Binding Brain, Body and World:

Pattern as a Figure of Knowledge in Andy Clark's Work on Predictive Processing

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Abstract: Over the past two decades, the predictive processing (PP) framework has emerged as an immensely influential research paradigm in cognitive science and beyond. This article analyzes the critical role that the notion of 'pattern' plays in the agenda-setting work of philosopher and cognitive scientist Andy Clark on PP and considers the project to develop the framework into a unified theory of the embodied mind. It argues that pattern contributes to this project not primarily as a full-fledged concept but rather as a figure of knowledge that shapes PP theory at a rhetorical and aesthetic level. The article offers a definition of figures of knowledge as a critical concept and suggests to apply it more broadly to the study of pattern as "keyword of our times" (Franco Moretti).

Keywords: pattern; figure of knowledge; rhetoric of science; predictive processing; embodied cognition; Andy Clark

Introduction

Over the past decade, the predictive processing framework has emerged as a powerful and immensely influential research paradigm in cognitive neuroscience and beyond. For neuroscientist Lars Muckli (Casey 2018) predictive processing (PP) is as important to neuroscience as evolution is to biology and holds the key to understanding the basic operating principles of the brain. According to Andy Clark (2016), one of the leading philosophers of cognition working today, the framework offers the first glimpse of a "fundamental and unified science of the embodied mind" (p. 294). Karl Friston (2009), seen by many as the most influential neuroscientist alive, regards predictive processing as manifestation of a more fundamental principle that

governs all life on earth, the so-called free-energy principle. It is not surprising then that PP research is now receiving increased attention by a wider audience, with the year 2018 marking a particular threshold. In that year, several popular science and tech magazines such as *Wired, Quanta* and *Scientific American* introduced their readers to the new paradigm (Raviv, 2018; Cepelewicz, 2018; Ayan, 2018) and *The New Yorker* published an extensive portrait of Andy Clark in which staff writer Larissa MacFarquhar discussed PP in considerable detail (MacFarquhar, 2018).

The latter publication aptly highlights Clark's exceptional status in the field. Due to the accessible, interdisciplinary and visionary character of his work, Clark has arguably done more than anybody else for the elaboration and dissemination of the PP framework in cognitive (neuro)science and the human sciences in general. In his agenda-setting target article "Whatever next? Predictive brains, situated agents, and the future of cognitive science" he expounded the PP hypothesis of the brain as a "prediction machine" and described its potential to be developed into a "deeply unified theory of perception, cognition and action" (Clark, 2013, p. 181, 186). His book *Surfing Uncertainty: Prediction, Action and the Embodied Mind* (2016) further fleshed out the PP hypothesis and emphasized its ability to situate the brain in its bodily, social and cultural environments, a key objective of research on embodied cognition since the 1990s. Together with publications such as philosopher Jakob Hohwy's *The Predictive Mind* (2013), Clark's interventions stimulated more empirical research on PP and generated a broad interdisciplinary interest in the new paradigm that now ranges from psychiatry and psychology to the social sciences and humanities (Kukkonen, 2020; May *et al*., 2021). A 2020 research report, which was co-authored by Clark, concluded that while empirical support for the PP framework is "mixed" and "there is much work yet to be done" no "clear-cut counterevidence" was found so far (Walsh *et al*., p. 242, 261). Although the neural instantiation of predictive processing in the brain is still uncertain, the theory can be regarded as a "milestone in cognitive neuroscience" and also seminal for research on embodied cognition (p. 162).

In the following, I analyze the essential role that the figure of pattern plays in Clark's project to develop PP into a "deeply unified account of perception, cognition, and action" (Clark, 2013, p. 186). The concluding sentence of the preface of *Surfing Uncertainty* can give a first impression of the inconspicuous but nevertheless important role of patterns in this project:

> By the end of our story, the predictive brain will stand revealed not as an insulated inner 'inference engine' but

> an action-oriented engagement machine — an enabling [...] node in patterns of dense reciprocal exchange binding brain, body, and world. (Clark, 2016, p. xvi)

What stands out rhetorically in this statement are the technological metaphors of the "'inference engine'" and the "engagement machine" and the trope of the "node in patterns of exchange" between brain, body and world. Node is a term from network theory that gets a metaphorical ring when applied to the brain's relations to its environment. Its combination with "patterns" sounds somewhat unusual; the phrase "node in *networks* of exchange" would be closer to the source of the trope. However, as we shall see, it is precisely the *patterned* character of this exchange that supports the unifying ambition of Clark's approach and "binds" brain, body and world and, by extension, sensory perception, cortical processing and embodied action.

Importantly, pattern is not one of the key concepts of PP; it doesn't appear in the index of Clark's book and is never explicitly defined. Nevertheless, the term appears 169 times in the 306 pages of *Surfing Uncertainty* — once on every other page on average — and does a lot of persuasive and — as I will show — *figurative* work in binding the key domains of the embodied mind. As I suggest, this figurative work of the term can be seen in other fields and disciplines as well and contributes to the current status of pattern as a "great keyword of our times" (Moretti, 2017, p. 4).

