AVANT, Vol. VI, No. 2/2015
ISSN: 2082-6710 avant.edu.pl/en

Poetic justice: A commentary on Joseph B. McCaffrey's "The brain's heterogeneous landscape"

Witold M. Hensel
Faculty of History and Sociology
University of Bialystok
whensel@poczta.onet.pl

Abstract

The paper is a commentary on McCaffrey (2015). I begin by arguing that the two views on brain pluripotency that McCaffrey intends to reconcile, namely those of Price and Friston (2005) and Klein (2012), are not really in conflict. The alleged disagreement between them stems from two interpretative failures: first on the part of Klein, who has misrepresented the views of Price and Friston, and second on the part of McCaffrey, who has misconstrued Klein's position. I then take issue with McCaffrey's claim that each of the structure-function mapping strategies he discusses allows researchers to discover a different kind of pluripotency: (1) where each subregion of a pluripotent brain area performs a specific function, (2) where a brain area performs a single function in multiple mechanisms (networks), and (3) where a brain area performs multiple functions in multiple mechanisms (networks).

Keywords: cognitive neuroscience; brain pluripotency/multifunctionality; structure-function mapping strategies; functional cognitive ontology; kinds of multifunctionality; cognitive ontology revision; systematic mapping; context-sensitive mapping.

Current research in cognitive neuroscience suggests that most areas of the human brain are pluripotent. For example, according to a meta-analysis conducted by Michael L. Anderson (2010), if the brain is divided into 66 large cortical regions of interest (ROIs) proposed by Hagmann et al. (2008) then a typical region is activated by tasks from nine out of eleven domains (the domains used by Anderson include: action execution, inhibition and observation, vision and audition, attention, emotion, language, mathematics, memory and reasoning). The pluripotency persists even if the brain is carved up into 998

smaller areas—in which case the average brain region is implicated in performing functions from over four domains (see Anderson 2010: 258).

This raises a number of questions regarding function–structure mappings obtained through neuroimaging and lesion studies. Does every brain region perform a single function connected somehow with the different tasks it involves or does it perform different functions in different contexts? If genuine pluripotency exists, how can we account for it? Do results of neuroimaging studies place any constraints on processes posited within cognitive psychology? If so, what are those constraints? Is it possible to construct a correct functional ontology, i.e. a systematic function-structure mapping that would help us to predict function from structure and structure from function, and, if so, then what methodological guidelines should we appeal to in this endeavor and why?

Joseph B. McCaffrey (2015) appears to be solving one of the problems concerning pluripotency. He argues that there is no single strategy for discovering structure-function mappings because there are different kinds of multifunctionality: whether a given strategy works or not depends on the mechanistic organization of the brain region involved. This *functional heterogeneity hypothesis*, as he calls it, is intended to resolve a debate between Cathy J. Price and Karl J. Friston (2005) and Colin Klein (2012).

McCaffrey distinguishes three methods of dealing with apparent pluripotency. The first, which he calls the *subdivide-and-conquer strategy*, consists in looking for distinct subareas underlying each function. If this strategy succeeds then the brain region under investigation is revealed to consist of separate functionally specific circuits.

The second method, which McCaffrey calls the *systematic mapping strategy* and attributes to Price and Friston (2005), consists in treating multiple tasks as a single, more abstract cognitive function. (The name of this approach comes from the fact that, according to McCaffrey, its purpose is to obtain *systematic mappings*, which would enable us to predict function from structure and vice versa.) More specifically, if system S is described as performing functions f_1, f_2 and f_3 then we should find a level of description at which functions f_1, f_2 and f_3 are instances of a single "suitably general" function F. For example, the left posterior lateral fusiform (PLF) is activated when subjects are: (1) viewing words, (2) reading, (3) naming pictures, (4) viewing pictures of animals, (5) making action decisions or (6) imagining objects (this is intended as an illustration, so the list is incomplete). After analyzing the available data, Price and Friston have concluded that, since PLF activation is strongest when a motor response is retrieved from sensory clues, it would be best to label PLF as a sensorimotor integration area (see Price & Friston 2005: 265-267). At this level of description, then, PLF performs a single cognitive function. Although calling PLF a sensorimotor integration area allows Price and Friston to make

a persuasive argument for revising the received cognitive ontology of reading, it does not yield a systematic mapping, as sensorimotor integration does not imply PLF activation (after all, most of the cortex is engaged in sensorimotor integration in one way or another). This is why "the systematic mapping strategy" is a bit of a misnomer. From now on I am going to call this method "the find-a-suitably-general-label strategy".

