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## Coordinated pluralism as a means to facilitate integrative taxonomies of cognition

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The past decade has witnessed a growing awareness of conceptual and methodological hurdles within psychology and neuroscience that must be addressed for taxonomic and explanatory progress in understanding psychological functions to be possible. In this paper, I evaluate several recent knowledge-building initiatives aimed at overcoming these obstacles. I argue that while each initiative offers important insights about how to facilitate taxonomic and explanatory progress in psychology and neuroscience, only a “coordinated pluralism” that incorporates positive aspects of each initiative will have the potential for success.

**Keywords:** cognitive ontology; experimental paradigm; neuroscience; progress; psychology; pluralism; taxonomy

### Introduction

Psychological functions are complex phenomena insofar as the biological systems that exhibit them consist of physical parts and processes that span multiple levels of organization from genes to neurons to behavior. Each ontological level may be probed to identify their causes. The areas of science that investigate them are many and diverse and incorporate a wide variety of techniques including psychological tasks, functional neuroimaging and genetic interventions.

There is widespread agreement that progress in understanding how the brain gives rise to psychological functions requires *integration* of the constructs, data, and explanations of the diverse areas of science involved in trying to understand them (see e.g., Bilder, Howe, and Sabb 2013; Cuthbert and Kozak 2013; Piccinini and Craver 2011; Poldrack et al. 2011; Sanislow et al. 2010; Stinson 2016). Yet, over the past decade, philosophers and scientists have identified a number of conceptual and methodological obstacles to integration, primarily having to do with the stability of our current taxonomy of psychological functions. First, investigators working in the same and different areas of psychology and neuroscience do not share a stable vocabulary of hypothetical constructs designating psychological functions (see e.g., Bilder, Howe, and Sabb 2013; Poldrack et al. 2011; Poldrack and Yarkoni 2016; Sullivan 2016a, 2016b, 2016c; Uttal 2001). The experimental paradigms that they use to investigate these functions also are not standardized across researchers, making the comparability of results across research studies purportedly investigating the “same” phenomenon tenuous at best (see e.g., Carter and Barch 2007; Poldrack and Yarkoni

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2016; Sullivan 2009). Additionally, in some areas of neuroscience, investigators place less emphasis on carefully evaluating “what” phenomenon the experimental paradigms they use actually measure (see e.g., Abend 2016; Krakauer et al. 2017; Poldrack 2010; Sullivan 2009, 2010, 2014a, 2016a).

No one believes that these obstacles will be easy to overcome and a number of independent collaborative knowledge-building initiatives have emerged over the past decade to address them. One aim of this paper is to evaluate the potential of these initiatives to achieve this aim. To do this, I appeal to Carl Hempel’s (1959/1965) framework for thinking about how taxonomic progress ought to proceed in science. Hempel claims that, ideally, scientific taxonomies pass through two distinct stages. First, researchers with different theoretical understandings of phenomena of mutual interest construct a shared vocabulary to individuate and organize those phenomena into groups. This facilitates the pragmatic aim of ensuring effective communication across different scientific communities interested in the same phenomena. Once a shared vocabulary is constructed, scientists go in search of the regularities that underlie the phenomena and the taxonomy is revised and updated when the categories fail to track real divisions in the causal structure of the world. Hempel regards realization of the pragmatic aim as prerequisite for realization of the realist one. He does not, however, comment on the possibility that progress towards the realist aim may put the stability of the original categories in jeopardy; potentially compromising the pragmatic function they were originally intended to serve. Given that such instability is a real possibility, I suggest that proposed revisions to scientific taxonomies must strike a delicate balance between pragmatic and realist goals. I explain that the aim of striking such balance in psychology and neuroscience is especially challenging because conceptual and investigative practices are not sufficiently coordinated.

I move on to consider a set of knowledge-building initiatives, which each are intended to provide solutions to the lack of conceptual and methodological coordination we find in contemporary psychology and neuroscience. I evaluate the extent to which each initiative successfully realizes and/or balances the pragmatic and realist goals of scientific taxonomies. I argue that while each yields important insights as to how to facilitate taxonomic progress in psychology and neuroscience, only a coordinated pluralism that incorporates positive aspects of each initiative and implements them on a broad scale in psychology and neuroscience will have the potential for success. By “coordinated pluralism” I mean simply that scientists may structure – that is, “coordinate” – their conceptual, investigative, taxonomic and integrative practices in ways that strike an appropriate balance between pragmatic and realist goals.

### “Fundamentals of Taxonomy”

In *Fundamentals of Taxonomy* (1959/1965), Hempel put forward a general account of how taxonomic change *ideally* ought to happen in science as part of an invited address to the American Psychopathological Association (now the American Psychiatric Association (APA)), which was struggling to develop a taxonomy of psychopathological phenomena that could readily be used by clinicians and scientists who had different theoretical understandings of mental illness.<sup>1</sup> Hempel’s basic idea was that scientific classification systems first pass through an initial “descriptive” phase in which observable features of phenomena are used to specify necessary and sufficient conditions for category membership.<sup>2</sup> The resulting *operationally defined* categories (see Chang 2007; Feest 2005) serve to facilitate communication among investigators having different theoretical perspectives who are “engaged in a common research project” but lack a shared vocabulary.