Pattern as a Figure of Knowledge

Before I turn to the "patterns" in Clark's work and PP discourse, a few remarks on my use of the term *figure* are in order. Importantly, I do not use this term in its common rhetorical sense as meant to indicate "devices of word arrangement" (Fahnestock, 1999, p. 10) but in a broader, epistemico-aesthetic sense. I define figures of knowledge as critical keywords in the production of knowledge that combine conceptual with figurative meaning, with the latter including both imagery (in the sense of figurative language) and figuration in the sense of spatio-temporal arrangement and material shape (Müller, 2008). In the case of pattern, the latter can include imageries of spatial arrangement, rhythm, formal congruency, geometry etc. Broadly put, figures of knowledge thus fuse concept and image; in this way, they can "make the non-conceptual intelligible and the conceptual concrete and sensually graspable [*anschaulich*]" (Müller, 2013, p. 30).[1]

[1] Figures of knowledge is an emergent concept at the intersection of philosophy, history of science and literary studies. It has roots in the

The scientific concept of networks, for instance, can be approached as a figure of knowledge in this sense. On the one hand, "networks" in science often come with a considerable degree of conceptual precision and definitional exactitude; for this reason, the networks of social network analysis are different from those of actor-network theory. On the other hand, the term also mobilizes a host of figurative meanings that can defy translation into the language of scientific definitions but nevertheless affect the creation of knowledge. These figurative meanings can range from metaphorical associations with biological webs and material networks to visual assumptions about forms and shapes of connectivity (Breidbach, 2008; Friedrich, 2015). They can even invoke a multimodal "network aesthetic" that amounts to a "worldview," i.e. the idea that our world essentially is a world of networks (Ngai, 2012, p. 368). Studying figures of knowledge thus means to analyze the interplay of conceptual specificity and figurative meaning in the production of knowledge that they afford.

Compared to the regular rhetorical understanding of "figure," this approach can seem general and unspecific, but it is useful for my study of pattern in PP discourse and Clark's work for three related reasons. First, it helps to theorize the peculiar status of "pattern" in contemporary scientific and scholarly discourses as a term that is often used but *not* in many cases specifically defined as a concept. Observers from different fields have noted that, in spite of the term's increasing popularity, a "rigorous philosophical approach to the concept of patterns" is lacking in the humanities and human sciences (Dixon, 2012, p. 191); that the term largely "remains un-theorized" in design theory and architecture (Andersen & Salomon, 2010, p. 126); and that it is hardly ever turned into a "full-fledged social science concept" (Swedberg, 2014, p. 92). Therefore, it is all the more important to bring the various dimensions of figurative meaning into view that are mobilized in the ubiquitous use of the term, such as its unifying effects in Clark's work.

Second, figures of knowledge are *not* limited to the status of particular tropes, defined as departure from the common or "ordinary" meaning of a word (Fahnestock, 2011, p. 100, 123). Intriguingly, in most cases pattern is *not* a metaphor and does not

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Kantian distinction between concept (*Begriff*) and intuition (*Anschauung*) and Michel Foucault's archaeological research on the epistemological impact of "figures of knowledge" such as *aemulatio* and taxonomy (Foucault, 1966/2005, p. xi, 19-20 *et al.*; Konersmann, 2011; Müller, 2008 & 2013). Recent work on figures of knowledge includes studies of the figure of psycho-physical parallelism in experimental psychology in the late 19th century (Wegener, 2007 & 2009).

imply a transfer of the term from a "proper" context to a new one (p. 105). The history of the term "pattern" in the English language is rich with shifts and turns, such as its extension from signifying a "model" from which things can be made to a "regularity" that is observed in the world (Moretti, 2017, p. 4-5).[2] However, it does not seem very productive to try and determine degrees of metaphoricity in the term; "patterns of behavior" are not more or less metaphorical than the "patterning" of a piece of clothing. A broad definition of figurative meaning in the sense proposed here makes it possible to address the issue of imagery without fixation on one trope in particular and to focus on "images, schemes, models" (Müller, 2013, p. 29) as well as on auxiliary tropes that figures of knowledge mobilize in the production of meaning.

Finally, the concept of the figure enables me to analyze the persuasive power of Clark's work as an effect of interacting rhetorical and aesthetic levels of semiosis. As I will demonstrate, Clark's argument regarding the unifying character of PP relies on rhetorical strategies as well as on an aesthetic validation of pattern as a figure of connection and mutual fit. The notion of figures of knowledge makes it possible to conjointly address these rhetorical and aesthetic dimensions by using insights from the rhetoric of science (Fahnestock, 1999; Gross, 1990 & 2006) and the aesthetics of knowledge (Grieser, 2017; Borelli and Grieser, 2017).

