An Account of the Relationship between Psychological Capacities and Neurobiological Activities

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Abstract

This paper addresses the relationship between psychological capacities, as they are understood within cognitive psychology, and neurobiological activities. First, Lycan's (1987) account of this relationship is examined and certain problems with his account are explained. According to Lycan, psychological capacities occupy a higher level than neurobiological activities in a hierarchy of levels of nature, and psychological entities can be decomposed into neurobiological ones. In the second half of this paper, an alternative account is laid out. This new account uses levels of organization and levels of explanation to create a two-dimensional model. Psychological capacities occupy a high level of explanation relative to the cellular and molecular levels of organization. Consequently, according to this model, psychological capacities are a particular way of describing the activities that occur at the cellular and molecular levels of organization.

1 Introduction

This paper proposes a model for understanding the relationship between psychological capacities and neurobiological activities. Here *psychological capacities*, or just *the psychological*, will refer specifically to the capacities that are defined and explained within the domain of cognitive psychology. Typically, *psychological capacity* refers to a certain class of abilities that can be addressed from a number of perspectives besides cognitive psychology, for example, from within neurobiology or cognitive science. In this paper, however, *psychological capacity* will only refer to capacities understood in psychological terms (i.e., described in psychological language). And *neurobiological activities* will refer to the processes—and the entities that participate in those processes—that occur within the brain.

Herein I am not addressing whether psychology is autonomous from neurobiology or whether psychology can be reduced to neurobiology. These are issues that concern the ultimate status of the science, psychology. The topic in this paper is the relationship between psychological things and neurobiological things, and I begin by assuming that they are related. The question then is, how can each be understood such that it is explicitly consistent with the other? The answer to this question will indicate how they are related.

The standard way of addressing this problem is to say that the relationship between psychological capacities and neurobiological activities is similar to the relationship that exists between the entities described in chemistry and the entities that belong to physics. In the latter case, to put it simply, physics is more basic than chemistry, and the entities that belong to the domain of chemistry are composed of the entities found in physics.

Lycan has developed a detailed account of the relationship between psychological capacities and neurobiological acitivites that utilizes this chemistry-physics model and the hierarchical organization that it depends on (1987, see also 1981, 1991). According to his account each psychological capacity can be decomposed into component parts. Each of these components can then be similarly decomposed, and if the process is continued, the decomposition will eventually yield neurobiological and neurochemical entities—and still lower level entities if it is further continued.[1]

Lycan is correct that the hierarchical organization found in nature has a central role in explaining the relationship between psychological capacities and neurobiological activities. But his account contains certain problems that are a result of locating psychological capacities directly on this hierarchy. As an alternative, I outline a model that utilizes a similar hierarchy, but does not locate psychological capacities (as they are described within cognitive psychology) directly on that hierarchy. An additional set of levels, a hierarchy of levels of explanation, is needed to correctly situate the psychological with respect to the neurobiological.

2 Lycan

2.1 Three Central Features

Lycan's account has three central features. The first is the claim that psychological capacities should be understood in teleological terms. Thus, for Lycan, the function of a psychological capacity is the purpose of that capacity with the understanding that this purpose has been established by natural selection.

The second feature is what Lycan calls *homuncular functionalism*. This is the idea that psychological capacities can be decomposed into simpler components, each of which can be thought of as a homunculus that carries out a specific task. Together, this collection of homunculi performs the psychological capacity. Each one of these homunculi, which are basically sub-capacities, can then be explained by another set of homunculi (i.e., sub-sub-capacities), and so on. As Lycan says,

> To characterize the psychologists' quest in the way I have is to see them as first noting some intentionally or otherwise psychologically characterized abilities of the human subject at the level of data or phenomena, and positing—as theoretical entities—the homunculi or sub-personal agencies that are needed to explain the subject's having those abilities. Then the psychologists

[1] This account is similar in some respects to one developed by Dennett (1978), to whom Lycan attributes the basic idea. It is also similar to a view defended by Craver (2002).

> posit further, smaller homunculi in order to explain the previously posited molar behavior of the original homunculi, etc., etc. (1987, 40)

The motivation for analyzing psychological capacities in this way is explanatory. Each of these steps to "smaller" homunculi introduces new sub-capacities that are, individually, contributing less to the performance of the psychological capacity itself. The collection of simpler components explains how the higher level function is performed.

The third feature of Lycan's account is a hierarchy of levels of nature. The basic idea here is familiar. Compositionally, the entities found in nature can be put into a hierarchy. For example, organisms are composed of cells, cells are composed of molecules, molecules are composed of atoms, and so on.[2] In this hierarchy, as Lycan points out, the constituents of any particular level can be explained functionally, by referring to their purpose, or structurally, by referring to their parts, which occupy a lower level in the hierarchy. The entities at this lower level can also be characterized functionally or, by dropping down another level, structurally. Thus, as Lycan makes clear, "function" and "structure" occur throughout the levels of nature; the labels are simply relative to a place on the hierarchy.