Operational definitions were not the endgame of science according to Hempel; they served only as an important practical starting point. Sciences should rather strive to move away from operational definitions to conceptual taxonomies having “systematic or theoretical import” (Hempel 1959/1965). What Hempel meant by this was that sciences should aim to discover “general laws or theoretical principles which reflect uniformities in the subject matter under study” and “which provide a basis for explanation, prediction, and generally scientific understanding” (Hempel 1959/1965, 146). Discovering such general laws or theories would prompt revisions to scientific taxonomies such that the categories would ultimately correspond to *bona fide* divisions in the natural world, or “natural kinds” (see e.g., Khalidi 2013 for further and recent discussion). Hempel in fact claimed that whereas operationally defined concepts have either/or criteria of application, taxonomic progress in areas like psychiatry will likely give way to dimensional rather than categorical understandings of psychiatric kinds (Hempel 1959/1965, 153).

One limitation of Hempel’s account is the lack of direction he provides as to how to balance the *pragmatic* goal of maintaining a workable and stable taxonomy that facilitates mutual understanding across scientists interested in the same phenomena, with the *realist* goal of modifying scientific taxonomies to accommodate the causal structure of the world (see Haslam 2013). Presumably, if taxonomic categories are to be revised as new information about mechanisms comes in, the categories are not supposed to be stable. Yet, if the categories are in flux until that time at which science “gets the world right”, it is not clear how they can continue to serve the pragmatic aim for which they were originally intended.

That Hempel offers no normative prescriptions as to how to balance these two aims of scientific classification may indicate that he did not regard the potential instability of scientific categories in the face of mechanistic discovery as a problem. Indeed, he appears sympathetic to the idea that while different areas of science may have the same set of operationally defined categories in common, theoretically informed refinements to these categories could occur within different areas of science that investigate the phenomena designated by those categories. Thus, while operational definitions may remain stable *between* different areas of science that investigated the same phenomena, discoveries made *within* those areas (e.g., psychodynamics, biophysiology, biochemistry, physiochemical) could result in “classifications of mental disorders [...] increasingly reflect[ing] theoretical considerations” (Hempel 1959/1965, 150). Despite such theoretical pluralism, perhaps Hempel thought that operationally defined taxonomies would remain fixed in ways that would continue to enable scientists coming from different areas to understand each other, even if conceptual change was happening “behind the scenes” in each area of science.

Perhaps not coincidentally, the *Diagnostic and Statistical Manual of Mental Disorders* has not been modified *significantly* over the years in response to genetic, physiological and functional discoveries pertaining to the mechanisms of psychopathological phenomena. Since the development of *DSM-III*, the authors of the manual have, at least in part, sought to preserve operationally defined categories of disorder, upholding the pragmatic aim of facilitating communication across clinicians over that of validity (see e.g., Haslam 2013). Within areas of science investigating psychopathological phenomena, discoveries have been made that are regarded by some as relevant to revising the categories. However, the manual has resisted such changes. In fact, “the DSM-5 Task Force”, which “oversaw the new edition” of the manual, “recognized that research advances will require careful, iterative changes if DSM is to maintain its place as the touchstone classification of mental disorders” (APA 2013, 5). While they believe that the “DSM must evolve

in the context of other clinical research initiatives in the field” and be updated as reliable scientific findings come in, they recognize that “finding the right balance” between the pragmatic and realist goals “is critical” (APA 2013, 5). Moving too quickly to update the manual in the face of scientific discovery could potentially undermine the inter-rater reliability – indeed the conceptual stability – that the current categorical system is supposed to ensure.

Hempel’s account of taxonomic change is relevant for my purposes in the rest of this paper for several reasons. First, Hempel importantly recognized that scientific taxonomies are often subject to two constraints, one pragmatic and the other realist. When multiple areas of science are interested in the same phenomena, it is important that those areas of science have a shared vocabulary to conceptualize those phenomena. Without such a shared vocabulary that facilitates effective communication, progress in understanding those phenomena is not possible. Realization of the pragmatic aim is also prerequisite for realization of the realist one. If investigators cannot agree on what the phenomena are, the ensuing miscommunication will be a barrier to the kind of collaboration across investigators requisite to discover nature’s joints. What Hempel neglected to mention, however, is what should be done as the drive to discover mechanisms begins to compromise the stability of the shared vocabulary, but yet its very stability is necessary for ensuring conceptual and explanatory progress.

The challenge of striking a balance between these two aims is particularly acute in the mind-brain sciences where taxonomic and explanatory progress with respect to psychological functioning is taken to require input from multiple different areas of science. As I explain in the next section, current conceptual and methodological practices in the mind-brain sciences currently are not coordinated in ways that facilitate the pragmatic goal, which thus also threatens the realist one.

### **Conceptual and methodological pluralism unbridled**

Over the past two decades scientists and philosophers have noted that rampant conceptual and methodological pluralisms in psychology and neuroscience are impediments to conceptual and explanatory progress. Russell Poldrack and Tal Yarkoni, for example note, “cognitive neuroscience” alone “is awash in a sea of conflicting terms and concepts” (2016, 588). They agree with William Uttal that this is in part a consequence of “hypothetical psychological constructs [being] invented ad lib and ad hoc without adequate consideration of the fundamental issue of the very plausibility of precise definition” (2001, 90). Indeed, if we look across different areas of neuroscience, although investigators appear to have terms like “attention”, “memory”, “encoding” and “forgetting” in common, “the concepts that the terms designate are not” shared (Roediger, Dudai, and Fitzpatrick 2007, 1). Each discipline, rather, “contributes a distinctive vocabulary of terms and acronyms, all embedded to some degree or another in zeitgeists and conceptual frameworks” (Roediger, Dudai, and Fitzpatrick 2007, 1). This prompts miscommunication across investigators, which is one barrier to the development of a taxonomy of psychological constructs that realizes the pragmatic goal.

