allowing an exploration of 'semantic synchrony.' This is only possible because we open our analysis to both statistical linguistic descriptions and characterisations taken from analysis of dynamical systems. While I use this as an opportunity to note ongoing methodological integration in my own laboratory, there are other developed frameworks worthy of discussion. In an important instance, Eliasmith (2003) argues that cognitive functioning of the brain, extraordinarily complex and multi-scale in nature, ought to be investigated with all the computational tools at the disposal of cognitive scientists (to be drawn from all three commonly recognised theoretical frameworks). He discusses an elegant array of analytic armaments to accomplish this task, based primarily on representational and dynamical concepts (dubbed 'R&D' theory) in neurocomputational models and modern control theory. The aim is to help the field move beyond mere metaphors and into concrete analysis already well-established in other fields that study complex systems (see also Eliasmith and Anderson 2003, for a full presentation of the theoretical and methodological framework).

These two strategies of methodological integration are no less important than the more theoretical strategies described previously. They tackle real problems of both applied and theoretical value in order to understand cognitive functioning, at multiple levels of description. The limitations of any individual theory may be assessed to a valuable extent when subjected to these challenging simulation and analysis contexts.

4.4. *Summary*

The following avenues for a pluralistic cognitive science were recommended in the foregoing sections: diversity but linking through complex systems, theoretical integration to derive diversity, hybridism and analytic integration. All to some extent have exemplary research programmes in place. These are not programmes of sheer relativism or nihilism. They are perhaps better termed 'integrative pluralist' frameworks (Mitchell 2003, 2004), in that they offer modes of inquiry that do not lean on fundamentalism as a needed epistemological tenet for progress. Instead, they allow cognitive science to embrace a broader scope of theories to help predict and explain brain and behaviour in the various contexts in which they take place, and the diverse measurement schemes we have available to carve them up.

5. Conclusion: cognitive science without ontology

I start this concluding section with a very simple thought experiment. Imagine the following scenario. A man wanders up to you on a Memphis street and tells you he has '...discovered it all,' then points westward and says he has 'a theory of the Mississippi.' If such a thing were actually to happen, you might respond (if you chose to) in at least two ways. If dismissive but needy for entertainment, you could roll your eyes, take to this curious proposal, and ask, 'Oh yeah, what is it?' then listen intently. Another response may be the following: 'What do you mean? What about the Mississippi? What aspect?' You might furrow your brow when considering the proposal seriously. The very idea of a *Theory of the Mississippi* seems strange. The Mississippi is a complex 'entity.' From very fine-grained ecological aspects, to relevance to human industry and geological history, the river has characteristics that span a vast range of concerns. If some of the foregoing discussion in this article is accepted, this extremely simple scenario captures perhaps the very sentiments one should have if such a person were to wander up and state: 'I've discovered it all: I have a theory of cognition.' A similar response would take the form: what about cognition, what aspects? Cognition, as identified with the functioning of our brain-behaviour-environment system, is extraordinarily complex just like the Mississippi. It is also, as described in the previous sections, subject to a wide variety of explanatory concerns and methodological techniques. These collections of ideas and techniques tend to focus on *particular* aspects of cognition.

A turn of phrase is often used to qualify these aspects of cognition that scientific research investigates or identifies: They are studied 'from a . . . *perspective*'. Interestingly, words that sometimes travel with 'perspective' include 'slogans' and 'commitments' (e.g. van Gelder 1998), but these differ markedly from what 'perspective' connotes. Slogans are simple and fixed expressions. Commitments can fix a set of beliefs. Perspectives instead vary, and derive from standpoints of observation. As in our own visual experience in everyday contexts, where you stand or how you hold an object can change the way it appears. It is perhaps in this sense that competing theories of cognitive science serve as perspectives. The observer dictates the regularities that emerge as soon as he or she sticks her measurement devices into the system (Van Orden et al. in press). Giere's (2006) perspectival approach to a pluralist science is based on exactly this intuition. By exploring the case study of human colour perception, he argues that certain apparently inconsistent perceptual standpoints cannot be ascribed with rightness or wrongness – they are simply different. Giere intends this case study to be a broader lesson for science. The various frameworks on offer for exploring different phenomena, from physics to cognitive science, offer perspectives. One is a pluralist in cognitive science if it is believed that human cognition is sufficiently complex to admit of multiple perspectives that may appear inconsistent, but cannot be distinguished in terms of correctness.