2.2 Lycan's Account

The three features just discussed are used by Lycan to generate an account of the relationship between psychological capacities and neurobiology activities. The first step is determining how teleology is related to homuncular functionalism. To accomplish this, Lycan suggests that "teleologicalness of characterizations is a matter of degree" (1987, 43). A psychological capacity that is at the top of a hierarchy created by homuncular functionalism is characterized in very robust teleological terms. As the decomposition proceeds downward, however, the characterizations become progressively less teleological. As a result, the jobs that the smallest homunculi perform are more likely to be understood in mechanical terms than in teleological terms (1987, 44).[3]

The next step is combining homuncular functionalism and the hierarchy of levels of nature. Since they both have a levels structure, they can, in theory, be combined. And Lycan claims that "for single organisms, degrees of teleologicalness of characterization correspond rather nicely to levels of nature" (1987, 45). By this he means that the functions of the entities found at higher levels of nature are the result of natural selection, while the functions of the entities that occur at lower levels are less likely to be thought

[2]Lycan does not provide a very thorough explanation of the significant features of a level of nature. His definition is: "levels [of nature] are nexus of interesting lawlike generalizations, and are individuated according to the types of generalizations involved" (1987, 38). Referring to "nexus of interesting lawlike generalizations" does not appear to be (and may not be intended as) a precise criterion. In any case, this definition presumably allows Lycan to draw on anything that falls within the purview of science.

[3]Lycan uses an example to illustrate this notion of degrees of teleologicalness that is discussed in the next section of this paper (see figure 2). In that example, as we move down this hierarchy created by homuncular functionalism from a *face recognizer* to an *analyzer* to a *scanner* to a *light meter* and to *photosensitive chemicals*, each characterization is, Lycan suggests, less teleological than the previous one.

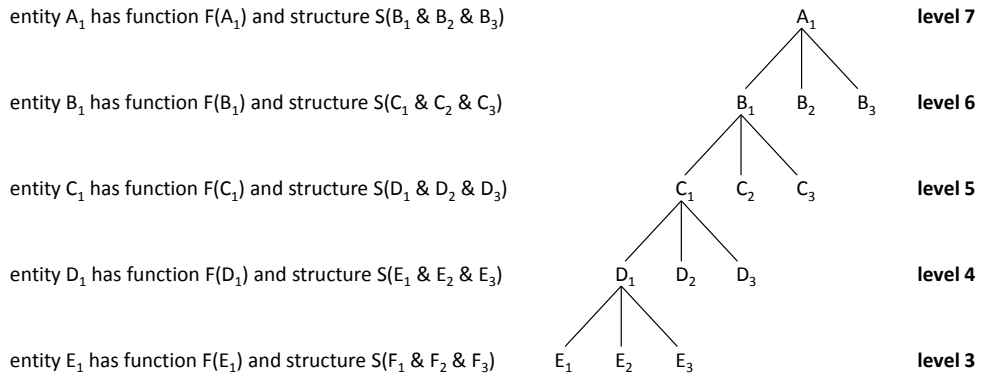

Figure 1: On the left are the functional and structural characterizations of the entities at each of several levels of nature. See text for further explanation. The same information is represented on the right as a hierarchy.

of in terms of purpose or design. Of course, the hierarchy created by homunucular functionalism also has this feature: higher level homunculi are more teleological than lower level ones. Thus, Lycan is able to claim that homuncular functionalism, which was originally a resource dedicated to understanding psychological capacities, is actually a part of the hierarchy of levels of nature.

We now have an account of the relationship between psychological capacities and neurobiological activities. The psychological, which are "highly teleological characterizations" at the top of the homuncular functionalism hierarchy, occupy a relatively high level of nature. As characterizations are offered that are less teleological—as psychological capacities are decomposed via homuncular functionalism—the move is made to lower levels of nature, eventually reaching a level occupied by neurobiological entities. In outline, this account is represented in figure 1.

Because each entity occurs at a level of nature, each can be characterized functionally or structurally, and how this is done is relative to the level of nature that is being focused on. For instance, at level 5 in the figure, entity C_1 has some particular function: function $F(C_1)$, and C_1's structure is made up of the entities that it is composed of: D_1, D_2, and D_3, which are found at the next level down. D_1, D_2, and D_3 are characterized functionally at this lower level of nature, and their structures are explained by the entities that occupy level 3.

With respect to the psychological and the neurobiological, psychological capacities are found at a higher level of nature, say level 7 in figure 1, while neurobiological activities occupy one of the lower levels.[4] Thus, $F(A_1)$ might be the ability, described in functional terms, to comprehend language. And, according to this model, the structure of this ability is found at level 6. Each of these entities at level 6, B_1, B_2 and B_3, has its own function, which is a sub-capacity of language comprehension. Down at level 3

meanwhile, entity E_1 is, let's say, a particular protein found in neurons. Thus, according to Lycan, the relationship between psychological entities and neurobiological ones is this composition relationship that can be observed by looking across levels of nature.

2.3 A Face Recognizer

An example that Lycan uses to illustrate his model is the capacity for face recognition (1987, 43–44). And although the details of the example are fictitious, the example does show how, on his account, a psychological capacity is related to the relevant neurobiological activities.

