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Dissipation, Integration and Practical Pluralism: The Case of Cognitive Science

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1. Background and goals

In a summary of their Nobel-winning work, Laughlin and colleagues (2000) critique a lingering dogma among many practicing scientists, that "[k]nowledge of the underlying physical laws alone is sufficient for us to understand all things, even ones that cannot be seen." (p. 32). Such is the clarion call of theoretical fundamentalism, the notion that there is (or will be) a single coherent, closed-form theory permitting us to understand all things at once. It sustains a prevailing cultural cachet, perennially illustrated in the physical sciences and its associated popular writings on cosmology, quantum theory, the strum of high-dimensional strings, and so on ("[t]he lure of reductionism is strong", Greene, 2020, p. 68; cf. Teller, this volume). This fundamentalism ("monism," "unicity of representation," etc.) is a bold goal, with captivating historical examples. However, despite its alluring properties, we have enough evidence to cast doubt upon it. For instance, Suppes (1978) observed that if we treated humanity's scientific activities as a source of data about science itself, we see a proliferation of new problems, new theories, new methods, and new ideas, with little abatement (cf. Anderson, 1972). Such is the clarion call of theoretical pluralism. Various versions of pluralism have been articulated by many, and about many domains (Anderson, 1972; Atmanspacher & beim Graben, 2007; Butterfield, 2011; Cartwright, 1999; Crutchfield, 1998; Dale, 2008; Dupré, 1993; Giere, 2010; Horst, 2014; Kellert et al., 2006 and chapters therein; Laughlin, 2005; Looren de Jong, 2002; McCauley & Bechtel, 2001; Mitchell, 2003; Smolensky, 2012; Zwaan, 2014).

All this may be old news to the reader of this chapter. Yet pluralism has not achieved the kind of cultural sway that fundamentalism has. One reason for this, as noted in the introductory chapter to this volume, is because these accounts of pluralism rarely intersect, especially across disciplines. The value of the present volume is to create connections across disciplines through specific pluralist ideas, not merely by juxtaposing our accounts but by elaborating on potential relationships and their associated benefits. Pluralism is not simply remarking on the mixture of theories and their debates across the sciences. Instead, pluralism might do something for us. At a minimum, it has three such practical implications: for advancing (i) theoretical debates within specific fields (Teller, this volume, and the current chapter; Horst, 2007, 2016), (ii) pedagogy of various kinds (Bascandziev, this volume; Bélanger, this volume; Mortimer et al., this volume), and (iii) scientific culture more broadly (Ruphy, this volume; Shtulman, this volume). These seem like viable normative goals if one adopts pluralism.

In this chapter, we focus on (i), the theoretical usefulness of pluralism. We are interested in how a robust pluralism could influence theoretical debates in different scientific fields. Our area of expertise, cognitive science, will serve as the primary vehicle for our discussion. To organize this discussion, we identify a tension that simmers under much work on pluralism, between "dissipative" and "integrative" pluralism. The former highlights differences among theories, seeing proliferating accounts of even similar phenomena as drifting apart, taking on their own character. A purely dissipative pluralism would lead to distinct accounts for virtually every single

observable phenomenon. In contrast, integrative pluralism highlights potential similarities and seeks to link theories by various formal or informal strategies. In an extreme form, an integrative pluralist may invest too much in seeking overly abstract linkages that account for very few specific phenomena or get caught in an attempt as futile as the fundamentalist's to integrate over all our diverse knowledge, but in ever more abstract ways.

This tension relates to the usefulness of pluralism, such as to do work for us cognitively (cf. Horst, this volume). As noted in this volume's opening remarks, integration is cognitively effortful, and a more dissipative approach may be both justifiable on explanatory grounds and more cognitively efficient. Our discussion here resonates with several other chapters in this volume, as we see many corresponding concepts throughout, including explanatory coexistence heuristics (Friedman & Goldwater, this volume; Legare & Shtulman, 2018), compatible vs. incompatible pluralism (first few chapters of this volume), and cognitive pluralism and incommensurability (Horst, this volume).

This tapestry of possibilities for pluralism suggests that the tension between dissipative and integrative approaches reflects a plurality in itself. This is best illustrated through (ii), the practical pedagogical elements of pluralism. It is common to ask students to contrast or compare ideas or theories, and an instructor can vary the extent to which a task highlights differences or similarities. The tension, in the pedagogical context, is more like a "dial" that can be turned up or down to encourage particular ways of thinking. Settings on the dial may have distinct benefits for different situations. By analogy, the same may be said for the focus of this chapter: Practicing scientists may choose to sharply distinguish theories as being on completely different levels of inquiry or to invest the cognitive effort to integrate them. They may vary this strategy, too, with related theoretical and cognitive costs and benefits.