I fully share the conviction of many scholars in science and technology studies and beyond that knowledge always is produced in complex material-semiotic ecologies that involve language and textuality as well as various biological, social and technological materialities (Rickert, 2013; Pickering, 2017). Patterns certainly are no exception. In this paper, however, I mostly focus on the textual and discursive side of things. I start with an exploration of pattern as a figure that facilitates the "binding" of brain, body and world through semantic range and the use of *incrementum*. I then turn to its role in the construction of an isomorphic "fit" of neural and environmental patterns and the aesthetic validation of this imagery.[3] In the conclusion, I offer a brief reflection on the

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[2] The current version of the *Oxford English Dictionary* lists fourteen different major meanings of the term ("pattern, *n.* and *adj.*", 2021). The broad semantics of the term pattern in the English language has previously been noted by translator Karin Band and cognitive scientists Douglas Hofstadter and Emmanuel Sander (Band, 2001; Hofstadter & Sander, 2013, p. 81-82).

[3] My paper is not primarily intended to contribute to the debate about neurorhetorics and the rhetoric of neuroscience (Harris, 2013; Gruber, 2016; Gibbons, 2018). However, I want to point out that the study of patterns might by an excellent test case for the double bind of these two

relevance of my findings for the larger turn to patterns in the present-day human and social sciences.

Binding Brain, Body and World

Much of the appeal of the PP framework and the excitement it causes arguably lies in its ability to explain cortical processing in a way that is intellectually elegant, integrative, and transferable to a wide variety of contexts. PP breaks with the longstanding assumption that the brain is essentially a stimulus driven organ that processes sensory input in a bottom-up manner. Instead, the brain is seen as constantly predicting its input and own states based on probabilistic estimations (which are mostly modelled according to Bayesian statistics). Only the discrepancy between bottom-up signals and top-down predictions — the so-called prediction errors — are fed upward in the processing hierarchy. Probabilities are estimated by a multilevel generative model that is realized in the brain; it is called "generative" because it models how sensory input is generated by causal and material relations in the world. The key objective of this processing mechanism is to minimize prediction error, which can essentially be achieved in two ways: by altering predictions (*perceptual inference*) or by actions that bring about changes in the sensory input (*active inference*).[4] "Action" here can range from minute eye movements to large scale, multi-agent interventions in the physical and social world that increase predictability (such as road surface marking, social norms etc.). Crucially, in the PP framework perception, cognition and action are inherently *entangled* in a constant feedback loop of prediction error minimization, which explains the framework's potential for a unified theory of the embodied mind. As Lars Muckli explains, vision does not start with sensory input but with probabilistic estimations of what we will see around the corner and embodied action that can make predictions and input match (Casey, 2018). The world in which such agents live is a "world made of patterns of expectation," as Clark puts it, "in which all our mental states are coloured by delicate estimations of our own uncertainty" (Clark, 2016, p. xvi).

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approaches. On the one hand, embodied cognitive science has means to explain why cognitive agents need and enjoy patterns to structure their worlds (Harris, 2013, p. 2-4). On the other hand, these insights should then also be applied to the rhetoric of cognitive science and neuroscience itself.

[4] This summary is based on Fabry (2018) and Wiese & Metzinger (2017).

The relevance of patterns for this framework seems evident at first sight: without patterns and regularities there can be no prediction. In his classic essay "Real Patterns" (1991), philosopher Daniel Dennett states that where "utter patternlessness prevails, nothing is predictable" (p. 30). Clark does not cite Dennett's paper, but his argument is similar: the metaphorical "stream" or "flow" of sensory input is "predictable just to the extent that there is spatial and temporal patterns in that flow" (Clark, 2016, p. 6, 171). Hence, it is the brain's task to discern these patterns to make predictions of future input possible:

> [N]euronal populations learn to predict various organism-salient regularities obtaining at many spatial and temporal scales. In so doing they lock on to patterns specifying everything from lines and edges, to zebra stripes, to movies, meanings, popcorn, parking lots, and the characteristic plays of offense and defence by your favourite football team. (Clark, 2016, p. xv)

It is a key question for the PP theory how the "locking on" of neurons to patterns in the world is realized in the brain. But before I address this issue in the next section, I want to draw attention to the intriguing diversity of cultural, social and biological patterns that Clark lists in the second sentence of the quotation. His list seems designed to highlight the great variety of environmental regularities that aid predictive processing in the brain; it includes patterns observed in nature (zebra stripes) and in culture (movies), stable patterns (parking lots) and emergent patterns (football tactics) and patterns with no obvious materiality at all (meanings). The phrase "specifying everything" is intriguing here: it points to the specificity of all these patterns but also claims that the property of being patterned is a *shared*, fundamental quality of "everything" that is important to the predictive brain in the world.