One way that face recognition might be carried out, Lycan suggests, is by implementing the following process. A particular program is engaged only when the input is a face viewed from either the right, left, or straight-forward profile. A *viewpoint locator* identifies which profile it is, and an *analyzer* then codes the relevant features based on what the viewpoint locator has told it. This information is then passed on to a *librarian* who compares it with information that is stored in memory. If a match is found, the librarian will be able to look at the identification tag attached to the information stored in the memory. The librarian will then pass the identification tag on to the *public relations officer* who will be able to give instructions to the appropriate *motor subroutine*, which will then verbally enunciate a name.

This description of these entities and their activities is one level below the teleologically defined face recognizer: a device that's purpose is to recognize faces. If information about any of these particular sub-capacities is called for, then each can itself be decomposed. For instance, the analyzer might be a *projector* that projects a grid onto the profile and a *scanner* that encodes each square of the grid in a binary code to be passed on to some sub-capacity of the librarian. If more information about the scanner is required, the scanner can be decomposed into a *light meter* and some way of reporting "0" or "1" based on the degree of darkness. The light meter can then be explained by invoking photosensitive chemicals, and so on. Thus, in several steps the face recognizer has been decomposed into relatively non-teleological chemical entities.

While this example is a good illustration of homuncular functionalism, it is also supposed to be consistent with the hierarchy of levels of nature. Each of the "homunculi"—e.g., the librarian, the projector, the scanner, and the lightmeter—are located at some level of nature. The face recognizer occupies the highest of these levels. One level below the face recognizer are the viewpoint locator, analyzer, librarian, public relations officer, and motor subroutine, which together make up the structure of the face recognizer. The entities at this lower level of nature have functional characterizations, and they are characterized structurally in terms of the entities found at the next lowest level. The function of the analyzer, for instance, is to encode the information provided to it, and the analyzer's structure is a projector and scanner, which are found one more level down.

[4]Lycan locates psychological capacities just below the level of the organism itself (the organism is an "institution" containing the psychological capacities [1987, 40]), but several levels above the neurobiological. To locate the psychological directly at the neuroanatomical level is, he says, "implausible" (1987, 59).

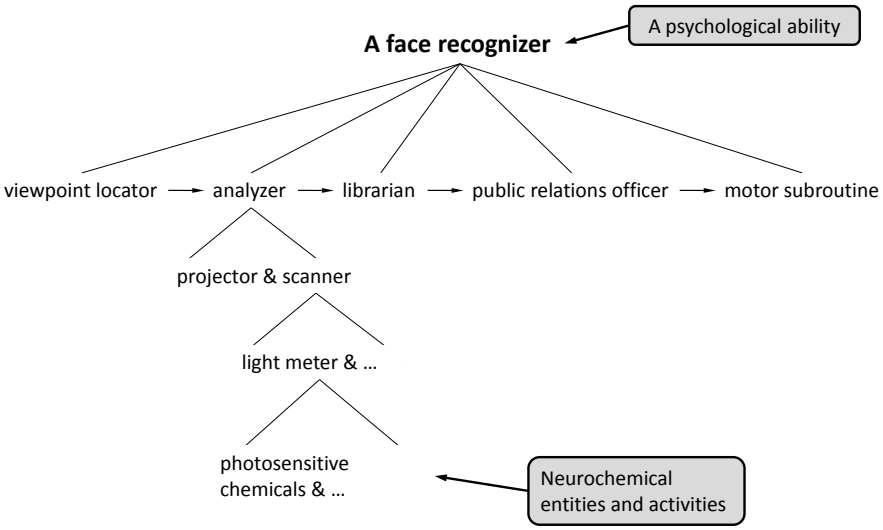

Figure 2: Lycan's example of the decomposition of a face recognizer. These levels are, hypothetically, part of the hierarchy of levels of nature.

Now Lycan is not actually suggesting that these are entities that occupy levels of nature or that the process he has described is how this psychological capacity, face recognition, is carried out. He does, however, believe that legitimate descriptions of the decomposition of psychological capacities into neurobiological (and lower level) entities can be produced using this format.

2.4 A Problem with Lycan's Account

Although this account has many attractive features, there are reasons to be skeptical about the way that it construes the relationship between psychological capacities and neurobiological activities. The source of the problem is that Lycan employs a single type of hierarchy, his levels of nature. Because he takes it that the hierarchy created by homuncular functionalism is part of the hierarchy of levels of nature, everything that is included in his account has to have a place on some level of nature. Consequently, everything is given the same ontological status. Entities occur at different places on the hierarchy, but, according to Lycan, all are found in nature and all can be characterized both functionally and structurally. It is far from clear, however, that the hierarchy created by homuncular functionalism really is part of the hierarchy of levels of nature or that everything that Lycan includes in his account should have the same ontological status.

It is useful to note that the alternative is to understand psychological capacities in purely functional terms and to treat the functional decomposition as a largely theoretical endeavor. When the functional decomposition is purely theoretical (so to speak), the sub-

capacities and sub-sub-capacities have an explanatory role, but they are not intended to occupy different levels of nature. This is what we find in Cummins' account of functional analysis (1975, 1983), and so following Cummins' account would not provide any grounds for mapping the functional (i.e., homuncular) decomposition onto the hierarchy of levels of nature.