The chapter is organized as follows. Before we turn to cognitive science to illustrate this distinction between dissipative and integrative pluralism, we will first flesh out a particular recursive consequence of plural thinking. This aside will then motivate the discussion of dissipative and integrative plurality. We focus on cognitive science as an illustration of how these strategies have influenced it, and where there may be untapped practical consequences of pluralism. We argue that integrative pluralism has been insufficiently explored for theories of complex cognitive phenomena. Adopting pluralism in general, especially an integrative approach, may have benefits and we illustrate some of these. In our conclusion, we return to the core ideas of the present volume and discuss implications for pluralism more broadly.

2. Pluralism[Pluralism]

In this section, we argue that when a scientist adopts pluralism as a strategy to understand some phenomenon, then that scientist will have to decide what *kind* of plural thinking is required: a second-order pluralism. When a thorough pluralism is adopted, one cannot assert which of these variants of pluralism should be favored in absolute terms. There are at least two arguments for this entailment, framed concisely here:

> *Argument from generalization*. If scientific problems are typically complex enough that multiple accounts are required to fully grasp an answer to them, then *assessing* that mixture of relevant scientific theories itself may be subject to multiple second-order perspectives. If one accepts that there is a similar challenge in assessing how plural accounts are moderated themselves, then this second-order concern — moderating that moderation — motivates precisely the same plurality.
>
> *Argument from application*. When one accepts that plural perspectives emerge from a mixture of enticements, goals, constraints, and limitations of a specific scientific context, then we can simply point out that the second-order pluralism is itself subject to the same contextual features. In other words, second-order theorists (such as philosophers of science) may differ in how theories ought to be combined *for specific second-order contexts*. Thus, depending on one's overall epistemological goal and other contextual factors, different sorts of theoretical combinations may be called for.

These arguments frame a recursive problem. Pluralism is a kind of epistemological stance that naturally cascades on the conditions around a discussion itself. A pluralist may set out a range of conditions (e.g., the value of compatible vs. incompatible variants), and a conversation partner may say "There's an alternative view of that distinction" or "You're missing a third possibility" or "That's quite wrong, here's a better framing." It leads to a kind of recursion that requires the pluralist to debate the theoretical variety of a given subject matter and the manner of debate itself. Here we see hints of why monism remains a dominant theme in wider scientific culture. The narrow normativity of a monist is highly restrictive, casting debate partners into a kind of singularity, where matter and mode of discussion are taken ideally to converge themselves, too. It is understandable that the hope for convergence would be normally preferred to proliferation.

These reflections imply that there will not be a single plural variant, even within a circumscribed domain or phenomenon. Using terms from the introductory chapter to this volume, we can call this a generalization of the minimal pluralist thesis:

> p_m* (minimal pluralist thesis, *generalized*): In many cases, agents navigate a plurality of distinct and at least partially incompatible pluralities about a phenomenon, each having a range of contexts or conditions where it is legitimately or preferentially used.

Again, this is because a robust pluralism itself applies across orders of explanatory complexity, including pluralist accounts themselves. Put simply, if one asserts that distinct theories may be embraced for distinct phenomena, goals, etc., then similarly distinct manners of pluralism over them may be adopted for distinct epistemological aims at a second (or third, etc.) order of complexity.

This perspective necessitates a more practical aim for pluralism, even at these more abstract conditions, to determine how one should compare, contrast, integrate, etc. competing accounts. It

is, therefore, possible to overemphasize one plural strategy over another. Because representational[1] pluralism has a distinct pragmatic flavor to it, we can similarly take a pragmatic strategy to these second-order explanatory aims. If one has a particular epistemological aim, then it may be valuable to adopt a robust dissipative approach (in which one assesses distinct theories independently). Under another aim, integrative approaches may be better (in which one sees value in the cognitive effort).[2] And this may be true in the same domain, for the same phenomenon. This motivates an assessment of the benefits of a given plural strategy, of which there may be many, varying along different dimensions. Below we consider one such organizing dimension for pluralistic thinking, which was briefly discussed above: the spectrum of approaches that vary in how dissipative versus integrative they are.

3. Dissipative and integrative approaches

For the past few decades, after failing to yield a clear consensus on various theoretical matters, cognitive science has adopted a kind of *de facto* dissipative pluralism. One reason we choose "dissipative" is that it is merely descriptive. "Incompatible," as a term for plural accounts, connotes that these accounts are explicitly incommensurable in some way, either by intention of practicing scientists or by philosophers studying them. Dissipative pluralism can emerge from such intentional distancing among devotees of competing accounts. It may also emerge from a passive drifting apart, or even from a kind of despondency. This is detectable in the tone of Neisser's recommendations on taking challenging theoretical positions:

> 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 generalizations. Maybe they are right. (Neisser, 2003, p. 165)

We also choose this term for rhetorical purposes. Intense debate over theoretical accounts can be thought of as generating a metaphorical "heat," a dissipative process. Out of this dissipation of energy alone we may see an emergence of passive pluralism, a coexistence of themes merely because the energy has run out, the glow of the embers has faded, and there is other work to do.

