Is "Cognitive Neuroscience" an Oxymoron?

Dan Lloyd

Keywords: time, temporality, phenomenology, default mode, cognitive neuroscience.

Could "cognitive neuroscience" be an oxymoron? "Cognitive" and "neuroscience" cohere only to the extent that the entities identified as "cognitive" can be coordinated with entities identified as neural. This coordination is typically construed as intertheoretic reduction between "levels" of scientific description. On the cognitive side, folk psychological concepts crystallize into behavioral taxonomies, which are further analyzed into purported cognitive capacities. These capacities are expressed or operationalized in paradigmatic experimental tasks. These cogs comprise a stable ontology, sustaining more than a century of psychology. On the neural side, the biological hierarchy from cells to brains also affords a steady ontology that coordinates a sea of research using a dazzling array of techniques. The interdiscipline of "cognitive neuroscience," then, supposes that the two ontologies can be bonded in identity. That is, cognitive entities will turn out to be configurations of neural entities, in something like the way chemical substances turn out to be configurations of atoms. If, on the other hand, this intertheoretic reduction ultimately fails, the consequences are serious: one or both of the ill-matched ontologies must be false. Or, if both are true, then they are ontologically disjoint. In that case, even deeper suppositions come into question. Cognition would be irreducible to brain function; without cognitive neuroscience, perhaps dualism would true after all.

In their useful commentaries, Keith Frankish and Sergi Costafreda have extended the discussion in "Through a Glass Darkly" toward these most general issues. Neural modularity is the glue between "cognitive" and "neuroscience," affording the reduction of particular cognitive functions to activity in particular regions of the brain. For the reasons discussed in the target paper, modularity is implicitly assumed in many experiment analyses, but these local blind spots can be circumnavigated by comparing multiple studies. Thus, meta-analysis has special work here. More than just a tool for amplifying the power of individual studies (while weeding out false positives), in this application meta-analysis bears on the fundamental hypotheses of modularism, and ultimately on the possibility of cognitive neuroscience.

In the target article, I discuss the correlation of working memory tasks with dorsolateral prefrontal activation. Using the same 478 studies, we can briefly consider the more general question of modularism. The Brainmap database (brainmap.org) categorizes 37 behavioral domains, a robust psychological ontology (which has been tested for consistency in application (Fox et al., 2005;

Table 1. Behavioral Domains in the Brainmap database.

Action.Execution (Ae)	
Action.Execution.Speech (Aes)	
Action.Imagination (Aim)	
Action.Inhibition (Ai)	Emotion (E)
Action.Motor Learning (Aml)	Emotion.Anger (Ea)
Action.Observation (Ao)	Emotion.Anxiety (Eanx)
Cognition (C)	Emotion.Disgust (Ed)
Cognition.Attention (Ca)	Emotion.Fear (Ef)
Cognition.Language (Cl)	Emotion.Happiness (Eh)
Cognition.Language.Orthography (Clo)	Emotion.Sadness (Es)
Cognition.Language.Phonology (Clp)	Interoception.Hunger (Ih)
Cognition.Language.Semantics (Clsem)	Interoception.Sexuality (Isx)
Cognition.Language.Speech (Clsp)	Perception.Audition (Pa)
Cognition.Language.Syntax (Clsyn)	Perception.Olfaction (Polf)
Cognition.Memory.Explicit (Cme)	Perception.Somesthesis (Psom)
Cognition.Memory.Working (Cmw)	Perception.Somesthesis.Pain (Psomp)
Cognition.Music (Cmus)	Perception.Vision (Pv)
Cognition.Reasoning (Creas)	Perception.Vision.Color (Pvcol)
Cognition.Space (Csp)	Perception.Vision.Motion (Pvm)
Cognition.Time (Ct)	Perception.Vision.Shape (Pvsh)