But, of course, Lycan does think that the levels created by the homuncular decomposition are the same as part of the hierarchy of levels of nature. One result of Lycan's position is that every entity in the hierarchy created by the decomposition of a psychological capacity has to have functional (i.e., relational) as well as intrinsic (i.e., non-relational) properties. There must be, on the one hand, *the component's function*, but also *stuff that it is made out of*. But there is nothing about psychological abilities themselves that requires us to understand these functionally defined capacities as entities that have intrinsic properties that are different from the intrinsic properties of lower level entities. (Or otherwise stated, there is no reason to think that psychological capacities are made out of stuff that is different—in some way—than the stuff that lower level entities are made out of.)

Plus Lycan has not actually found a physical device that can be identified with a functionally characterized capacity, for example, in the way that a pumper of blood has been identified with the physical organ that we call the heart. Consider the face recognizer example again. On Lycan's model a psychological entity such as the face recognizer has to be a physical device that is not just a collection of neurobiological entities (e.g., neurons), even if it can be decomposed into a collection of neurobiological entities. But these sorts of physical devices are not exactly lying around to help substantiate Lycan's model.

Furthermore, it is also worth noting that if a psychological capacity does not have an explicitly physical characterization, then the decomposition of the psychological to the neurobiological is impossible. A functional capacity can be decomposed into subcapacities by employing Cummins-style functional analysis, and a physical system can be decomposed into its component parts. But the move from the functional decomposition to the physical decomposition is not simply another step in the decomposition. Rather, the move from the functional to the physical is an identification—the identification of the physical parts that carry out a particular function or set of functions.

It might be helpful at this point to look, in a more general way, at the nature of the problem that Lycan's model encounters. Consider two sets of things. Set (1) is atoms, molecules, and a cell. Set (2) is a segment of deoxyribonucleic acid, a gene, and a carrier of hereditary information. In (1)—leaving our reductionist tendencies aside—the three can be understood as different physical things, the latter composed of the former. In (2) the relationship is different. In this case, there is no way to understand these three as different physical entities. The only explicitly physical stuff is the segment of DNA; the others, the gene and the carrier of hereditary information, are just different ways of describing this physical material.

The difference between these two sets of things demonstrates where Lycan goes wrong. The entities in (1) clearly exhibit the hierarchical organization that Lycan relies

on, and Lycan's account is capable of describing a relationship like the one between cells and atoms. The things in (2), meanwhile, cannot be put into the same sort of hierarchy. This is because a *carrier of hereditary information* is a functional description that does not have any intrinsic properties besides those of the DNA. Thus, a carrier of hereditary information cannot be decomposed into a gene and a gene cannot be decomposed into a segment of DNA. Rather, a carrier of hereditary information just is a segment of DNA. And the same goes for the gene: it just is a segment of DNA. Consequently, Lycan's account is not useful for understanding the relationship between a carrier of hereditary information and DNA (or between a gene and DNA).

Lycan errs by not realizing that the relationship between psychological capacities and neurobiological activities is similar to the relationship between the carrier of hereditary information and a segment of DNA. Because there is no "stuff" that a psychological capacity is besides a collection of neurobiological entities and their activities, it is a mistake to think that psychological capacities and neurobiological entities occupy different levels in a hierarchy of levels of nature. And as a result, the relationship between the psychological and the neurobiological cannot be as Lycan describes it.

3 Levels of Organization

A more satisfactory account can be developed if multiple hierarchies are used. One hierarchy is needed to organize the things that are found in nature, but a separate set of levels is needed to track the different descriptions of the things found in nature. To this end, the account developed here uses *levels of organization* to order the things that are found in nature and *levels of explanation* for the descriptions of these things. This section will examine levels of organization and explain how they should be understood. In the next section, the same will be done for levels of explanation.

Although levels of organization are similar to Lycan's levels of nature, it is worth looking at a couple of the specific features of levels of organization in order to understand the role that these levels have in this account. The first important feature is the composition relation. The entities at one level are composed of the entities found at lower levels, and so composition orders the levels in the hierarchy. But composition alone cannot be used to establish a hierarchy of levels of organization. If it were, then a new level would be created every time two entities were combined, and this would create far too many levels. The resulting hierarchy would not be helpful for thinking about how nature is organized. Therefore, in addition to composition, another feature needs to be invoked. The two usual candidates are either *structure* or *interaction*.

When structure is a feature of levels of organization, levels are specified in terms of the significant structures that appear at different scales. This is, for instance, how Churchland and Sejnowski delineate levels of organization (1992). As they employ this idea, empirical research determines which structures are the significant ones, and not merely aggregates of lower level components. Hence, on their view, when a scientific consensus determines that a particular natural structure is important, that agreement indicates a level of organization.