By contrast, integrative pluralism is an active exercise in which a pluralist's task is not so much to show why different perspectives are appropriate but how exactly one might create a new perspective that takes their most valuable parts. The result of the theoretical debate here is to remark that multiple accounts are the norm but there is value in connecting them, in understanding why each works (without necessarily reducing one to the other). This is relevant to a compatible pluralism from the introductory chapter. The integration may result in a new singular theory, or it may result in a kind of collection of valuable theoretical tools that stand in their specific contexts of inquiry, while the links between them deepen our understanding.

We aim to elaborate on this promise of pluralism to propel theoretical advances, highlighting the case of cognitive science. Given the prior section on generalized minimal pluralism, this dissipation-integration distinction may be best remarked as a tension among various pluralistic

strategies. We would not argue that any particular approach to pluralism has adopted an exclusively dissipative or integrative approach. Though a more elaborate exegesis would be called for in assessing this, it does seem to this chapter's authors that dissipation is the more common outcome. Nevertheless, there are indeed instances of integrative pluralism in cognitive science, although they are relatively fewer in number (and the pluralist remarks that this is for good reason!).

The term "pluralism" itself connotes this kind of dissipation, a fractionation of accounts into new varieties. Consider Cartwright's (1999) classic notion of a nomological machine. The metaphor of a "machine" refers to the scientist's tendency to arrange the world *just so* and build theories exclusively within the boundaries of that "machine" (we might call this an "experimental treatment," or "measurement context," etc.). They are invented and implemented — and, in principle, we may create new ones at any moment. Cartwright remarks on this kind of conceptual fractionation into a patchwork. Mitchell (2002), taking a more integrative stance, argues that linking these frames of investigation yields significant benefit, even when they seem quite distinct, and illustrates this with the domain of biology (cf. Looren de Jong, 2002). Mitchell herself provides an elegant summary of this tension:

> I have attempted to steer clear of two undesirable methodological pitfalls. The first is an isolationist stance which partitions scientific investigations into discrete levels of questions and their corresponding answers in a way that precludes the satisfactory investigation of any of the levels. The second is an uncritical anarchism that endorses all and any propositions. Neither of these positions correctly locates where and when competition in fact occurs between theories and explanations in biology. (Mitchell, 2002, p. 68)

Whether one is Cartwright or Mitchell, the cognitive, epistemological value of pluralism needs also to be highlighted (in which case one is Horst, perhaps). As an illustration of our points, we look at the classic "framework debates" that took place within cognitive science. The heat of these debates has to a great extent dissipated, and what is left is a kind of *de facto* dissipative pluralism in which distinct theories coexist but do not participate commonly together on sets of phenomena (Contreras Kallens & Dale, 2018). The putative value of plurality in such a scenario would be to consider alternative accounts together to variegate one's understanding of specific cognitive phenomena. But this is indeed rare and difficult, and so this passive dissipative outcome may have led to a broad under-appreciation of a plural perspective (for some early counterexamples, see review in Dale, 2008).

In the spirit of this volume, we propose that a pragmatic agenda should be adopted to navigate this tension. In cognitive science, a dissipative pluralism is most consistent with incompatible representational pluralism; instead, *prima facie*, integrative pluralism seeks a kind of compatibilism. However, it does not need strict compatibility: finding how and which parts of these approaches are compatible is a further intellectual exercise by the pluralist herself. Among the best-known variants of integrative pluralism is that of Mitchell cited above, in the realm of

biology. The creative exercise of integrative pluralism, in Mitchell's words:

> By disambiguating the question to be answered by an explanation – i.e., what is the evolutionary origin of a trait or behavior we observe now – one is still left with a plurality of potential causes acting at a number of levels of organization which may well constitute *compatible answers* to that single question. (2002, p. 57, emphasis added)

In this case, then, elaborating on these possible answers and their compatibility, and furthermore choosing among them, "integrating" in short, is a further step in the process of finding an explanation for complex phenomena. In the next section, we move into cognitive science as a specific domain in which to frame the pragmatics of pluralism and offer some specific examples of theories and integrations.