As mentioned in Section 4, Dewey and Bentley (1949) proposed a system of organising scientific knowledge that emphasises the role of the active participants in that knowledge. This 'transactional' approach to epistemology encourages the integration of scientific vocabularies into the particular contexts of their use. The contexts are the problems and situations faced by these participants. Their notion of transaction is rich and nuanced, and Dewey goes to some length to ensure it is not misinterpreted. One important feature of transactional activities is the central role of observation as an activity that includes 'the observer, the observing, and the observed' (p. 131). While this pragmatic system and its suggested vocabularies for the sciences can seem archaic in many places, its recommendations are deeply relevant to current discussion. The results of these scientific transactions are urged to have freedom 'to select and view all subject matters in whatever way seems desirable under reasonable hypothesis, and regardless of ancient claims on behalf of either minds or material mechanisms, or any of the surrogates of either' (p. 137).

It is here that perhaps fundamentalism differs sharply. Holding that there is a final theory of cognition is akin to saying that there is some fundamentally correct and comprehensive perspective on *what cognition is*. When one espouses such a viewpoint, it is a natural consequence to reject (or relegate as crude approximations) all other perspectives that may characterise aspects of cognition differently. Is this because a system cannot be two kinds of things at once? We now know that even at the level fundamental physical descriptions this is not true. In a system as complex as human beings, variable perspectives may produce seemingly variant patterns and principles that are nevertheless individually valid and useful in particular situations and problems.

The title of this final section is adapted from Putnam's recent book *Ethics without Ontology* (2004). In it, Putnam argues for taking up this Deweyan approach to problems of human science, philosophy and society. The central idea of this collection of lectures is to challenge the notion of ontology as a useful enterprise to help these problems. He discusses 'the supposed philosophical subject of Ontology – which I have been discussing implicitly all along as well, by arguing that it does not *do* anything for us in ethics or philosophy of mathematics or philosophy of logic or theory of scientific method – and pronounce an ''obituary'' upon it' (p. 70, original emphasis). Fundamentalism seeks a foundational ontology for cognitive processes. If cognitive science were to take Putnam's advice in its own problem domains, and reconsider the notion that theories are inherently meant to capture things that 'exist' in some fundamental sense, then a plural approach to cognitive constructs and processes becomes more possible. To query whether some theoretical entity 'really exists' assumes that 'exist' has some one coherent meaning in scientific contexts – but statements containing the word 'do not have a single absolutely precise use but a whole family of uses' (p. 37). Over a century ago, another pragmatist and forebear of psychology considered such problems of finding some fundamental word or notion to solve a fundamental metaphysics:

> But if you follow the pragmatic method, you cannot look on any such word as closing your quest. You must bring out of each word its practical cash-value, set it at work within the stream of your experience. It appears less as a solution, then, than as a programme for more work, and more particularly as an indication of the ways in which existing realities may be changed. *Theories thus become instruments, not answers to enigmas, in which we can rest.* (James 1904, original emphasis)

The purpose of this article was to consider the possibility of pluralism in cognitive science, and offer some of its positive possibilities. Through these pragmatic philosophers, a pluralistic approach to a very complex domain of problems has a strong philosophical underpinning. A cognitive science without ontology focuses instead on theories as tools carefully concocted to solve particular problems or handle particular situations. Theories are born out of transactional relations between the scientist and his or her subject matter.

Neisser (2002) seems to lament this potential turn in the field, already occurring to some extent through the increasing focus on particular, local psychological problems: 'In the coming era of cognitive neuroscience and connectionism, perceptionists would find it more rewarding to seek concrete understandings of well-defined phenomena than to pursue vague and broad generalisations. Maybe they are right' (p. 165). A further goal of this article was to supply some review of and recommendations for solutions beyond resignation to sheer locality. Through what may be termed 'dynamical integration,' a focus on the emergent characteristics of complex non-linear systems, and relevant explanatory schemes based on their analysis (e.g. symbolic dynamics), a plural approach may nevertheless have some roots in theoretical integration. I reviewed ways of assembling concrete solutions into simulations and analyses that may help make new discoveries, and unveil new avenues of investigation.

While my own research seeks dynamical description of complex behaviour (e.g. McKinstry et al. 2008), my aim was to persuade about the possibility of taking pluralism seriously. As a viable stance on handling multiple theories in the field, it may have useful and interesting consequences for cognitive science. The hypnosis induced by one conceived ontology of entities and processes for cognitive science can cloud this recognition. I hope nevertheless to have convinced, at least to some extent, that pluralism is a viable dialectic alongside the more prominent, current one.

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