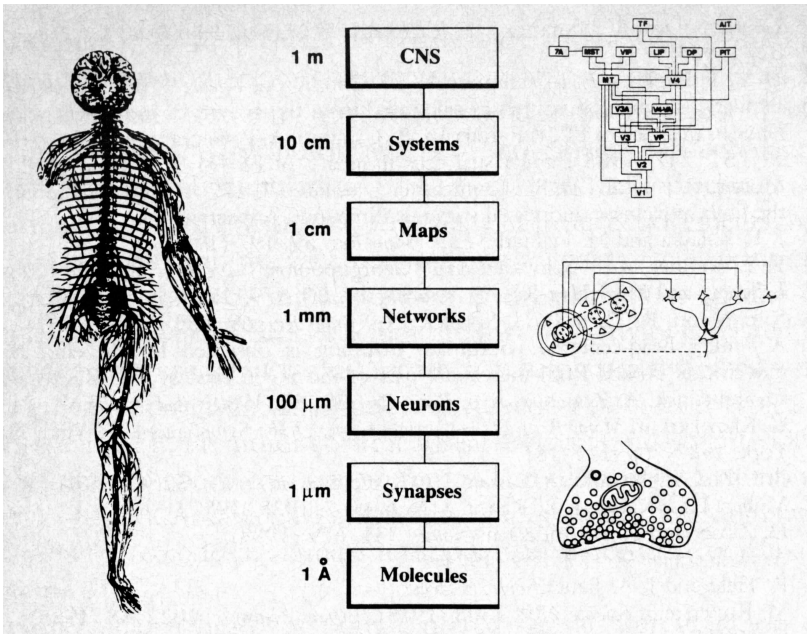

Figure 3: In the center is the hierarchy of levels of organization that Churchland and Sejnowski suggest is found within the scope of the brain. They propose the following levels: systems, topographic maps, local networks, neurons, synapses, and molecules (1988, 742; see also 1992, 29–48;). On the right are a map of the visual system (top), a network for processing visual information about bars of light (middle), and a chemical synapse (bottom). On the left is Vesalius's drawing of the human brain, spinal column, and peripheral nerves.

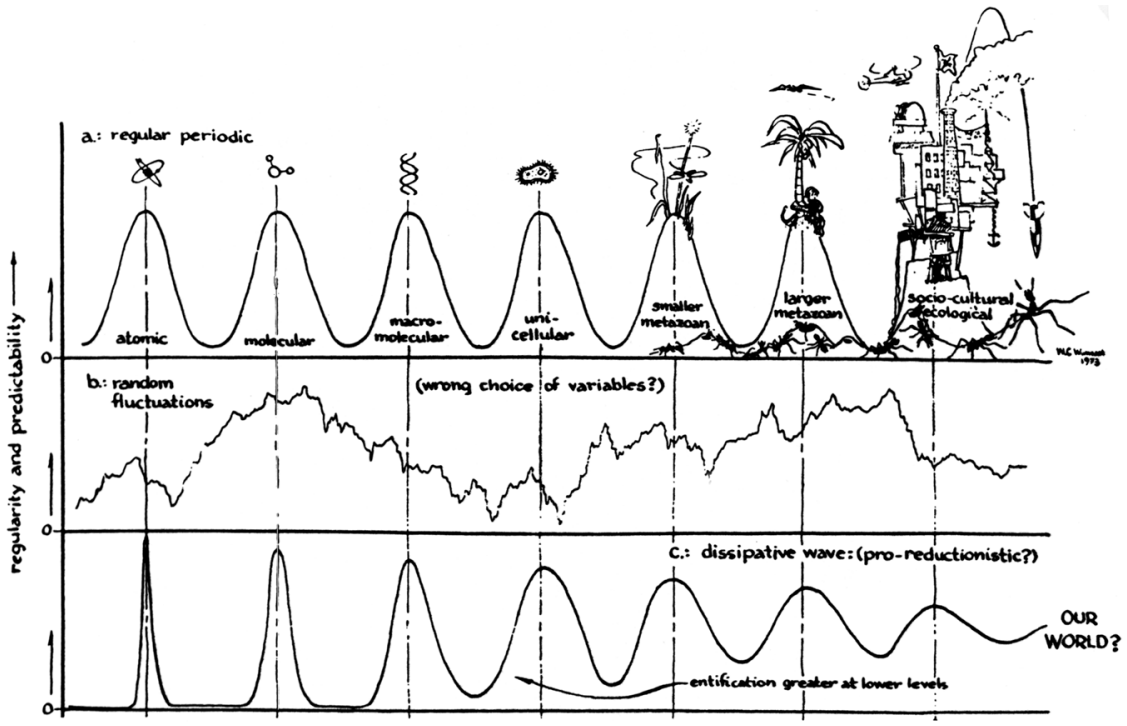

Figure 4: Wimsatt's diagram of different possible plots for size versus the regularity and predictability of interactions. The top plot suggests that the regularity and predictability of interactions (on the y-axis) is highest for the sizes of existing entities: atoms, molecules, cells, etc. The slightly less regular plot on the bottom ("Our World?") suggests that the regularity and predictability of interactions are quite high for smaller sizes and becomes progressively less regular as size increases, although they still exhibit an above average degree of regularity for the standard classes of entities. From Wimsatt (1976, 240).