4. The case of cognitive science

This volume on representational pluralism comes at an intriguing time for the field of cognitive science. In the past decade and especially very recently, significant debate has emerged about cognitive science as the interdisciplinary study of the mind (Gentner, 2010; comments in Gray, 2020; Núñez et al., 2019; Contreras Kallens et al., in preparation). This debate has focused primarily on whether cognitive science has lived up to this interdisciplinary definition. Some say that it has (e.g., Bergmann et al., 2017), others that it hasn't (e.g., Núñez et al., 2019), and some have shared mixed opinions on the matter (e.g., Cooper, 2019). Alongside this debate about interdisciplinarity, commentators have also raised a question relevant to the present volume: What is the core knowledge of cognitive science? This question resonates very elegantly with the concept of representational pluralism. Consider, for example, Núñez and colleagues (2019) oft-cited commentary, which prompted much of this recent discussion (see Gray, 2020):

> …undergraduate curricula and faculty backgrounds give the impression that cognitive science has gradually turned its unified effort into an eclectic group of academic practices that no longer have clear common goals, research questions or theories […] 'cognitive scientist' today is often used as a catch-all designation to label (or self-label) scholars with a dizzying array of unrelated interests and theoretical orientations. (Núñez et al., 2019, p. 782)

Their commentary illustrates the wide relevance of pluralism itself. It bears on our theories, how we compare them or have them compete, choose among them or embrace many in their alluring variety. But it also bears on how we teach these theories and related domains, how we establish a shared culture of knowledge through programs and curricula. The introductory chapters to the present volume illustrate these overlapping issues clearly and elegantly.

It may be argued that cognitive science is uniquely poised to consider this issue of representational pluralism. The first chapter of this volume highlights the cognitive value of

pluralism. For one, it is this plurality of explanatory schemes across disparate disciplines that motivated early cognitive science as a new discipline itself (Bechtel et al., 1998). A stark illustration of this is the famous Macy Conferences from the mid-20th century, attended by Mead, Wiener, Shannon, Ashby, and many others. One lore around these conferences is that it had hosts who were designated as monitors to ensure that none of these figures overly attended to their own disciplinary boundaries (see Dale, 2021). The very origins of the field are in the perceived cognitive benefits of this variety. But what to do with it? In a critical review of this conference's proceedings by cognitive psychologist George Miller (1953), we find an early expression of skepticism that this sort of pluralism can be so easily deployed. The review's substance and style may surprise readers more than a half-century later: "I am not at all sure how to review this book. I am not even sure it is a book. It looks like a book. It is nicely printed and bound like a book, and it will go on a shelf with books, but inside the spinach-green binding some puzzling and un-book-like things are lurking." (Miller, 1953, p. 661)

The Miller review starkly illustrates the difficulty of establishing bold pluralistic agendas without eliciting various kinds of critiques. They echo the chapter of Bélanger and Potvin (this volume) on the dialogues of "m" and "p": Pluralism can lack the desirable (though perhaps illusory) coherence of monism, and whatever coherence it achieves is merely a veneer (in Miller's review, for example, one veneer is taken to be an emphasis on processes of "communication"). The more recent concern raised about cognitive science now is that it is fractious, disparate, and incoherent — both in its theoretical composition and relatedly (and perhaps partly as a consequence) in the curricular structure of the discipline (Núñez et al., 2019). It is, in and of itself, a discipline beholden to plurality and suffering from the cultural and epistemological costs associated with this philosophical stance. At least, such is how some describe it — as a raw form of dissipative pluralism.

Signs of this fractionation occurred decades ago in cognitive science. To some observers, it seemed quickly to reduce itself to finding answers to standalone theoretical oppositions: *Is knowledge innate, or learned? Is the mind a classical computational system, or something else? Are categories built from prototypes or exemplars? Are mental processes contextual or independent? Is the mind primarily conscious or unconscious?* Many core debates continue, but the vibrancy has to a great extent dissipated. In an early sign of this fatigue, Newell famously lamented debates about such binary oppositions, referring to it as playing "20 questions" with nature (Newell, 1973). Some researchers have responded to this dissipation of foundational debate by digging in – focusing on their own models, or avoiding the general debate of contrasting them with others; a tacit commitment to dissipative pluralism. It is perhaps no surprise given Newell's comment that some, including Newell, have looked to computational modeling as a way of understanding how to integrate distinct theoretical accounts. Newell, for example, specified a set of computational conditions to have a very general model of the mind that integrates many theories in his "Unified Theories of Cognition" (Newell, 1994). Though we will not review these here, such "hybrid" models may offer an explicit computational avenue to think about pluralism and are themselves attempts at integrative pluralism (see discussion in Dale, 2008; Dale & Vinson, 2013; Jilk et al., 2008; Sun et al., 2001; also Friedman & Goldwater,

this volume).