A corresponding problem is the multiplicity of experimental paradigms and protocols used to investigate psychological functions in both human and animal models (Sullivan 2009). An experimental paradigm is a set of procedures for producing, measuring, and detecting a cognitive capacity of interest in a laboratory (Feest 2010; Sullivan 2009). Experimental paradigms (or tasks or tests) are used to *operationally define* (Chang 2007; Feest 2005) psychological constructs. Yet, experimental paradigms have mutable parameters with respect to such things as stimulus type, stimulus duration, inter-stimulus and inter-

trial intervals (Sullivan 2009). Investigators currently have the freedom to develop new paradigms or modify existing ones to suit their investigative purposes. The end result is that “there are few standardized versions of the tasks used in cognitive neuroscience” and “a number of different researchers may use similar but nonidentical tasks to measure the same cognitive construct” (Carter and Barch 2007, 1134). This methodological pluralism is also a barrier to realization of the pragmatic aim of a shared taxonomy of psychological functions. It is widely recognized that discovering the neural, molecular and genetic bases of cognitive functions is not something that will happen in a single laboratory; it requires input from investigators working in many different laboratories in different areas of science. Scientists thus need to be able to synthesize data emanating from multiple different laboratories. Yet, given that even subtle differences in experimental paradigms across laboratories may result in variations in the effects under study in those laboratories, scientists have no real grounds for saying that the same psychological construct is being detected in all cases in which the “same” paradigm is being used. Thus, although progress towards the realist goal is contingent on integration, the investigative practices of mind-brain scientists currently are not amenable to realization of the pragmatic goal (see e.g., Sullivan 2009; Sullivan 2016a, 2016b, 2016c).

A third problem in the contemporary mind-brain sciences concerns the issue of *construct validity* (see e.g., Cronbach and Meehl 1955; Shadish, Cook, and Campbell 2002; Sullivan 2016a, 2016b, 2016c). Ideally, an investigator aims to design an experimental paradigm that produces an instance of the construct he intends to detect and measure. He ought to want the match between the effect he produces in the laboratory and the phenomena he takes to be grouped together under the general construct to be valid. Another way to put this is that he aims for the experimental paradigm he selected to have a high degree of “construct validity.” Construct validity “is involved whenever a test is to be interpreted as a measure of some attribute or quality which is not operationally defined” (Cronbach and Meehl 1955, 282). It “involves making inferences from the sampling particulars of a study to the higher-order constructs they represent” (Shadish, Cook, and Campbell 2002, 65). Experimental paradigms or cognitive tasks may have anywhere from a low to high degree of construct validity. The higher the degree of construct validity, the closer the match between the effect under study in the laboratory and the cognitive phenomena designated by the construct.

Achieving construct validity, however, is an iterative process.<sup>3</sup> It requires an investigator to be vigilant in evaluating not only the meanings of the constructs she deploys, but the experimental paradigms she uses to produce, detect and measure instances of them in the laboratory. This involves the processes of “construct explication” and “construct assessment” (Shadish, Cook, and Campbell 2002). These processes may be understood in terms of a series of questions that investigators ask themselves about the constructs they are investigating and the paradigms they use for detecting them. Such questions include: (1) Which instances of worldly phenomena should be grouped together under the concept designating the construct? (2) Which investigative strategies will yield instances that instantiate it? (3) Are the investigative strategies adequate, or should they be modified? (4) Given the data these investigative strategies yield, should the construct be revised to exclude phenomena that do not belong in the category or to include additional phenomena that do?

However, we do not find a consistent emphasis on construct validation, explication, and assessment across laboratories and investigators in the same and different areas of cognitive psychology and neuroscience (see Sullivan 2016a, 2016b). Thus, it is not uncommon for investigators to be unsure what constructs the experimental paradigms they are using

actually measure, and intuitive judgments often inform the design of experimental paradigms and interpretation of results obtained using them (see e.g., Abend 2016; Figdor 2011; Francken and Slors 2014; Poldrack 2010; Sullivan 2010, 2016a, 2016b, 2016c).

Psychology and neuroscience thus find themselves in a similar (though seemingly worse) position than the APA found itself in the 1950s. Different scientists interested in understanding psychological functions and their mechanisms share neither a vocabulary of terms designating psychological functions nor standardized sets of procedures for producing, detecting and measuring them. Some psychologists and neuroscientists have recognized these problems and a number of knowledge-building initiatives have emerged to address them. In the next two sections, I evaluate these initiatives with respect to how well they realize and balance pragmatic and realist constraints on scientific taxonomies and whether they pave the way for taxonomic progress.

### **Facilitating taxonomic progress: databases and ontologies**

In the biological sciences, databases have been instrumental in bringing together data from diverse sources and securing the stability of constructs, thereby facilitating communication across different areas of science that study the same phenomena (see e.g., Leonelli 2009, 2013). During the past decade, a number of different platforms and databases (e.g., Brain-Map, Neurosynth) containing functional and structural data from thousands of published neuroimaging experiments have been developed in the hope that the same kinds of strategies will facilitate progress in cognitive neuroscience. These databases have been used to conduct automated meta-analyses that integrate neuroimaging data from a diverse array of experiments and represent it in the form of brain activity maps. This is achieved by means of labels designating different functional domains (e.g. emotion, cognition, action) and/or labels corresponding to functions within those domains (e.g., fear, episodic memory, olfaction). Inputting a label such as “attention” or clicking on that label enables a user to generate a single brain activity map that synthesizes all of the neuroimaging data associated with that label. One can also compare and contrast brain activity maps that are generated for different labels.