The ubiquity of patterns in Clark's approach to PP, however, does not stop here. According to Clark, it is not just the outside world that is patterned but embodied cognition itself as well. Hence, patterns span and connect all of the three key entities mentioned in the mission statement of *Surfing Uncertainty*, namely "brain, body and world." Intriguingly, this is a list as well, but by no means a random or unordered one. From a rhetorical perspective, the phrase "brain, body and world" can best be described as *incrementum*, i.e. an "ordered series, a series that goes somewhere" (Fahnestock, 1999, p. 92). According to the common definition, an *incrementum* lists items that "share an attribute in increasing or decreasing degree," as Jeanne Fahnestock explains; the series "silver, gold and precious stones," for instance, is structured according to the increasing rarity and value of the items listed (Fahnestock, 1991, p. ix, 96). The phrase

"brain, body and world" is primarily structured according to levels of nestedness, imaginatively situating the brain *in* the body and the body *in* the world. This notion is expressed in a remark by philosopher Mike Wheeler who states that it is the task of research on embodied cognition to "put cognition back in the brain, the brain back in the body, and the body back in the world" (Wheeler, 2005, p. 11). This nestedness, however, also suggests that brain, body and world share a common quality that makes their putting-together possible and makes them complementary parts of a larger whole.[5] Or, as Jeanne Fahnestock puts it: the main "conceptual work" of *incrementum* consists in positing that the items in a series share the same "attribute" and form a "connecting series" based on an underlying ordering principle (Fahnestock, 1999, p. 95-97).

Interestingly, Clark already used this *incrementum* in the subtitle of his influential 1997 monograph *Being There: Putting Brain, Body and World Together Again*. Since then, this phrase has become a programmatic slogan of so-called 4E-approaches to cognition that study the mind as extending into its environments, embodied in whole organisms, embedded in various contexts and enacting (rather than representing) the world. It has been cited and rephrased in numerous publications (Wheeler, 2015; Crippen & Schulkin, 2020), appears more than a dozen times in *Surfing Uncertainty* (Clark, 2016, p. 2, 235, 245 *et al.*) and also informs the division of this work into three parts: the book starts with a part on cortical processing in the *brain* (entitled "The Power of Prediction"), then moves on to a section largely devoted to prediction and the *body* ("Embodying Cognition") and concludes with a chapter on the extension of cognition into the socio-cultural *world* ("Scaffolding Prediction"). Hence, this *incrementum* can very well be seen as "epitome" (Fahnestock, 1999, p. 24) of the 4E-approach to cognition in general.

Against this background the unifying function of "pattern" in Clark's work in PP becomes clear as well: patternedness is the shared attribute and connecting element of brain, body and world. Throughout his writings, Clark consistently describes all of these entities as patterned. Out of the 169 references to patterns in *Surfing Uncertainty* about 30 relate to patterns in worldly environments and roughly 50 to internal structures and activities of the brain. The latter include references to the brain's structural connectivity (the "gross pattern of physical linkages" through which neurons interact) as well as to functional connectivity (the

[5] For these reasons I regard the phrase in question as an *incrementum* rather than as *gradatio* and *diaeresis*, which both lack the element of ordered increase (Fahnestock, 2011, p. 214-246).

temporal coincidence of neuronal activity across brain regions) and to effective connectivity (the "short-term patterns of causal influence between neural events") (Clark, 2016, p. 147; 103, 149 *et al.*). Moreover, patterns continuously appear in Clark's discussion of "patterns of sensory stimulation" (ca. 35 references) and of bodily action (15 references), such as "patterns of gaze fixation" or consumption patterns as identified by online search engines (p. 121, 129, 57, 75).[6] Patterns thus have an inconspicuous but pervasive presence in the argumentative texture of the book, spanning across and connecting "brain, body and world."

It would be interesting to further explore how these various (brain) patterns are constituted in the material-semiotic interplay of neurobiology, scientific terminology, brain imaging technologies (such as fMRI and PET) and the statistical modelling of data obtained by these methods. Here, however, I want to focus on the ubiquitous presence of the term pattern in Clark's work and its low degree of conceptual distinctiveness. In fact, many of the patterns that Clark mentions are quite specific. "Patterns of effective connectivity," for instance, can refer to the strength of the coupling between certain visual and motor areas in the brain as modulated by prediction errors in another brain structure (Clark, 2016, p. 149). The materiality and kind of relation that the term pattern signifies here — the altered strength of a neural connection — is arguably very different from the biochemical processes that lead to the formation of zebra stripes in the skin of this animal or from the linguistic and cultural patterns that Clark cites (such as football tactics).

The recent rise of pattern as a (proto)concept in various disciplines has led researchers to ask questions about the definition of the term and to distinguish between different kinds of patterns. For instance, what are the differences between patterns emerging in evolutionary systems and patterns that are purposefully designed (Dixon, 2012)? Are patterns an element of homeostatic regulation or rather agents of randomness and transformation (Andersen & Salomon, 2010)? Should they be defined in terms of data compressibility, as Dennett suggests, or, in a more phenomenological manner, as "a regularity — with or without exception — observed in the natural or cultural world" (Bod, 2020, p. 1)?

In Clark's texts, such distinctions are not addressed. The term pattern is rather used as a broad *hypernym* (Fahnestock, 2011, p. 63) or container term that is largely synonymous with

[6] Other examples of perceptual patterns include "patterns of energetic input" and "proprioceptive patterns" (Clark, 2016, p. 19, 21, 122).