But what are these theories of cognitive science that are competing? It may help the reader unfamiliar with cognitive science to learn of some of its contrasts. We showcase some of these in Table 1 (adapted from Contreras Kallens & Dale, 2018). Readers will of course be familiar with some of these key debates from philosophy and other fields: Is the mind like a symbolic computer? Is it more like a connectionist neural network? Are embodied processes central to the mind, or is it more abstract and encapsulated? Do social and ecological contexts matter centrally to mental processes? We have our Newellian questions again, and how one answers these questions is a projection into a particular theoretical landscape (cf. Table 1 in Thelen & Bates, 2003). Indeed, in an analysis of the theoretical composition of cognitive science, Contreras Kallens and Dale (2018) analyzed abstracts from hundreds of articles reflecting different theoretical accounts. They found that linguistic features for these theories distinguished them. This worked even when the authors omitted obviously overlapping technical terms. What this implies is that theories are overtly showing, in their linguistic expression, the subtle distinctions among the perspectives that they supply.

<<< TABLE 1 HERE >>>

So, we have distinct kinds of analysis and distinct perspectives that can be detected even from echoes of the words used by researchers applying particular theories. We have the beginnings of a dissipative process again, where even the subtle network of terms used by theories could be drifting apart. But what kind of integration processes might bring these back together? What practical theoretical value might this integration bring? We consider a few clear examples of this and articulate what they might mean for maintaining rich connectivities across these distinct accounts. Each example illustrates a practical benefit of integration by achieving a particular kind of rapprochement among theories. These rapprochements themselves show that integrative pluralism has finer-grained distinctions with corresponding practical theoretical benefits. These ideas are illustrated in Fig. 1.

Formal integration (A): Dynamical systems and symbolic computation

Dale and Spivey (2005) explored how the formal framework of symbolic dynamics may facilitate linkages between dynamical systems theories and symbolic theories of cognitive science (cf. Crutchfield, 1998; Shalizi & Moore, 2003). One major feature of dynamical systems theories of cognitive science is that the positing of abstract, categorical cognition is avoided — cognitive systems (neural systems in particular) flow continuously through states that may be better described by certain systems of mathematics and *not* by symbolic computation of a digital computer.

In the realm of symbolic dynamics, though, these formalisms find a bridge. This bridge is built by taking a dynamical system and *partitioning* it into coarse-grained states, and then representing its behavior as a set of symbols (see Fig. 1A). This area of mathematics has shown that you can

precisely recover fundamental properties of some dynamical systems from these symbolic sequences. The symbolic and dynamical descriptions of one system form a complementary whole. In the symbolic case, the researcher can anchor an understanding to almost-stable patterns of values (the symbols); the dynamicist can understand the *transitions* between these symbols when needed (but may not fathom the symbols without the epistemological anchor of the partition). There is a cognitive benefit to embracing both (see also Kelso & Engstrøm, 2006; Tabor, 2002). Note though that the compelling case for pluralism here is that these perspectives have an underlying equivalence, a formal mathematical junction point of integration, despite being radically different on the surface (see also Beer & Williams, 2015).

Computational integration (B): Bayesian processes and neural networks

Consider two competing theories in Table 1: Bayesian cognition and connectionism. These theories have subtle distinctions. Bayesian approaches tend to be more abstract, and they tend to take a page out of symbolic theories that assume that human minds represent "hypothesis spaces" and compute probabilities over them using a kind of optimal computation derived from Bayes theorem.[3] Neural networks would see any such cognitive machinery as *emerging* from complex interactivity among lower-level processes — such as finding statistical features in an environment of various kinds. These are indeed distinct ontologies, echoing the concerns of the representational pluralist (see Fig. 1B).

But these modeling frameworks are not completely incompatible either. Low-level neural processes could implement Bayes theorem in some way, such as by optimally responding to uncertain environmental information (Deneve, 2008), and higher-level neural network models can be approximated by using Bayesian probabilities too (Hernandez-Lobato & Adams, 2015; cf. Richard & Lippmann, 1991). In an important sense, these are *computational* integrations, and exploring this integration may help us to better understand when a particular computational tool is called for over another. Despite these potential connections, the debate about these two theories has often seen them as incompatible (see discussion in Griffiths et al., 2010; McClelland et al., 2010).

Conceptual integration (C): Neural networks and dynamical systems

An elegant integration of neural network perspectives and dynamical systems can be seen in Onnis and Spivey (2012). Here they illustrate *direct* mappings between state-space descriptions of dynamical systems and population codes of neurons, and they describe how one visualization may help to think about a cognitive process in a particular way compared to others (see Fig. 1C). A classic illustration of this integration is the work of Beer (1995; see also Beer & Williams, 2015). In this work, minimal artificial agents are built from neural networks and can be directly represented as systems of mathematical equations. The architecture of a neural network helps us to understand how a system is configured and interacts; the dynamical equations give a certain distillation of its behavior over time (Bechtel & Abrahamsen, 2006; Eliasmith, 1996). In the case of Beer, there is also an explicit formal equivalence between representational schemes, with an

invitation to consider one or the other depending on one's goal to understand a system's behavior. In the case of Onnis and Spivey, this integration is by a mapping of visual/conceptual descriptions, each giving a different flavor of an underlying process.