How do databases facilitate the pragmatic goal of scientific taxonomies? The short answer is “they don’t”. Curators decide which labels will be used to classify data within a given database and thus, which labels users can use to retrieve and integrate data. The labels designating psychological functions that current databases contain do not reflect intra and interdisciplinary consensus as to how to generally define or how to produce, detect and measure the phenomena designated by those labels. Thus, these labels do not satisfy the pragmatic constraint on scientific taxonomies; conceptual disagreements across investigators as to how to define the constructs designated by the labels persist. Far worse, these databases run afoul of the realist aim. When a user inputs a label into a given database to conduct a meta-analysis of the literature, the brain map generated abstracts away from details about the contexts, experimental paradigms and protocols used to produce each data set. Yet differences across laboratories in terms of how a given psychological function is produced, detected and measured, may correspond to differences in the mechanisms productive of these functions across these different contexts (Sullivan 2009). Thus, we should not expect that amassing potentially discordant data from many different laboratories under a single common label (e.g., “attention”) will shed light on real divisions in the causal structure of the world (Sullivan 2016a, 2016b, 2016c). Databases do not achieve the pragmatic goal of creating a common vocabulary for cognitive neuroscientists, nor do they facilitate attainment of the realist goal. The

achievement of such aims requires investigators to actively coordinate their conceptual and investigative practices. But how might they do this?

One aim of the *Cognitive Atlas*, a collaborative web-based knowledge-building project, is to promote such coordination (Poldrack et al. 2011; Poldrack and Yarkoni 2016). The Atlas is an ontology that aims to systematically depict: (1) psychological functions currently under study in cognitive neuroscience, (2) the experimental paradigms/tasks/tests used to investigate those functions, and (3) the relationships between (a) different functions and (b) different paradigms used to investigate those functions. General definitions are provided for each hypothetical psychological construct (e.g., “attention”, “working memory”) identified in the *Atlas*. Each experimental paradigm, task or test that the Atlas contains is also given a general definition. Atlas users can develop a basic understanding of the psychological landscape under investigation in cognitive neuroscience and (to a much lesser extent) cognitive neurobiology, where experimental paradigms are used to investigate the mechanisms of psychological functions in animal models. One can also use the Atlas to identify links between hypothetical constructs designating psychological functions and the experimental paradigms used to operationalize them. The Atlas is also designed to interface with neuroimaging databases like BrainMap and Neurosynth, offering a different conceptual-theoretical framework for extracting and synthesizing together behavioral, structural and imaging data from the published record.

How does the Atlas fair with respect to the pragmatic and realist aims of scientific taxonomies? The Atlas represents a positive advance towards the development of standardized definitions for psychological constructs and standardized procedures for investigating them. Its very existence is thus an important first step in achievement of the pragmatic goal insofar as it may contribute to “reduc[ing] the likelihood of miscommunication between researchers” about how to categorize and individuate psychological functions (Poldrack and Yarkoni 2016, 604). Additionally, it allows its users to identify and document when they agree or disagree about (a) how a term designating a construct is defined and (b) the asserted relationships between different constructs. It also allows users to see which experimental paradigms and task contrasts have been used to investigate which functions.

The Atlas, however, has practical limitations. First, although it is a community-based knowledge-building initiative, members of the scientific community have to opt-in to contribute to it and use it. Thus, achieving the pragmatic goal of developing a shared vocabulary is contingent on the participation and cooperation of the cognitive neuroscience community and other relevant scientific communities invested in understanding psychological functions and their mechanisms. It is important to recognize, however, that even if scientists from all of the relevant communities opt-in to using the Atlas, this alone will not be sufficient for changing conceptual and investigative practices across the mind-brain sciences in ways that ensure that investigators share a vocabulary of psychological constructs and standardized sets of procedures for producing, detecting and measuring them. As I show in the next section, scientists also have to opt-in to collaborate and coordinate their practices to bring such changes about.

The Atlas is also intended to function as an alternative framework for integrating neuroimaging data by means of meta-analyses, yet it suffers from similar kinds of problems that I attributed to databases earlier in this section. Although it enables users to integrate data across research studies that use the same experimental paradigm or task contrasts (or the same construct labels), there are other alternatives for representing the features of experimental paradigms that may put us on better epistemic footing for determining when two versions of the same paradigm are detecting the same psychological function or not. For example, while the Atlas allows paradigms to be searchable by name (e.g., “Sternberg



item recognition task”), another alternative ontology, the Cognitive Paradigm Ontology (CogPo) (Turner and Laird 2012), represents experimental paradigms in terms of three features: (1) the stimuli used in the paradigm, (2) the task instructions provided to the subjects run through the paradigm and (3) the responses expected from subjects after being run through the paradigm. CogPo represents these three features because its developers recognize that in “the experimental psychology and cognitive neuroscience literature [...] experimental paradigms can vary tremendously in the stimuli that are presented to the subject, the response expected from the subject and the instructions given to the subject” (<http://www.cogpo.org>). Meta-analyses that abstract away from such details may integrate data that does not belong together under the same construct label. Although focusing on three parameters of experimental paradigms alone may leave out other parameters of research studies that can also vary from one research study to the next, CogPo importantly sheds light on some of the parameters of experimental paradigms that need to be kept constant across research studies to facilitate the comparability of results across those studies.