Table 1). For each of the 1,249 experiments, activations were identified by Brodmann area, a stable (although somewhat crude) ontology for the brain. On average, each behavioral domain activated twenty-two Brodmann areas (out of a possible eighty-four). Conversely, on average each Brodmann area was activated by experiments in seventeen distinct domains. It should be noted that these statistics have been corrected for multiple comparisons and base rate effects; the counts are the robust and repeated observations of many different experiments.[1] Individual areas vary in their multitasking, but even the queen of modules, primary visual cortex (area 17), subserves not only visual perception (including color and motion), but also processes of cognition specific to language (speech and semantics) and reasoning overall. Conversely, the "narrow" visual tasks that attempt to isolate visual shape, color, or motion all activate at least ten (and as many as eighteen) areas outside of the classical modules of areas 17, 18, and 19. One can speak of modular tendencies, perhaps, but only with an unwieldy set of qualifiers attached.

Does this signal the failure of a unified cognitive neuroscience? It would, if modularity were the only way to conceive of the reduction of cognition to neural dynamics. The meta-analysis suggests that brain regions (Brodmann areas) are multitasking, shared resources. But not every Brodmann area is involved in every task. Tasks deploy overlapping sets of brain regions, which sets can be compared according to their degree of overlap. In this way, we can determine similarity among patterns of activity over many areas even if individual areas cannot be decoded. We can think