Empirical integration (D): Embodied and symbolic cognitive processing

There has been a long-standing debate about whether cognition uses action and perception systems to function. The basic theoretical opposition takes the following form: Is core cognition a more encapsulated, abstract process of symbolic manipulation? Or is cognition making use of similar action-perception representations (from the *body* itself) to process information? These debates find expression in an intriguing collection of essays in de Vega et al. (2008), where their relevance for language-related cognition, like reading, is assessed. Indeed, language has often served as a focal point for this debate. If it can be shown that when the mind processes language it uses embodied information, then it implies the embodied approach has some strong relevance even for processes that have long been thought of as the exclusive domain of symbolic approaches.

In a recent series of papers, Louwerse and colleagues have shown that *both* may be true of language processing and perhaps cognition more generally. This account is referred to as a kind of symbolic interdependency hypothesis (for a review, see Louwerse, 2021). By this account, symbols emerge in the mind through many mechanisms, and they become interdependent. Suppose you are introduced to a new term "splacket." You learn, without ever seeing it, that "splacket" is a sport that involves a racket striking an orange. The symbol interdependency approach argues that in that moment, you acquire new knowledge through extensive symbolic associations (racket, striking, orange, etc.), but that this learning also gets elaborated through simulation in your mind of the very embodied and perceptual aspects that accompany it (cf. Zwaan, 2014). These theories actually work together, and this is established through empirical illustration in behavioral and neural experiments.

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5. A canon for cognitive science?

Cognitive science's early history rapidly fell into an incompatibilist condition for its theories, with most resisting integrating them. The classic "framework debates" described above illustrate this. A further illustration of this is another debate from the era of connectionism: Can neural networks account for the systematicity of cognition at all? Arguments were offered by some that neural networks are not even candidates to explain human cognition because they cannot account for such complex cognitive abilities (Fodor & Pylyshyn, 1988). But the era of these heated debates is long gone – instead of a consensus, a more dissipative style of pluralism has emerged, a passive coexistence of many types of theories with specific representational emphases and no aims to replace one another. These emphases no longer intersect, and they have evolved into their own research communities and agendas. The aforementioned commentary on cognitive science

by Nuñez et al. (2019) is a kind of lament to this outcome.

What we reviewed above is that there are intriguing streams of thought about integrative pluralism — adopting a distinct plural strategy. That is, the problem with Nuñez et al.'s lamentation is that it constitutes but a snapshot of a discipline ripe for the creation of various integrations of the key insights and methods of the stalemated rival approaches. The benefits of pluralism are significant, and they have relevance to the concepts of incompatibility and compatibility discussed here and elsewhere in this volume.

Compatible formally, incompatible intuitively (A)

Example integration A illustrates, with the formal equivalence of dynamical systems and symbolic dynamics, is that we can be mathematically certain of a relationship across representational formats, yet at the same time find it difficult to intuit this relationship. Researchers studying some dynamical systems may feel as if they haven't understood the full system itself until they have both the equations but also the symbolic description. These descriptions are complementary, and they may appear incompatible, but they can be seen as equivalent in a fundamental sense with the appropriate conceptual tools and theoretical integration.

Computational compatibilism (B)

Example B illustrates that bringing Bayesian models together with neural computing regimes can enhance both. We have apparent full compatibility between computational approaches. We discover that one can enhance computational understanding of the other, and potentially expand our understanding of brains and minds by exploring how they function together. This does not mean that the accounts are equivalent. Instead, they become distinct computational components of a broader set of *new* models that integrate both approaches.

Conceptual compatibilism, distinct tools (C)

Onnis and Spivey (2012) illustrate through visual heuristics that neural networks and dynamic systems are part and parcel of the same underlying concepts, but they can be described in distinct ways that have a more faithful mapping to their prior representations. But these representations can be shown to be equivalent in an important way — not by formal means though, but by creative visual mapping of the underlying concepts. We have a sudden integration of these accounts by literally *seeing them* differently. Still, at the end of this exercise, a researcher can make use of a subset of these visualizations to render the insight desired, now knowing that energy need not be expended to contrast them as competing concepts.

Coexistence of representational formats (D)

The recent positions of Louwerse, Zwaan, and others show that theories may be discovered not

to be equivalent at all, but to be descriptions of different aspects of the one underlying system. One may ask how embodied accounts and symbolic accounts differ so markedly from each other. An answer, by this research, is that the human mind simply has no problem operating in distinct ways depending on some contexts. As Louwerse and others have shown, both representational formats may be operating simultaneously to contribute to cognitive processing (e.g., Louwerse & Hutchinson, 2012). The theories are thus reflective of coexisting cognitive processing. This is a kind of empirical integration, an illustration by direct observation that theories are not in opposition. The outcome is an exhortation to determine *how* they work together rather than seeing them always in opposition; in other words, an invitation to integration.