Scientists involved in the aforementioned knowledge-building initiatives recognize these limitations of current databases and ontology building projects and have thus sought to develop other complementary approaches that are more directly geared towards coordinating investigative practices in psychology and neuroscience. One such database is the *The Experiment Factory* (<http://expfactory.org>), which is an “open source of behavioral experiments for reproducible science” (Sochat et al. 2016). It provides users with a collection of experimental paradigms and experimental paradigm batteries (groups of experimental paradigms to be run in sequence) that can be implemented in (i.e., run on a local computer) and standardized across local experimental contexts. Its developers importantly recognize that “the administration of behavioral and experimental paradigms for psychology research is” currently “hindered by lack of a coordinated effort to develop and deploy standardized paradigms” (Sochat et al. 2016, 1). The Experiment Factory offers a means by which to make such coordination and standardization possible.

If different investigators working in different laboratories reach some agreement about which paradigms ought to be used to study which psychological functions and which features of those paradigms need to be standardized across laboratories, it could facilitate a shared vocabulary of psychological constructs across researchers. More specifically, investigators who implement the same experimental paradigm or paradigm battery in their laboratories will be more confident that they are all individuating the same (or close to the same) psychological function. Results from meta-analyses that integrate neuroimaging data across these different implementations into brain maps will likely be taken as unproblematically revealing structure-function mappings.

While the Experiment Factory is another important open source knowledge-building initiative that could put psychology and neuroscience on a trajectory towards a shared taxonomy of psychological functions, its primary limitation is that it requires researchers to actively use it. Yet, given what I have said previously, developing experimental paradigms that effectively individuate discrete psychological functions is an iterative process that requires investigators to think about how to define the psychological functions that they are investigating and to think about whether the experimental paradigms they are deploying actually individuate the psychological function of interest. So it seems that at a bare minimum, those investigators who opt-in to using the Experiment Factory will need to interact as a community to facilitate conceptual progress. While its very existence is one important step towards coordinating conceptual and investigative strategies across investigators, it would seem that more coordinated interactions among investigators are required.

In summary, high-level community-based knowledge-building initiatives like the ones I have considered in this section will likely not, on their own, result in taxonomies of psychological functions that satisfy Hempel's two objectives. I make the case in the next two sections that realization of these objectives also requires individual scientists and scientific communities to interactively structure and coordinate their conceptual and investigative practices with an eye towards attaining them.

### Scientific repertoires

At least some psychologists and neuroscientists, particularly those who conceive of mental illness as involving disruptions in psychological functions, do not regard the aforementioned knowledge-building projects as sufficient for advancing our understanding of these functions. Rather, they believe that collaborative knowledge-building initiatives are essential for achieving this goal. Two such initiatives are the Cognitive Neuroscience Treatment Research to Improve Cognition in Schizophrenia (CNTRICS) and the Research Domain Criteria (RDoC) Project, which are funded by the National Institute of Mental Health (NIMH). CNTRICS and RDoC may be regarded as examples of what Rachel Ankeny and Sabina Leonelli (2015, 2016) refer to as "scientific repertoires" and what Kathryn Tabb (2016) dubs "psychiatric repertoires". Briefly, a *repertoire* "encompasses well-aligned assemblages of the skills, behaviors, and material, social and epistemic components that a group may use to practice certain kinds of science, and whose enactment affects the methods and results of research" (Ankeny and Leonelli 2016, 18). They are typically "large-scale" (although they may indeed start out smaller scale) and involve "the production and development of knowledge within the various social, cultural, institutional, and economic environments in which scientific research occurs" (Ankeny and Leonelli 2016, 19). In the next two sections, I evaluate the CNTRICS (see also Sullivan 2014b) and RDoC initiatives (see also Sullivan 2016b), with respect to how well they balance pragmatic and realist constraints on scientific taxonomies.

*CNTRICS*. For at least two decades, psychologists and neuroscientists have been sympathetic to the idea that schizophrenia may involve disruptions in fundamental domains of psychological functioning like those under study in psychology and neuroscience. A key case in point is schizophrenia, which is identified in the DSM as a psychotic disorder that may involve "delusions, hallucinations, disorganized thinking (speech), grossly disorganized or abnormal motor behavior (including catatonia), and negative symptoms". By the late 1990s, schizophrenia was thought to involve "neurocognitive" deficits and a group of academic scientists, members of the pharmaceutical industry and Food and Drug Administration (FDA) sought to develop paper and pencil based tasks as a means to identify these deficits and determine their functional consequences (Green 1996; Green, Kern, and Heaton 2004). This approach was supposed to facilitate the discovery of the mechanisms of these deficits, so that viable therapeutic interventions could be developed to treat them. This initiative, known as *Measurement of Treatment Effects on Cognition in Schizophrenia* (MATRICS), resulted in a set of "well-standardized tests with well known, strong measurement properties" (Carter and Barch 2007). Yet, because these tests were pencil-and-paper based, they suffered from two specific limitations: they could not be used in neuroimaging studies nor were they translatable at the level of animal models. The tests thus could not be used to identify the neural mechanisms of neurocognitive dysfunction in schizophrenia nor aide in the discovery of viable pharmacological interventions.