"regularity" and never defined explicitly. Therefore, differences between various kinds of patterns do not register in the argumentative texture of Clark's work. In absence of more specific definitions, "pattern" can smoothly slide up and down the "scale" of generality (Fahnestock, 2011, p. 64) — from "specifying everything" to very particular connections in the brain — without notice of its potentially polysemous character. And for this reason, patterns can also figure effortlessly as the binding element of brain, body and world, the threefold epitome of the embodied mind.

Gripping Patterns

The figurative work of patterns in Clark's writings on PP, however, is not limited to providing an axis for this *incrementum* but also extends to modelling the nature of the connection between brain, body and world itself. Intriguingly, Clark's programmatic phrase about "putting" brain, body and world "together again" not only proposes to recover a lost unity that was demolished by representational and computational approaches to cognition by separating the mind/brain from its corporeal and worldly surroundings. It also figuratively suggests a complementary *fit* of the now scattered pieces that should be assembled to form a whole again — just like the pieces of the anthropomorphic egg "Humpty Dumpty" in the famous English nursery rhyme that inspired Clark's use of the phrase "putting together again": "Like Humpty Dumpty, brain, body, and world are going to take a whole lot of putting back together again. But it's worth persevering because until these parts *click into place* we will never see ourselves aright or appreciate the complex conspiracy that is adaptive success" (Clark, 1997, p. 222, emphasis added).

To understand the scientific and figurative logic of this "fit" and "clicking into place" better it helps to once more return to Clark's metaphor of the predictive brain as a "node" in the reciprocal exchange of brain, body and world (2016, p. xvi). How exactly can the brain become such a "node" and "link up" with the body and the world? As seen above, on the PP view it is the function of generative models to relate incoming sensory data to top-down predictions. But how are these generative models realized neurophysiologically in the brain and how do they encode sensory patterns and predictions? This question leads straight into a long-standing debate in cognitive science and philosophy, the so-called "representation wars" (Williams, 2017; Downey, 2018; Constant *et al.*, 2021). Should we assume that the brain in some way generates internal "representations" of the world, possibly by encoding and manipulating input and ideas in a system of logical

symbols similar to computer processing? Or must the brain be seen as part of a larger, dynamical system that includes the body and the environment as well and that operates not by abstractly *representing* but by performatively *enacting* the world, as posited by Francisco Varela, Eleanor Rosch and Evan Thompson in their immensely influential work *The Embodied Mind* (1991)?

This is a thorny question for Clark and an embodied approach to PP in general. On the one hand, the very notion of a generative *model* implies that regularities of the world *are* somehow represented in the brain, as Clark concedes (2016, p. 293). On the other hand, such representational logic threatens to fall back to a view of the brain as passively reconstructing the world, thereby again isolating it from its surroundings. Assuming this perspective would mean, as Clark notes, to leave "the true path of enactivist virtue" set out by Varela and others (2016, p. 291).

Like other PP scholars, Clark opts for a middle position. He firmly rejects the notion of a "passive 'mirroring'" of the world in the brain that suggests a mechanical reflection of a pre-given environment. He quotes Richard Rorty's influential metaphor of the "mirror of nature" — a critical term for the representational epistemology in much of western philosophy — and points to the "chronic failure to find inner representations of the world" in the brain (Clark, 2016, p. 293, 177). Yet he also asserts that the world is "encoded" in the brain — not symbolically, but through *probabilities* that are inherently orientated towards action (p. 181). In generative models, information *about* the world and how to act *in it* are inseparably entangled. Thus constituted, these models get a "*structured grip*" on the world, as Clark puts it, "a grip that consists not in the symbolic encoding of quasi-linguistic concepts but in the entangled mass of multiscale probabilistic expectations used to predict the incoming sensory signal" (p.107-8; emphasis in original).

This statement shows that the theory of probabilistic representation comes with its own repertoire of tropes and imagery. It includes, among others, the metaphors of the "grip" on the world and the "dance" between bottom-up signals and top-down predictions that the predictive brain performs.[7] Significantly, these terms suggest an active and *embodied* engagement with the world and thus resonate well with the 4E-approach to cognition. Sense modalities are important here as well. The

[7] For other examples of the "grip"-metaphor see Clark (2016), p. 3, 6, 21, 23 *et al*. and Clark (2015), p. 15, 22. For 'bottom-up/top-down dance' see Clark (2016) p. 41, 57, 190 and Clark (2013), p. 189-90. The metaphor of the dance also appears in enactivist phrases such as the "dance of brain, body and the world" (Clark, 2016, p. 244).

representationalist metaphor of "mirroring" relates to vision and connotes a distant and reflexive relation of the brain to the world. "Grip," by contrast, relates to touch and suggests a direct, physical contact with the environment that provides a tangible hold.[8]

These tropes of bodily engagement, in turn, are directly related to the figure of patterns in creating the isomorphic imagery of an "active 'fitting'" of the brain and the world (Clark, 2016, p. 293). Consider this passage from *Surfing Uncertainty* in which Clark describes probabilistic representations as

> firmly rooted in the patterns of organism-environment interaction that served up the structured sensory stimulations reflected in the mature probabilistic generative model. The role of that generative model is to deliver an efficient, context-sensitive grip upon a world of multiple competing affordances for action. [...] Instead of simply describing 'how the world is', these models [...] are delivering a grip on the *patterns that matter* for the *interactions that matter* (p. 291-92; emphasis in original).