The second option, interaction, is a way of characterizing levels of organization that has been developed by Wimsatt (1976, 2007). When interaction is used as a feature of levels of organization, levels are identified by the regular and predictable interactions that occur among certain entities. A collection of entities interacting with each other in regular and predictable ways—and in many cases depending on these interactions—constitutes a level of organization (1976, 239–42). So, for example, organisms like ourselves have relatively regular and predictable causal interactions with each other and other animals. These interactions indicate that there is a level of organization for organisms. At a smaller scale, the same holds for molecules. They interact with other molecules, and these interactions signify a level of organization—and likewise for subatomic particles, atoms, and cells, to name a few more. Regular and predictable interactions indicate a sub-atomic level, an atomic level, and a cellular level of organization.

Structure and interaction are each features that are useful for certain purposes. Here, because the goal is understanding the relationship between psychological capacities and neurobiological activities, levels of organization should identify activities, not just structures.[5] Therefore, the levels of organization have to be based on regular and predictable interactions among entities. Doing so generates the following series of levels: a level of organization for organisms, a level for cells, one for molecules, and a level for atoms (figure 5). There are other levels on this hierarchy, but the cellular, molecular, and atomic levels of organization are the ones that fall within the scope of the brain. Importantly, the significant brain structures—the brain hemispheres, brain lobes, and functional brain areas—are not included in this hierarchy because they do not participate in causal interactions. Their parts, neurons, interact with each other, but these aggregates do not themselves interact, and so there is not a level of organization dedicated to any of them (for a more detailed discussion of this issue, see Johnson [2009]).

Now that we have a clear idea of what levels of organization are and how the hierarchy of levels of organization is constructed, we can see that psychological capacities do not have a place on this hierarchy, at least not qua psychological capacities. In order to integrate psychological capacities and the neurobiological activities that are found on the hierarchy of levels of organization, a second resource is needed, levels of explanation. But before turning to levels of explanation, we can take a moment to look at why psychological capacities, as they are described within cognitive psychology, do not have a place directly on the hierarchy of levels of organization.

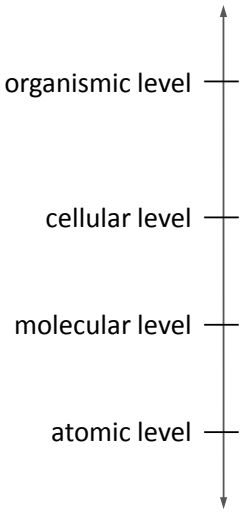

Figure 5: The levels of organization that fall within the scope of the brain.

Generally speaking, the identification and description of psychological capacities is accomplished by *methodological functionalism*. For cognitive psychology, methodological functionalism amounts to observing the inputs that individuals receive and the outputs that they produce and then suggesting internal components that can explain how the inputs are turned into outputs.[6] Our understanding of psychological capacities is—at least until recently, and still for the most part—based entirely on this process. For example, a psychological capacity such as language comprehension is only understood in terms of its function. When internal components are proposed in order

[5]Stepping back for a moment, the reason we are interested in neurobiological activities at all, rather than just neurobiological entities, is because psychological capacities are processes. They are temporally extended, and they typically transform an input into an output. Thus, in order to establish the relationship between psychological capacities and something neurobiological, we have to focus on neurobiological activities, not neurobiological structures.

to explain language comprehension, no physical material is referred to. The components are just elements that help us understand how the capacity is able to do the job that it does.

Because neither the psychological capacities themselves nor these components refer to any physical material, there is nothing about psychological capacities that makes it appropriate to place them at a level of organization. In order to understand how psychological capacities are related to the activities that occur in nature, a way of representing the relationship between these functional descriptions and the activities at the levels of organization is needed. For this we turn to levels of explanation.

4 Levels of Explanation

In a hierarchy of levels of explanation, each level is a different type of description of the same process. Marr's *Vision* contains the clearest articulation of what levels of explanation are and how they are used (1982). In this book, and in the work that preceded it, Marr lays out his account of the visual process using three levels of explanation. Because these three types of descriptions are the standard ways of describing a mental process, Marr's basic account will be adopted here.[7]

Marr's three levels are, from the highest level to the lowest: the level of the computational theory, the level of the representation and algorithm, and the level of hardware implementation. The *level of the computational theory* is the level at which the "information processing tasks" that humans perform are described in a non-causal way; the description at this level is a description of what the task is, not how it is carried out. As Marr says, it is at this level that "the underlying nature of a particular computation is characterized . . . . One can think of this part as an abstract formulation of *what* is being computed and *why*, and I shall refer to it as the 'theory' of a computation" (1977, 37).[8]

Looking at some examples, humans are able to perform all of the following tasks: adding quantities, understanding a natural language, holding information temporarily in short-term memory, and generating emotional responses to appropriate stimuli. The description offered at the level of the computational theory specifies what these tasks are that humans are able to perform so successfully. Sometimes providing this description is straightforward, as it is for a task such as adding quantities. Other times it takes some

[6]For more information on methodological functionalism, see Polger (2004, 2009).

[7]Marr does not make a distinction between the terms *explanation* and *description*. I will refer to *descriptions* that occupy *levels of explanation*. Also, although it will not have any bearing on the project here, it is useful to note that there are other types of descriptions besides the three that Marr uses. Statistical descriptions are one example. Consequently, there can be other types of levels of explanation in addition to Marr's. And levels of explanation do not only apply to mental processes, but are used any time a higher level description is provided for a process.