NIMH established a related consensus-based initiative, *Cognitive Neuroscience to Improve Cognition in Schizophrenia* (CNTRICS), nearly 10 years later. Spearheaded by

Cameron Carter and Deanna Barch, CNTRICS took a “cognitively mechanistic approach” to understanding cognitive dysfunction in schizophrenia (Carter et al. 2008, 4). As an interdisciplinary initiative, it included “experts in basic cognitive neuroscience, clinical studies of cognition in schizophrenia, and animal pharmacology” as well as members of “small and large pharmaceutical, biotechnology and other relevant industry organizations” (Carter et al. 2008, 5). CNTRICS’ first aim was to identify a set of *valid* psychological functions likely to be disrupted in schizophrenia, and which could readily be investigated in humans and animal models. The second aim was to develop experimental paradigms that could be used to detect and measure these functions in human subjects and that could be standardized across laboratories. A corresponding set of standardized experimental paradigms was to be developed to detect and measure these functions in animal models. The “results of animal [and] human studies” were to be used as a basis for “identifying molecular targets that modulate cognition” (Carter and Barch 2007, 1132), with the ultimate aim to develop pro-cognitive agents to treat cognitive dysfunction in persons with schizophrenia.

CNTRICS has sought to achieve the aforementioned aims during numerous “consensus-building meetings” held periodically over the past 10 years during (Carter et al. 2008, 6). The initial meetings were “preceded by a set of interactive web-based surveys to include a broader range of participants” from the relevant fields of science “than [could] be accommodated at the meetings” (Carter et al. 2008, 6). Results from these surveys were used as a basis for “select[ing] constructs that ha[d] prominence in the field of cognitive neuroscience and substantial promise for delineating elementary cognitive processes that may be more closely connected to neural systems” (Carter et al. 2008, 5). During the first CNTRICS meeting this initial list of constructs was modified and the constructs were defined (Carter et al. 2008, 8). Importantly, participants at this first meeting “fully recognize[d] that even the parsing and definitions” that they “developed [...] were only one way of “carving cognition at its joints” and “[they did] not intend [their] definitions of constructs and cognitive domains to be reified in any way” (Carter et al. 2008, 8). Another way to put this is that while they sought to establish consensus definitions for these constructs, they were open to the possibility that the categories they were identifying may not track mechanisms and may need to be revised accordingly. In fact, when “the discussion among experts” during breakout groups at the first meeting “suggested a different parsing of cognition [than] the CNTRICS steering committee [had] initially proposed”, the initial taxonomy of psychological constructs was revised (Carter et al. 2008, 9).

The “initial list of candidate constructs” corresponded to “6 broad cognitive domains”<sup>4</sup> and included *working memory*, *episodic memory*, *attention*, *executive function*, *perception* and *social cognition*. Working groups were assigned to each psychological construct and a consensus-based approach was used “to identify a set of cognitive tasks that” could be used to “measure the cognitive constructs identified in the first meeting” with the aim of “identify[ing] the most validated cognitive measures” (Carter and Barch 2007, 1135). Research going forward was to be directed at “develop[ing] and establish[ing] appropriate psychometric (and practical) characteristics of such tasks, while retaining the initial validity that led to their selection in the first place” (Carter and Barch 2007, 1135).

Across numerous publications CNTRICS investigators sought to define and refine the original set of constructs and to identify how the constructs related to each other (see e.g., Barch, Berman et al. 2009; Barch, Braver et al. 2009; Butler, Silverstein, and Dakin 2008; Carter, Kerns, and Cohen 2004; Kerns et al. 2008; Luck and Gold 2008; Ragland et al. 2009, 2012; Barch and Carter 2007). Tasks that were thought to involve multiple cognitive processes were regarded as “less helpful for understanding the specific nature of cognitive deficits, for identifying useful drug targets, [and] for assessing change (e.g., test-retest

reliability) in specific cognitive functions” (Carter and Barch 2007, 1133). The scientists in turn sought to develop tasks that could measure more precise cognitive functions (e.g., like “control of attention” (see e.g., Luck and Gold 2008; Nuechterlein et al. 2009)). Achieving this goal required members of each working group to interact between CNTRICS meetings to select and refine the tasks and their associated constructs.

Within the context of CNTRICS, scientists sought to develop a taxonomy of psychological constructs to be shared by the initiative’s interdisciplinary members. The working groups developed sets of experimental paradigms for detecting and measuring those constructs in humans and animal models, sought to ensure that the paradigms satisfied the criterion of construct validity (i.e., that they measured the psychological functions they were intended to measure) and sought to standardize the implementation of those paradigms across CNTRICS members’ laboratories. I take these strategies to exemplify how scientists working within a repertoire can organize their practices so as to realize the pragmatic goal of developing a shared taxonomy of constructs. Notice, too, that such coordination brings CNTRICS closer to achievement of the realist goal of identifying the mechanisms of these functions. Members of the working groups are concerned to ensure that the psychological constructs and the tasks used to investigate them are sufficient for discovering their mechanisms.