The third method of coping with multifunctionality, attributed to Klein (2012), is the *context-sensitive mapping strategy*. Klein argues that the find-a-suitably-general-label strategy may yield trivial mappings. Instead, he proposes that brain region activations be mapped out relative to coactivation of other regions. Thus, brain region R_1 may perform function f_1 in one context, namely when region R_2 is also activated, and function f_2 in another context—when region R_3 is activated. In short, the function of a brain region depends on the neural network in which the region is being embedded.

McCaffrey reconciles the three strategies by adopting Carl Craver's (2001) mechanistic perspective and observing that there are three kinds of multifunctionality, each of which corresponds to a strategy discussed above. First, if a system component performs a number of functions and is decomposable into subcomponents such that every function of the component is performed by a different kind of subcomponent then this can be discovered by adopting the subdivide-and-conquer strategy. Arguably, this is not even a case of genuine pluripotency, since if the whole brain were made up of such "multifunctional" components, each sufficiently small brain area would perform a single function. Second, if a component (brain region) performs the same function in different mechanisms then Price and Friston's find-a-suitably-general-label strategy will probably help to discover that. And, third, if a component (brain region) performs different functions in different mechanisms then Klein's context-sensitive mapping strategy is called for. "The trick is determining when each approach is needed," concludes McCaffrey (2015: 1021).

Everyone should be happy with this solution. Klein as well as Price and Friston appear to be partly right and, owing to McCaffrey's perspicacity, the reader can now appreciate the exact nature and the limitations of their respective insights. Another victory for philosophy? Unfortunately, there are a few problems with McCaffrey's discussion.

First of all, there never was a genuine disagreement between Klein on one side and Price and Friston on the other, though Klein (2012) suggests otherwise. According to Klein, Price and Friston attempt to explain away the pluripotency of the brain by exploiting the trivial fact that anything that is describable as having multiple functions can also be described as having a single function. As he remarks, "Perhaps brain regions only appear pluripotent because we have not specified their function in suitably general terms. Make it abstract enough, and we will find that brain regions do only one thing after

all. Price and Friston take exactly this line." (Klein 2012: 954). But if this is what Price and Friston had in mind, their paper would have never seen the light of day. No peer-reviewed journal, let alone a respectable one, like *Cognitive Neuropsychology*, would have published it. The reason is clear. Everybody knows that you do not do cognitive neuroscience by pulling cheap linguistic tricks.

In case the reason I have given strikes you as too a priori, let me also quote a passage from the introduction to Price and Friston's paper:

> The simplest interpretation of functional neuroimaging data would be a one-to-one mapping between a cognitive process and an anatomical region. However, *the brain clearly does not and cannot operate in this fashion*, not least because the number of hypothesised cognitive processes exceeds the number of brain regions supporting them. (Price & Friston 2005: 262, emphasis added)

Similar remarks can be found in section "Structure-function mappings" (Price & Friston 2005: 272). In point of fact, the functional ontology Price and Friston envisage is a hierarchical structure. This implies that single regions and functions at a higher level are often decomposed into multiple regions and functions at a lower level. Needless to say, there is no mention of purging the functional ontology of one-to-many mappings between structure and function (pluripotency), as that would render the ontology empirically inadequate. The mappings proposed are not systematic in the sense of necessarily providing two-way predictions, but in the sense of being comprehensive and integrative (informed by various strands of psychological and neuroscientific research). One of Price and Friston's arguments is that we can use good functional ontologies to revise the biologically unconstrained cognitive categories provided by psychology, which may in a sense reduce apparent pluripotency. They do not claim, however, that all pluripotency can be eliminated in this fashion. It may also be worth noting that Price and Friston's proposal is entirely compatible with the sort of context-sensitive mapping advocated by Klein.

The second problem is that McCaffrey has misrepresented Klein's position just as Klein before him misrepresented the views of Price and Friston. To wit, Klein does not claim that it is *always* a bad idea to use labels that capture all the tasks a brain region has been discovered to support. He merely observes, quite rightly, that relabeling brain regions will not make pluripotency go away. In other words, he does not advocate *abandoning* the find-a-suitably-general-label strategy altogether—he only argues for network-oriented analysis.[35]

[35] McCaffrey says: "Colin Klein (2012) offers a very different take on multifunctionality: neuroscientists must abandon systematic mappings in favor of *context-sensitive* ones" (2015: 1014). Klein, on the other hand, writes: "I agree with Price and Friston that we need to rethink our cognitive

The third problem is that, although neat and pleasing, McCaffrey's claim that each strategy used separately may lead to the discovery of a different kind of pluripotency is false. A quick reminder: when successful, (1) the subdivide-and-conquer strategy is supposed to show that each of a region's functions is performed by a different subregion, (2) the find-a-suitably-general-label strategy is supposed to show that a region supports a single cognitive function across multiple domains and (3) the context-sensitive mapping strategy is supposed to reveal that a region performs variable functions in multiple domains. The trick, to repeat, is knowing when to take which approach.