This remark not only rehearses the unifying use of "patterns" as a hypernym across different domains that I discussed above but also describes patterns as the "hold" that generative models find in the world and on which they can get a "grip". In this way, the abstract generative model is turned into an agential entity that can perform the embodied actions of seizing and gripping. This in turn is possible because "patterns" can be imagined as a concrete physical object that is the hold and handle of this grip.

This embodied imagery is also activated when Clark states that generative models "*capture* patterns" in the input stream, echoing, in turn, his above-cited remark that "neuronal populations ... *lock on* to patterns specifying everything from lines and edges, to zebra stripes" and so on (2016, p. 293, xv). These metaphors — "capture," "lock on," "grip" — all suggest an embodied connection facilitated by a similarity in terms of *form*: something "fits" and gives a "hold" due to a congruency of shape. Importantly, this embodied isomorphism could not — or not as easily — be achieved by a word that is almost synonymous with pattern in Clark's writings, namely the term *regularity*. Arguably, all patterns in the brain, the body and the world that Clark talks about are ultimately related by statistical regularity. "Pattern" may

[8] In their enactive approach to affordances, Bruineberg and Rietveld explicitly employ different connotations of the term grip in the English language, ranging from the physical hold on objects to the cognitive grip on ideas and situations (Bruineberg & Rietveld, 2014, p. 3).

just simply be taken to mean "statistical regularity" and be replaced by this phrase. However, in such a replacement the embodied nature of the connection that Clark suggests would precisely get lost. This is, I argue, because the term "regularity" does not come with the same figurative meaning and connotations of materiality and *Gestalt* that "pattern" evokes (cf. Dixon, 2012, p. 194). "Patterns" suggest a particular shape and spatio-temporal arrangement; they can be "sculpted" to match other patterns, for instance when it comes to "sculpting patterns of effective connectivity" or "sculpting patterns of inference and action" (Clark, 2016, p. 149, 206 *et al.*). And they also give the necessary consistency and firmness to the metaphorical fluidity of the "sensory flow" and "input stream" in order to get a "grip" on it.[9]

Here the work of pattern as a figure of knowledge and, more specifically, as a figure of connection becomes evident. It shapes Clark's theory both through its general and inclusive definition *and* through the imagery that comes with it. To be sure, I do not mean to say that Clark's unifying project solely relies on this figure and I do not want to suggest that the term simply glosses over empirical gaps in research on PP.[10] Imaginative language and rhetorical devices can be a creative force in science, and they are still only one of its tools. But in this limited and specific sense, pattern as a figure of connection does its share of work in making the PP framework plausible — at a rhetorical and also at a more aesthetic level, as we will see now.

Patterns That Connect

It would be very interesting to further explore how this connective function of patterns plays out in the literature on the aforementioned free-energy principle that Karl Friston offers as a theory of the behavior of *all* dynamical systems, not just the brain. The free-energy principle is an information-theoretical framework in biology and neuroscience that regards the minimization of *surprisal* (i.e. long-term prediction error) and the generation of self-model evidence through active inference as imperative for all living systems under conditions of increasing entropy. From this general and highly abstract perspective, PP in the brain is only one specific case of self-organization through active inference. In a foundational article of this approach, Friston *et al.* suggest that pattern generation in embryogenesis (the early onset of cell

[9] For a discussion of isomorphic imagery in contemporary neuroculture in general see Besser (2017).

[10] For a recent mathematical formulation of generative models see Constant *et al.* (2021).

differentiation in plants and animals) follows the same principles of active inference as pattern formation in larger scale phenomena such as the brain and entire societies (2015, p. 8-9; cf. Kuchling *et al.* 2020). Similarly, Friston claims that there is a "necessary isomorphism between biological structures [in the brain] and the statistical structure of the world" (2019, p. 180) and that physical and behavioral patterns in cognitive systems "match" with patterns in their environments (Ramstead *et al.* 2020, p. 227). It seems that the free-energy principle in general also relies on pattern as a figure of connection, only at much larger time scales and across more domains of reality — from individual cells to societies — than the PP framework itself.

Here, however, I want to pursue a different route and focus more closely on the *aesthetic* dimension of patterns in the PP framework. This dimension explicitly comes to the fore in a philosophical elaboration of Clark's probabilistic approach to representation by philosopher Daniel Williams. Like Clark, Williams argues for a "structural resemblance" of generative models and worldly causes, stating that "the *pattern* of relations among elements in the one domain recapitulates the *pattern* of relationships in the environment." He concludes: "The upshot is a beautifully Aristotelian picture of the mind as an organ *enformed* by the dynamical structure of the environment it interacts with" (Williams, 2017, p. 154-55; emphasis in original). The phrase "beautifully Aristotelian" refers to the concept of hylomorphism, the immanent interaction of form and matter in Aristotelian philosophy. Remarkably, Williams calls this view of the predictive brain a "beautiful *picture*," thus describing it as a visual composition that is delightful to behold. Here, the figurative harmony of two kinds of patterns achieves an aesthetic validation of the theory through a notion of corresponding forms.