CNTRICS working groups involved a relatively small number of investigators compared to the total number of investigators in neuroscience at large who are interested in CNTRICS’ constructs. Given the size of the initiative and the relatively small number of constructs that were its focus, members were able to coordinate their conceptual and investigative practices across laboratories with an eye towards making taxonomic progress. Such coordination required significant time investment and hard work on the part of CNTRICS participants to interact and maintain effective working relationships.<sup>5</sup>

*RDoC.* As early as 2010, there was an emerging consensus at NIMH that in addition to schizophrenia, other mental disorders were best understood as involving disruptions in psychological and behavioral functioning. This prompted the development of a new framework for mental illness research, the RDoC Project. RDoC bears some similarities to CNTRICS. In fact, the “rigorous focus and collaborative process” of “both MATRICS and CNTRICS” that involved “distilling a large and nuanced literature to a manageable number of defined domains, followed by standardization of measurement – provided a template for the processes by which RDoC has advanced” (Morris and Cuthbert 2012, 30). RDoC, however, has a much broader scope insofar as it focuses on “more than one clinical concern (cognition in schizophrenia)” (Morris and Cuthbert 2012, 30). Its advocates maintain that understanding and explaining *all* psychopathological phenomena requires input from different areas of science that investigate the role of different units of analysis (e.g., genes, cells, systems) in the production of psychological functions.

At the center of the initiative is the RDoC matrix, which is a table for inputting data from these different areas of science. The matrix identifies five broad domains of psychological functioning, which constitute the rows of the first column of the matrix (<https://www.nimh.nih.gov/research-priorities/rdoc/constructs/rdoc-matrix.shtml>). These domains include (1) *positive* and (2) *negative valence systems* and (3) *cognitive*, (4) *social processing* and (5) *arousal/modulatory systems*. Constructs designating a subset of behavioral functions currently under study across psychology and neuroscience are identified and classified under one of each of the five functional domains. For example, *attention* and *working memory* are constructs that are classified as instances of cognitive systems. Each construct is also given a general definition. In most cases, these definitions make reference to neural, psychological and behavioral processes associated with the construct. For example, *fear* is

characterized as involving “activation of the brain’s defensive motivational system to promote” protective behaviors (i.e., neural processes), “a pattern of adaptive responses to conditioned and unconditioned threat stimuli” (i.e., behavioral/psychological processes) and possibly “internal representations and cognitive processing” (i.e., psychological processes) (<http://www.nimh.nih.gov/research-priorities/rdoc/constructs/acute-threat-fear.shtml>). The columns of the matrix reflect that research on domains of behavioral functioning spans multiple levels of organization from genes to cells to networks to behavior and includes multiple different areas of science (e.g., psychology, systems neuroscience, neurobiology). An additional column labeled “paradigms” is where *experimental paradigms* used to produce, detect and measure behavioral functions that correspond to the constructs in the matrix, are placed.

The development of the RDoC matrix and selection of RDoC functional domains, constructs and sub-constructs were the outcomes “of a collaborative effort of leading scientists across multiple workshops” (<https://www.nimh.nih.gov/research-priorities/rdoc/development-of-the-rdoc-framework.shtml>). An initial “field-wide” survey was conducted to identify “tasks and measurement tools that were recommended for inclusion in the RDoC matrix” and to solicit “general suggestions about the most important criteria for consideration in selecting candidate tests” (NIMH 2016). In later consensus-based workshops, small groups of investigators were assigned to each domain of functioning and asked to rate a set of 2–4 pre-selected experimental paradigms in terms of that paradigm’s ability to measure the associated construct (and to serve other related functions).<sup>6</sup> These meetings were intended to “initiate the development of standardized paradigms and measures” for coordinating the experimental study of these constructs across laboratories (NIMH 2016, 3). A forward-looking goal of the RDoC task force is to “ensure that all labs using a certain task are measuring the same phenomenon” (NIMH 2016, 6).

The RDoC initiative importantly recognizes that progress in understanding psychological functions requires coordinated efforts across those areas of science that aim to understand them. It emphasizes the importance of a shared taxonomy of psychological constructs (see e.g., Sanislow et al. 2010), a standardized set of experimental paradigms for investigating them, and consensus among its working groups that the selected paradigms measure the constructs that they are intended to measure (construct validity). Additionally, while RDoC encourages the standardization of experimental paradigms used to individuate RDoC constructs, its developers worry that emphasis on the pragmatic goal (i.e., inter-rater reliability) may thwart the realist one (i.e., valid constructs). Thus, the RDoC task forces put forward instructions for balancing pragmatic and realist goals in claiming that:

it is important to develop a set of paradigms and measures that are generally accepted by the field and which can facilitate comparisons across studies and sharing of data. However, if NIMH prematurely establishes a battery of affective, behavioral, and cognitive tasks for use in RDoC research, it runs the risk of hampering future methodological innovation and revisions to the RDoC constructs, which would have deleterious effects on the long-term development of RDoC. A reasonable compromise is to establish a set of standardized paradigms and measures which are appropriate for assessing RDoC constructs, but which are not required to be used in RDoC research. Such a list would offer the field some standardization that can foster data sharing through the RDoC Database (RDoCdb), but would require regular revision in order to incorporate new developments and findings. (NIMH 2016, 2–3)

In other words, as investigators involved in RDoC have made clear across a number of publications, the constructs are heuristics that will likely change in light of future discovery, but

such changes will not threaten the stability of the constructs just so long as the working groups regularly update them gradually so as to preserve the pragmatic aim while facilitating the realist one.