[8]It has been pointed out that *computational theory* is a confusing label for this level because it is not where a computational operation is described (Bechtel 1994; Bechtel et al 1998). As Bechtel, Abrahamsen, and Graham say, "[Marr] called his highest level *computational theory* (a label that many have found misleading; it is somewhat akin to Chomsky's notion of competence and might best be called task analysis)" (1998, 65).

work simply to identify the task. For example, that humans have short-term memory had to be discovered by Ebbinghaus in the 1880s (Squire and Kandel 1999). And for tasks such as understanding a natural language, although it is clear that humans are able to perform the task, specifying the exact nature of the task is a difficult problem.

Below the level of the computational theory is the *level of the representation and algorithm*. Here the procedures or operations that carry out—or at least operations that are sufficient to carry out—the task are described. The degree to which these operations describe the actual operations that are performed depends on the access that is available to the system. But, however accurate the proposed operation is, the description offered at this level does not reference the physical system that performs the task. It just describes the operation in terms of an algorithm and representations of the inputs for the algorithm to operate on. It is at the lowest level of explanation, the *level of hardware implementation*, that the physical mechanism that carries out the process is described.

Having reviewed the basics of Marr's account, we can now look at how the different descriptions that are offered by the various mind sciences correspond to these levels of explanation. But first it must be noted that although Marr focuses on descriptions of information processing tasks, a task is essentially the same as a capacity. A capacity is just the ability to perform a certain task.

Descriptions of psychological capacities that are offered within the domain of cognitive psychology are descriptions that belong at Marr's highest level. As mentioned previously, this level contains the theory of the capacity: a description of what the capacity is. Providing this description can be a substantial undertaking, and there are often competing descriptions offered at this level that correspond to differing ideas about the exact nature of a psychological capacity. This can be seen by looking at two descriptions of the ability to generate an appropriate emotion response. In a brief synopsis of his position Scherer describes the ability this way,

> the nature of an emotional reaction is based on the individual's subjective appraisal or evaluation of an antecedent situation or event. The evaluation is generally considered to rely on cognitive processing of environmental or proprioceptive stimuli. (1997, 114)

Robinson, meanwhile, suggests that this same capacity should be understood rather differently,

> Affective appraisals respond automatically to events in the environment (either internal or external) and set off physiological changes that register the event in a bodily way and get the agent ready to respond appropriately. An emotional response is a response set off by a non-cognitive affective appraisal. I speculated that there are probably a limited number of basic emotion systems each identified by a specific non-cognitive appraisal and the particular suite of behaviour it prompts. (2005, 89)

Scherer and Robinson agree that generating an emotion response when presented with certain kinds of stimuli is a task that humans perform. They just disagree about the exact

nature of this task. Scherer believes that it involves a cognitive evaluation of the stimulus, whereas Robinson is suggesting that it involves a simpler non-cognitive reaction to the stimulus. Importantly, this disagreement is limited to the level of the computational theory. Scherer and Robinson may disagree about the contents of the other levels of explanation as well, but the disagreement described here is not a disagreement about how this capacity is carried out. It is only a disagreement about what the capacity is.[9]

Marr's two lower levels focus on how the capacity is carried out. The description provided at Marr's middle level does this in a more abstract way and must contain a description of the procedure that carries out the capacity, as well as representations of the inputs for the procedure. Therefore, descriptions that are developed withing the field of cognitive science belong at Marr's middle level. These descriptions can be generated with a symbolic framework, a connectionist one, or some other—as long as the description is explicit about the process that transforms representations of the inputs into outputs. The lowest level of explanation provides a description of how the capacity is carried out in a more concrete way: in terms of the relevant biological material. Thus, these descriptions are developed within the domain of neurobiology.

5 Psychological Capacities and Neurobiological Activities

Using levels of organization and levels of explanation separates (1) the levels that are used to order those things that are found in nature, and (2) the different descriptions of those things that are found in nature. By keeping (1) and (2) separate, but showing how they are related, we can see how psychological capacities are related to neurobiological activities.

To create a single framework with these two types of levels, we need only notice that the lowest level of explanation and some level of organization identify the same class of things: the interactions of entities found in nature. Regular and predictable interactions are, of course, one of the central features of levels of organization. And the description supplied at the lowest level of explanation is a description of a biological mechanism, which is a specific series of interactions. Thus, while the description at the lowest level of explanation focuses on the particular series of activities that carry out a capacity, this circumscribed series of activities is set within all of the activity at a level of organization, which includes more interactions than just those that are concerned with a single psychological capacity.

The next step is determining where the hierarchy of levels of organization and this hierarchy of levels of explanation intersect. This requires finding the correct level of organization for the lowest level of explanation. Having already specified the levels of organization that fall within the scope of the brain, there are the following to choose from: the cellular level, the molecular level, and the atomic level—recall that there are not levels of organization for functional brain areas or other large scale brain structures.

[9]The descriptions that are in the quotations from Scherer and Robinson are brief, but a complete description at this level can be quite substantial if the capacity is characterized in detail. See Scherer 2001 and Robinson 2004 and 2005 for complete descriptions of their theories of emotion.