In the history of science such aesthetic appreciation of patterns is not new. Most notably and influentially, anthropologist and cyberneticist Gregory Bateson introduced the "pattern which connects" as an epistemic *and* aesthetic key concept in his work *Mind and Nature: A Necessary Unity* (1979). For Bateson, patterns are a common characteristic of all organisms and living systems. Defined as a similarity in formal relations, patterns appear in the symmetries of animal anatomy and the shape of flowers as well as in structural relations in language, formal resemblances in music and art, and relationship structures in cultures (Bateson, 1979, p. 7-13). The "pattern which connects" then is a "metapattern," namely the ability to see that pattern is *what* connects all living systems (p. 11). For Bateson, this "*wider knowing*" of connectedness is essentially not a scientific but an aesthetic achievement. It implies a "sense of aesthetic unity" that is

largely ignored in western epistemologies and makes it possible to appreciate "an ultimate unifying beauty" in the biosphere (p. 5, 16, 18). Phrased in more technical terms, "aesthetic" is the ability of a system to "recognize patterns in other systems and to see that they are part of its own setup as well" (Barck, 2010, p. 397).

There are manifold connections between Bateson's work and current PP research. Bateson's famous definition of information as "difference that makes a difference" is seen as a prefiguration of the PP concept of prediction error (Van de Cruys, 2014, p. 129) and Andy Clark (2010) has praised Bateson as a preeminent thinker of embodied cognition. At the same time, PP scholars like Williams and Clark might be skeptical regarding Bateson's spiritual inclinations; they also value formal and mathematical approaches to mind more than he did. What is important here, however, is that both share with Bateson an essentially ecological mode of thought that embeds human cognition in a patterned and *therefore* interactive relationship with its environments. From this ecological perspective the dynamic unity and congruency of mind and nature is valued positively, sometimes with explicit reference to aesthetics (as in Williams) and sometimes with a more crypto-aesthetic fascination with isomorphic patterns (as in Clark). Clark's titular metaphor of the surfer who stays "in the pocket" (2016, p. xiv) of the waves of sensory stimulation expresses a "joyful sense of oneness with the world" — to use Larissa MacFarquhar's (2018) felicitous phrase — that fits with these aesthetics of connection as well.

The interactive character of patterns seen in Clark's work is present in Bateson's thinking as well. Like today's PP researchers, Bateson was convinced that perception is an active process in which previous knowledge and sensory input together create something new. As an analogue of this process, he discussed the phenomenon of *moiré* patterns in which a repetitive design is overlaid by another pattern, resulting in a new pattern (also called an interference pattern). Bateson argued that, similarly, we carry in our minds "samples of various sorts of regularity" against which "we can try the information (news of regular differences)" from the outside (1979, p. 80). This means, as Peter Harries-Jones explains, that perceptions also "impose pattern on the 'outside'" (1995, p. 203). Perception therefore is a creative and aesthetic act in which cognitive agents resemble "an artist creating a composite of inner outer events" (Bateson, 1991, p. 223). Although the probabilistic element is missing, this idea of an active aesthetics of perception is not far at all from the PP concept of active inference.

These aesthetics of connection, however, have a downside as well when projected onto the social, political and cultural sphere. In Clark's work the unifying ambition of PP — together with the

focus on prediction error minimization — leads to a certain disregard of disjunctive and colliding patterns in society that do not form a homogeneous whole. As an example, consider the following remark from Clark's target article in which he describes how humans design their material-semiotic environments to reduce prediction errors. Clark here draws on the concept of "patterned sociocultural practices" (2016, p. 276) — i.e. regular, everyday activities in specific material-discursive environments (Roepstorff *et al*., 2010) — to explain the patterning of the physical and social world:

> Using a variety of tricks, tools, notations, practices, and media, we structure our physical and social worlds so as to make them friendlier for brains like ours. We colour-code consumer products, we drive on the right (or left), paint white lines on roads, and post prices in supermarkets. At multiple time-scales, and using a wide variety of means (including words, equations, graphs, other agents, pictures, and all tools of modern consumer electronics) we thus stack the dice so that we can more easily minimize costly prediction error in an endlessly empowering cascade of contexts from shopping and socializing, to astronomy, philosophy, and logic (Clark, 2013, p. 195).

This passage is illustrative of what critics have called the "optimistic basis" and "happy picture" of extended cognition in Clark's work (Kukkonen, 2018, p. 65; Williams, 2016, p. 79). Clark depicts human agents as being able to actively and successfully design their social and physical environments in a way that is "empowering" for all. The universalizing use of the pronoun "we," however, raises the question whether all members of a society dispose over equal means to "stack the dice," i.e. to influence socio-cultural patterns so that "costly prediction errors" are minimized. Picking up on Clark's examples, one may think of digital navigation systems (which can help avoid getting stuck in a traffic jam) or social codes (which regulate social interaction and help avoid *faux pas*). Not everybody may be able to navigate complex digital environments in equal measure and not everybody can read and act on relevant social codes with the same ease and fluency. Failures to do so might indeed be "costly" in a number of ways (economically, socially, emotionally). Hence, it is essential in this context to ask *who* creates such patterns for whom. Who can participate in and who is excluded from these processes? And what happens when different patterns of expectation *collide*?