RDoC has already been the subject of widespread criticism (see e.g., Lilienfeld 2014; Lilienfeld and Treadway 2016; Poland and Tekin 2017; Theurer and Hartner 2016; Sullivan 2016c) and I am not endorsing it as offering a correct approach for understanding and explaining mental illness. I merely mean to point out that RDoC and CNTRICS are two initiatives that offer important insights about how to effectively coordinate conceptual and investigative practices across the sciences of the mind and brain (and body) so as to achieve taxonomic progress. I think that taxonomic and explanatory progress in understanding psychological functions might be facilitated on a broader scale in the mind-brain sciences with initiatives bearing some structural and organizational resemblance to CNTRICS and RDoC (Sullivan 2016b).

### **Coordinated pluralism**

In the second section, I described a number of obstacles to progress in the mind-brain sciences with respect to understanding psychological functions and their mechanisms. I think what we find in the contemporary mind-brain sciences *is* “uncoordinated” or “self-defeating pluralism”. Pluralists in philosophy of science have emphasized the importance of a plurality of theories, concepts/conceptual frameworks, perspectives, methods, models and explanations to the advancement of scientific knowledge (see e.g., Chang 2012; Kellert, Longino, and Waters 2006; Mitchell 2003). The worry about preventing a thousand flowers from blooming is that it may block the possibility of novel discoveries and actually impede progress. However, the unfettered pluralism that we encounter in contemporary neuroscience is widely recognized as an obstacle to taxonomic progress. What we need instead is what I want to dub “coordinated pluralism”.<sup>7</sup>

We find a basic recipe for coordinated pluralism across the different initiatives that I have considered in this paper. High-level knowledge-building initiatives like the Cognitive Atlas, CogPo and the Experiment Factory are important for creating an online infrastructure to facilitate taxonomic change in psychology and neuroscience. However, investigators also have to collectively structure their conceptual and methodological practices in ways that facilitate taxonomic progress. On-line databases (BrainMap, NeuroSynth), ontologies (Cognitive Atlas, CogPo) and open source software (The Experiment Factory) will play important roles in guiding, informing and facilitating such coordination. Yet, as the CNTRICS and RDoC initiatives clearly illustrate, such coordination also requires the development of an organizational infrastructure – a scientific repertoire – that enables investigators from the relevant areas of psychology and neuroscience to collaboratively structure their conceptual and methodological practices in ways that more adequately facilitate taxonomic change.

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### Notes

1. At that time, the DSM (DSM-1) contained many psychodynamic terms, including “conversion”, “mental conflict”, “secondary gain” and “neurosis”, which did not “refer to directly observable phenomena” but instead “to theoretically assumed psychodynamic factors” that “ha[d] a distinct meaning and function only in the context of” a corresponding theory (Hempel 1959, 140). The problem was that the clinicians and scientists who used the manual hailed from a diverse array of theoretical backgrounds. Clinicians coming from different theoretical backgrounds either did not use these terms at all or used the same terms in different ways. This prompted miscommunication and correlated with “diagnostic agreement between clinicians (i.e., inter-rater reliability)” being “sometimes little better than chance” (Haslam 2013, 7)
2. Importantly, Hempel claims that not all terms in a given area of science are or can be operationally defined. He says, “It would be unreasonable to demand, however, that all the terms used in a given scientific discipline be given an operational specification of meaning; for then, the process of specifying the meanings of the defining terms, and so forth, would lead to an infinite regress. In any definitional context [quite independently of the issue of operationism], some terms must be antecedently understood; and the objectivity of science demands that the terms which serve as a basis for the introduction of other scientific terms should be among those used with a high degree of uniformity by different investigators in the field (Hempel 144).”
3. Uljana Feest 2010, 2011, 2016 describes the iterative and dynamic nature of concept formation and knowledge production in psychology.
4. Although the CNTRICS initiative (at least initially) aimed to develop treatments for impaired cognitive and emotional processing in schizophrenia (See Carter and Barch 2007, 1134), I am only focusing on work on cognitive constructs in this paper.
5. A series of meetings involving working task forces eventually led to the development of the Cognitive Neuroscience Test Reliability and Clinical Applications for Schizophrenia (CNTRACS) Consortium, which, by 2012 (Gold et al. 2012), had narrowed down the initial list of constructs to 4 constructs and 4 related tasks: (1) goal maintenance/dot probe expectancy task (DPX); (2) relational encoding and retrieval/relational and item specific encoding task (RISE); (3) gain control/contrast-contrast effect task (CCE); and (4) visual integration/jitter orientation visual integration task (JOVI). This is a much more modest list of constructs and paradigms than were originally being considered, which may mean that doing rigorous analysis of constructs and the tools used to measure them may actually serve to significantly narrow the pool of constructs considered to be valid and the pools of tasks thought to measure them. As an aside, there is little of the categories of folk psychology in this list of constructs. What role folk psychology ought to play in the sciences of the mind and brain remains a hot topic of debate (See for example Francken and Slors 2014; Hochstein 2012, 2013; Sullivan 2014a). Russ Poldrack also has a blog post on this issue with some interesting responses. <http://www.russpoldrack.org/2016/04/how-folksy-is-psychology-linguistic.html>
6. It was, however acknowledged that some paradigms did not allow behavioral assessment and required assessment at other levels of analysis (e.g., fMRI data).
7. In a recent presentation at the 25<sup>th</sup> Biennial Philosophy of Science Association Meeting, Noel Martin (Martin 2016) put forward an account of coordinating in the mind-brain sciences in response to my claim that current practices are not coordinated in ways that facilitate explanatory integration. What I mean by “coordinated pluralism” here differs from what he means by “coordinating”.

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