By adopting a more integrative stance, *many* epistemological opportunities become available. And these have direct cognitive implications for scientists themselves. Concepts are seen to blend in various ways, by mathematical equivalence in some cases, by conceptual or visual mapping in others. We may find theories are not in opposition at all but rather must get along, so to speak, in the same head. These cognitive heuristics offer a new path forward. Answering the concerns about a fractionated field described above, they may provide grounds for a new canon of cognitive science — the elaboration of multiple plural perspectives and their associated practical and pragmatic consequences and, importantly, the intriguing details of how the plural accounts reveal new theoretical relationships. In contrast to the famous adage, integration entails one step back and two steps forward.

Still, these examples also hint at subtler relationships between dissipative and integrative plural approaches. Consider example A again, with continuous and symbolic dynamics. There is a mathematical compatibility, but an intuitive *incompatibility*. These two accounts give a sharp explanatory contrast — and in so doing, reinforce rather different ways of thinking about a formal system. This suggests that the cognitive benefits of dissipation can sometimes accompany integration. Perhaps this tension itself is illusory.

6. Conclusion

As graduate students, we sometimes learn received lore, tales of our past discipline. And if one is drawn to major theoretical debates of the past, sometimes these stories involve anecdotes of curious exchanges in colloquia or at conferences. The authors recall one of these stories of past cognitive science shared with them by another mentor. The story takes place during a debate that occurred in the ’80s and early ’90s as the study of neural networks was reaching renewed heights. Many devotees of this new approach – then called “connectionism” – perceived their approach to be in direct opposition to ones that came before, especially theories that framed the mind as a kind of computer system manipulating symbols rather than neural patterns. In this story, participants from both camps were attending a plenary talk of some kind. Following the talk, participants got into such a heated debate that at least two of them were standing on their chairs for their (angry) voices to carry farther in the conference room.

To whatever degree it may be apocryphal, this exchange illustrates a surprising tendency towards

singular perspectives. Perhaps humans are drawn to the supposed elegance of unitariness, of simplicity. What other reason could these two individuals have for yelling at each other than believing their singular perspective to be correct? Readers of this volume, decades later, might imagine a similar exchange wherein one member of the debate is crying out something quite different: "You are both correct in a certain way! You just have to adopt a contextualist perspective on the role of theory!" This would not carry the oomph of the core debate, it might dissipate the heat in the room (at least as comic relief), but the paucity of such passionate exchanges these days suggests that the time may be ripe for more plural considerations.

The goal of this chapter was to consider pluralism as a kind of solution to these problems, especially in theories of cognitive science. We highlighted the distinction between dissipative and integrative pluralism, and we argued that this can be regarded as one dimension (perhaps among others) in which pluralism itself must be taken as a more complicated, variable tool itself subject to the constraints of context. A theorist can adopt a distinct plural perspective for distinct phenomena — and even for the same phenomenon, depending on their goals (e.g., pedagogical vs. non-pedagogical aims). Perhaps in this sense pluralism is to be taken as a fundamentally pragmatic perspective. As argued in section 2 above, once pluralism is adopted it cascades around a point of inquiry — of the phenomenon being studied, of the theories, considered, and of even the modes of discussion and inquiry itself.

Yet, this may sound more complicated than it needs to be. This recursive cascade can be "flattened" by seeing pluralism in general as an understanding that strict normative constraints on theory can be extremely limiting, especially theories regarding very complex systems that are not yet fully understood. As a meta-theoretical stance, it pries open the mind of the investigator to consider different kinds of relationships, across dissipative and integrative mindsets, with many potential practical benefits we have discussed in this chapter. In short, when trying to solve a problem, pluralism must be seen not as an evasion of conflict but as a drive to creatively repurpose whatever tools we might have at hand that yields the best results.