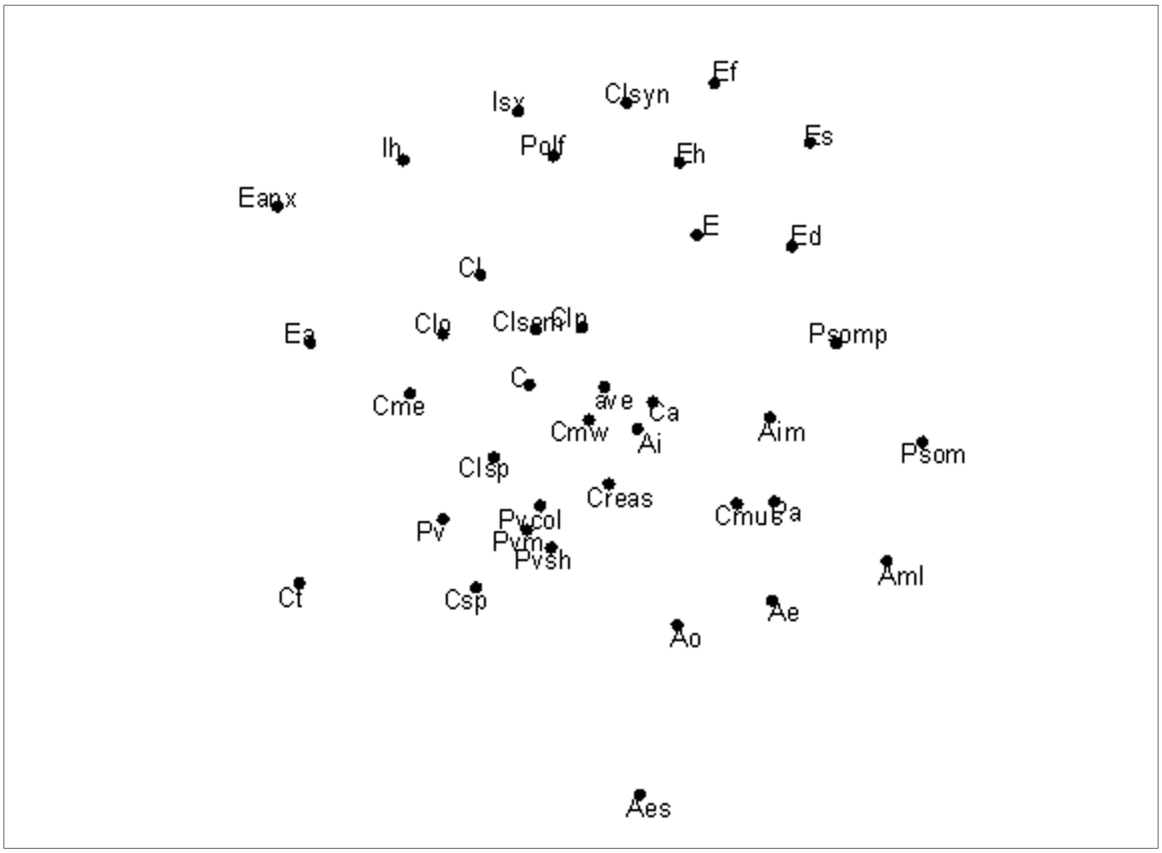

Figure 1. Distributed patterns of brain activation compared via multidimensional scaling. Distances on the map approximate dissimilarities among overlapping patterns of Brodmann Area activations, based on the meta-analysis of 1,249 functional MRI experiments. Behavioral domains follow Brain-map nomenclature, as abbreviated in Table 1. ("Ave" is the mean of map loci.) In this map, Kruskal's stress, a measure of inaccuracy, is .283, a high value indicating that an adequate map would require more dimensions. (Stress falls to .113 in five dimensions, for example.)

of similarity as nearness in an abstract space of brain activation patterns, and construct a map that coordinates brain patterns that could not be individually interpreted. Figure 1 is a map of this sort, constructed via multidimensional scaling. Brain space does not compress cleanly into two dimensions, so the map is highly approximate. It is nonetheless encouraging to consider the regions of relative similarity among brain activity patterns and the tasks that drive them. Patterns subserving vision (prefixed with Pv) are tightly clustered. Language tasks (Cl prefixes) cluster, except for syntax (Clsyn), and these are near memory and reasoning tasks. Broad but separate regions contain action subtypes (A prefixes) and emotion (E). Considering specific task types and their near neighbors is also encouraging: audition (Pa) resembles music cognition (Cmus); disgust (Ed) lands close to pain (Psomp); and so on.

Thus, this brief tale of two ontologies has a (provisionally) happy ending. The brain does organize itself in ways that reflect personal and subpersonal psychologies. Despite the dark glass through which we peer at the brain (and the over-simplifications of a meta-analysis), we can detect and classify semidistributed patterns of activity. We use meta-analysis not to sharpen the focus, but to widen the angle of view. Through this wide lens, it appears that individual brain regions cannot be assigned particular cognitive functions. Neural modularity is therefore challenged by the meta-analysis. However, the same wide lens reveals overlapping coalitions of brain regions; these coalitions support a diversity of psychological functions, and can fail in nonmodular ways (as in disconnection syndromes like, perhaps, schizophrenia). Neither psychology nor neuroscience need abandon its ontology for the sake of a coherent cognitive neuroscience, but it seems that the future of this interdiscipline lies "beyond modularity."

Note

1. In effect, a meta-analysis increases the number of trials in the experiments being compared, which increases the probability of confirming a hypothesis by chance. This risk is corrected by lowering the critical threshold for multiple comparisons. Here, we used a conservative Bonferroni correction. Before this correction, the meta-analysis showed that each behavioral domain activated forty Brodmann areas (on average), and each area participated in seventeen domains.

References

Costafreda, S. G. 2011. Meta-analysis, mega-analysis, and task analysis in fMRI research. *Philosophy, Psychiatry, & Psychology* 18, no.4:XX–XX.

Fox, P. T., A. R. Laird, S. P. Fox, P. M. Fox, A. M. Uecker, M. Crank, S. F. Koenig, and J. L. Lancaster. 2005. BrainMap taxonomy of experimental design: Description and evaluation. *Human Brain Mapping* 25, no. 1:185–98.

Frankish, K. 2011. Cognitive capacities, mental modules, and neural regions. *Philosophy, Psychiatry, & Psychology* 18, no. 4:XX–XX.

Lloyd, D. 2011. Through a glass darkly: Schizophrenia and functional brain imaging. *Philosophy, Psychiatry & Psychology* 18, no. 4:XX–XX.