The truth seems somewhat different, though. If we characterize the methodology of cognitive neuroscience in terms of the three strategies discussed by McCaffrey—and it should go without saying that such a description would be grossly oversimplified and incomplete—we would have to conclude that, when it comes to discovering functional mappings, researchers must repeatedly use both the subdivide-and-conquer and the context-sensitive mapping strategies. The former allows them to increase precision, whereas the latter yields a structured representation of collected data. The methods must be used repeatedly because new neuroimaging techniques offer new opportunities for subdividing and conquering. The fact that we have not discovered a pluripotent brain area to be composed of function-specific subareas does not imply that the brain area in question is not so composed, since our imaging techniques may be insufficiently precise. Similarly, when an area is discovered to be so composed, new neuroimaging findings may force us to attribute a new function to it and thereby render it pluripotent all over again. Also, pace McCaffrey, the context-sensitive mapping strategy may lead us to discover not only that an area performs variable functions in different mechanisms, but also that it performs a single function in different mechanisms. This would happen if we saw the same function being performed by a region in more than one context (I would argue that most of the time researchers recognize that the same function is being performed, even if different groups refer to it by different names—no special strategy is required[36]). In a degenerate case, the context-sensitive mapping strategy may even yield systematic mappings—if the same function showed up in all the contexts.[37]

categories. There is a different lesson we might draw" (2012: 956). He even discusses how to use the context-sensitive mapping strategy to drive ontology revision (see Klein 2012: 957-959).

[36] Of course, this may not be easy. As Kaplan and Craver (2016) point out, meta-analyses of neuroimaging findings are prone to gloss over differences in task and control conditions, contaminating our measurements of functional diversity. We can perhaps explain away at least some of the pluripotency by appealing to the presence of various kinds of noise in our data.

[37] Since the framework of context-sensitive mapping is an extension of context-free mapping, context-free mappings are reducible to context-sensitive mappings.

The status of the find-a-suitably-general-label strategy is different. Though it may sometimes facilitate discovery, its heuristic value is negligible. In order to discover that various groups of researchers call a single task by different names, one needs theoretical insight and an in-depth knowledge of the kind of tasks involved in each domain. A blind search for a "suitably general label" would be futile because no one would be able to recognize which proposed label was appropriate. In the typical case, relabeling serves to facilitate communication rather than discovery. In fact, the discovery precedes, and often motivates, the relabeling, and not the other way around.

It is worth noting, however, that the find-a-suitably-general-label method is easily replaced by a better and more general approach of revising the cognitive ontology. It is probably the latter strategy that McCaffrey has in mind when he claims that it can lead to establishing that an apparently pluripotent brain region performs a single cognitive function. Although difficult to characterize in sufficient detail, ontology revision is an important tool in the cognitive neuroscientist's toolbox. Besides reducing apparent functional diversity, it may help us discover both kinds of genuine pluripotency discussed by McCaffrey. For one thing, ontology revision may reduce functional diversity in one domain at the price of increasing it somewhere else. For another, ontology revision may involve adding a new cognitive function rather than removing an existing one.

References

Anderson, M.L. 2010. Neural reuse: A fundamental organizational principle of the brain. *Behavioral and Brain Sciences*, 33: 245-313.

Craver, C. 2001. Role functions, mechanisms, and hierarchy. *Philosophy of Science*, 68: 53-74.

Hagmann, P., Cammoun, L., Gigandet, X., Meuli, R., Honey, C. J., Wedeen, V. J., Sporns, O. 2008. Mapping the structural core of human cerebral cortex. *PLoS Biology*, 6(7): e159.

Kaplan, D.M., Craver, C.F. 2016. A registering problem for functional fingerprinting. *Behavioral and Brain Sciences*, 39: e124.

Klein, C. 2012. Cognitive ontology and region—versus network-oriented analyses. *Philosophy of Science*, 79: 952-960.

McCaffrey, J.B. 2015. The brain's heterogeneous landscape. *Philosophy of Science*, 82 (2015): 1010-1022.

Price, C.J., Friston, K.J. 2005. Functional ontologies for cognition: The systematic definition of structure and function. *Cognitive Neuropsychology*, 22 (3-4): 262-275.