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Endnotes

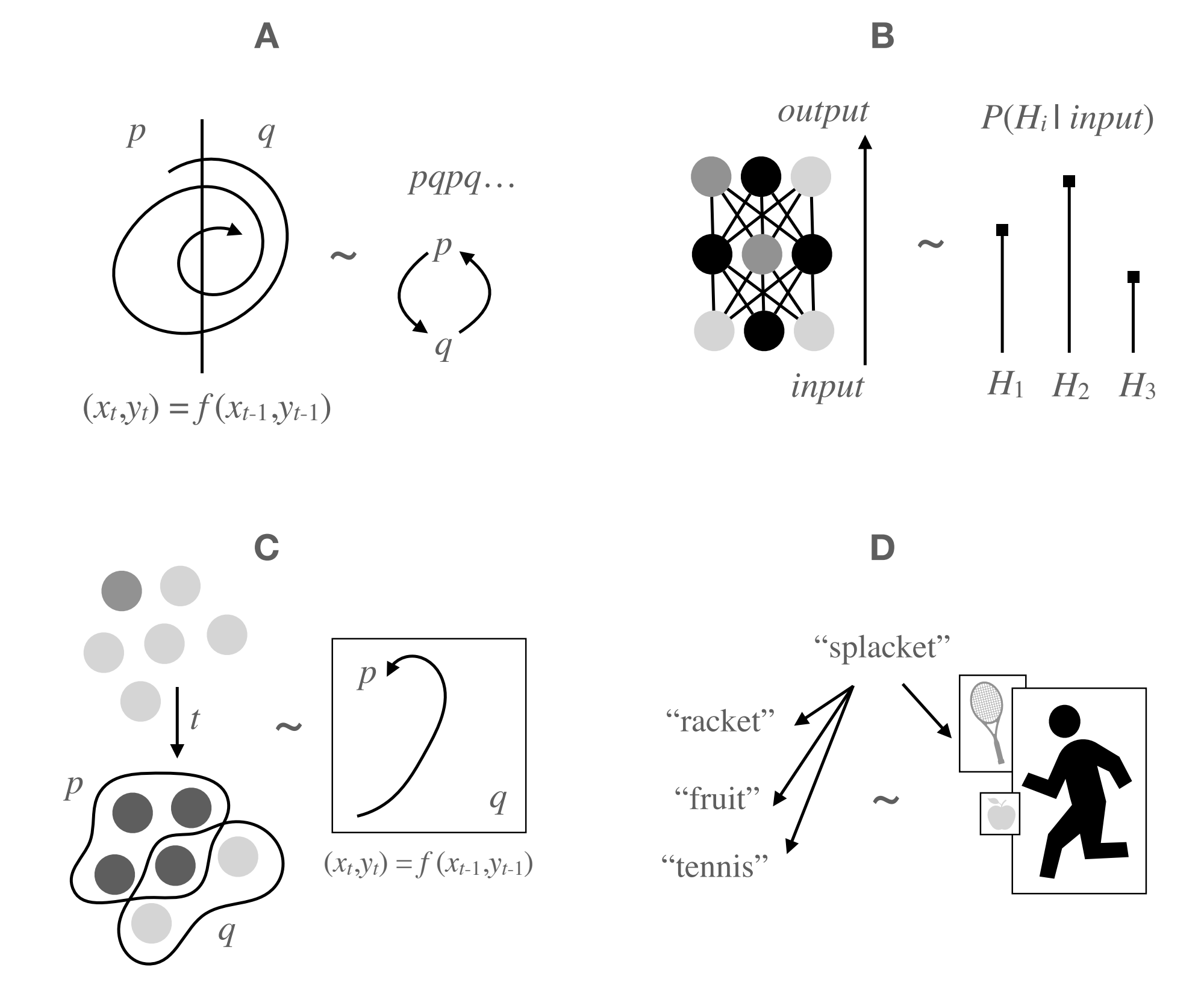
[1] We use "representational" to refer to how theories represent phenomena as sets of interlocking concepts and relationships. We attempted to be consistent with the definitions offered in the introductory chapters to this volume.

[2] Curiously perhaps, a monist's perspective may lie at one extreme corner of these plural schemes; a monist who is minimally pluralistic *recognizes the value of another theory*, because they see a viable cost-benefit ratio of the cognitive effort to reduce one representation to another.

[3] One of the findings reported in Contreras Kallens and Dale (2018) is that Bayesian papers cluster robustly with symbolic papers. Note also that these two approaches clustered, although less robustly, with connectionist papers.

Tradition	Description
Symbolic	Cognition is computation over internal states with semantic properties.
Connectionism	Cognition emerges from activity of interconnected nodes and parallel distributed processing (neural networks).
Bayesian	Cognition is rational probabilistic inference over a space of possible hypotheses.
Embodied	Cognition depends on bodily factors and might be partially constituted by them.
Distributed	Processes that happen at a scale beyond the individual can be part of cognition.
Enactive	Cognition is the self-organization of organisms and their integration to their environment through sense-making.
Dynamical	Cognition can be modeled with dynamical systems, even to the point of replacing computation.
Ecological	Cognition includes organism and environment through the direct perception and coupling of the former to the latter.

Table 1. Eight different theoretical traditions to studying various aspects of cognition. See Contreras Kallens & Dale (2018) for a complete version and representative citations.


A
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H_3
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p
q
$(x_t, y_t) = f(x_{t-1}, y_{t-1})$
D
“splacket”
“racket”
“fruit”
“tennis”
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