In principle, these questions can and have been addressed within the PP framework; there are, for example, several proposals to study cognitive dissonance, bias and patterns of inequality from

a PP perspective (Kaaronen, 2018; Hinton, 2017; Kelly *et al*., 2018). However, in Clark's work and other high-profile contributions to the discussion a more unifying view of patterns as creating "shared social worlds" prevails (Clark, 2016, p. 288).[11] In Clark's above-cited explanation this unifying tendency is articulated in the image of the "endlessly empowering cascade of contexts." In PP parlance the metaphor of the "cascade" refers to the multi-levelled, bi-directional exchange of top-down predictions and bottom-up error signals. It thus captures a complex model of cortical processing in a noun phrase that designates an object in the physical world, which already is an intricate rhetorical procedure (cf. Gross, 1990, p. 71). Moreover, in Clark's comment the "cascade" also imaginatively blends cortical processing and social topology: a variety of "contexts" — shopping, socializing, astronomy, philosophy — are conjoined in one flexible structure that serves to minimize prediction error, suggesting a streamlined integration of different socio-cultural fields and practices. Similarly, Clark acknowledges the existence of a plurality of social worlds, practices and languages but still mostly focuses on their internal cohesion (Lupyan & Clark, 2015, p. 282-3; Clark, 2016, p. 269-88; Clark, 2015, p. 10). Towards the end of *Surfing Uncertainty*, he states that the different "takes on the world" that people have are constantly put to "public critique and systematic, multi-agent, multigenerational test and refinement." The "best" models of the world serve as the basis for "cumulative, communally distributed reasoning" and new predictive processing regimes (Clark, 2016, p. 278-79).[12] This Popperian view not only implies agreement on the criteria for the "testing" of world-models but also describes collective world-making as an accumulative rather than a fractioned and contradictory process. Patterns connect and add up rather than collide and divide.

Conclusion

I hesitate to assert that this focus on that which is *shared* in "social worlds" is a direct consequence of the unifying ambition of Clark's theory. The integration of action, perception and cognition does not necessarily require a harmonious view of the social. Moreover, one should keep in mind that it is Clark's project to understand

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[11] The papers by Ramstead *et al*. (2016), Constant *et al*. (2019) and Veissière *et al*. (2020) are examples of this trend.

[12] Nathaniel Rivers and Jeremy Tirrell point to similarities between Clark's view of distributed cognition and the classical rhetorical concept of "productive strife" (*agōn*) as a form of conflict resolution (Rivers & Tirrell, 2011).

how human cognition works, not how society functions. What I do want to conclude, then, is that pattern as a figure of connection supports this project in a number of related ways. It binds sensory perception, cortical processing, and embodied action together by presenting them as fitting and interlocking regularities. Thereby, it also works towards closing the gap between PP theory and the biophysical implementation of generative models. In addition, the figure provides a template for understanding multi-agent co-operation and the collective creation of designer environments. As I have demonstrated, these achievements do not solely or primarily result from a specific conceptualization of pattern but rather from *figurative* meanings (in a broad sense) that support and shape the argument.

As I mentioned throughout this paper, the emergence of pattern as a key term of PP discourse can be placed in the larger context of a turn to patterns in the humanities, arts, and sciences. Patterns, for instance, currently play a key role in attempts to describe the history of human knowledge as a history of pattern recognition (Bod, 2012 & 2019) and to identify "metapatterns" that span nature and culture (Volk, 1999 & 2007; Lent, 2017). In the social sciences, patterns are invoked in theories of digital society (Nassehi, 2019) while researchers in the digital humanities use the term to rethink the relation of the specific and the general (Manovich, 2018; Long & So, 2016; Moretti, 2017) and literary scholars turn to patterns to study posthuman and multipolar cultural formations (Hayles, 1999; Levine, 2015). At the same time, artists such as Ryoji Ikeda and Gerhard Richter explore a digital aesthetics of pattern formation (Ikeda, 2018; Richter, 2011). These various artistic, scholarly, scientific, and cultural investments in patterns are driven by a multitude of different motivations and disciplinary dynamics. However, they arguably all reflect the relevance of processes of digitization and pattern recognition across various fields.

It would be interesting then to study the emergence of pattern as a proto-concept in relation to this interdisciplinary developments. We might very well currently witness the formation of pattern as a new mega concept, comparable to "network", "system" or "structure" in previous decades. In this paper, I argued that pattern can be an appealing, productive and persuasive term in knowledge production not only because of its conceptual possibilities but also because of the figurative meanings that come with it. Therefore, a figure of knowledge approach may contribute to understanding the intriguing appeal of pattern as a keyword of "our times."

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