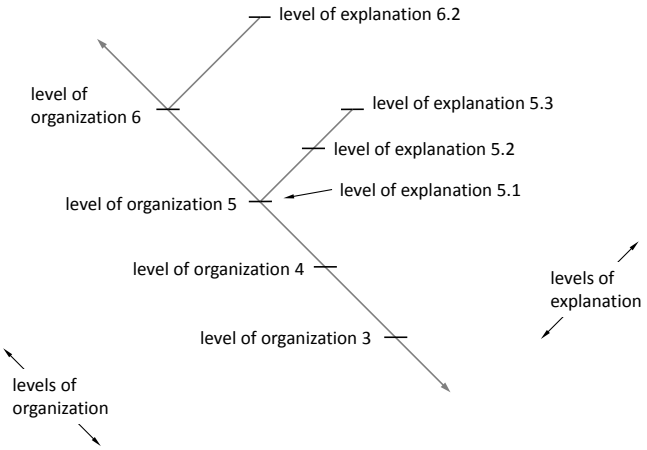

Figure 6: The two-dimensional model created by the intersection of levels of organization and levels of explanation. Levels of organization are on the leftmost axis. Levels of explanation are the hierarchies on the right. Levels 5.3, 5.2, and 5.1 can be thought of as Marr's three levels. Other levels of explanation are also possible, however. For example, level 6.2 is a description of some of the activities occurring at level of organization 6.

Of these levels, the cellular level of organization seems to be the most appropriate. The entities at this level, neurons, interact over the appropriate spatial and temporal scales to carry out psychological capacities, and much of the work within neuroscience is consistent with the idea that the activities at this level carry out psychological processes.[10] If this is the appropriate level of organization, then some of the activities that occur at the cellular level of organization—the activities and interactions of neurons—figure in the descriptions that occur at the lowest level of explanation. This intersection of levels of organization and levels of explanation creates a two dimensional model, a summary of which is shown in figure 7.

This model illustrates how psychological capacities are related to neurobiological activities. Psychological capacities are just a particular type of description of the activities that occur at the cellular level of organization. Psychological descriptions draw on

[10]This itself is a substantial topic. Nevertheless, there are plenty of examples of neuroscientific investigations into how psychological processes are carried out at the cellular level. See, for example, Graziano's work on microstimulation of the neurons in the motor cortex (Graziano, Taylor, & Moore 2002; Graziano et al. 2002); Rolls' investigation of the responses of neurons in the orbitofrontal cortex to certain kinds of visual information (Rolls et al. 2005; Rolls et al. 2006); or the progress that is being made on the control of prosthetic devices by cellular activity (Carmena et al. 2003; Tillery and Taylor, 2004; Velliste et al. 2008).

It is also interesting to note that the descriptions that Marr offered for the lowest level of explanation all involved activities at the cellular level of organization. The visual processes that he investigated are, he suggested, carried out by the activities of the neurons in the retina, the lateral geniculate nucleus of the thalamus, and the primary visual cortex (Marr 1982; Marr & Ullman 1981).

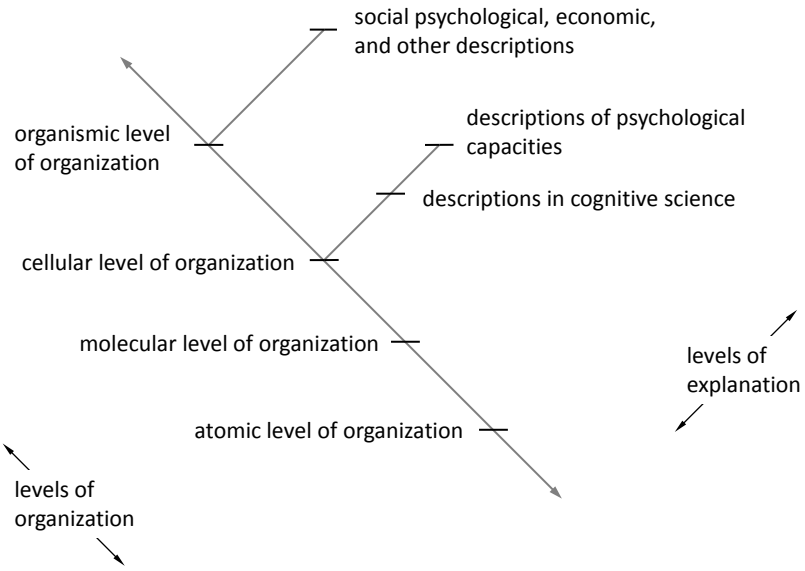

Figure 7: A two-dimensional model of levels. Levels of organization are on the left-most axis. Levels of explanation are the hierarchies on the right. The lower of the two hierarchies of levels of explanation is the one adopted from Marr. Descriptions of psychological capacities are at the top, descriptions offered in cognitive science are located at the middle level, and the lowest level of explanation coincides with the cellular level of organization. The other hierarchy of levels of explanation, which has social psychological and economic descriptions at the highest level, is included to demonstrate that levels of explanation are utilized any time descriptions are offered of the activities found at a specific level of organization.

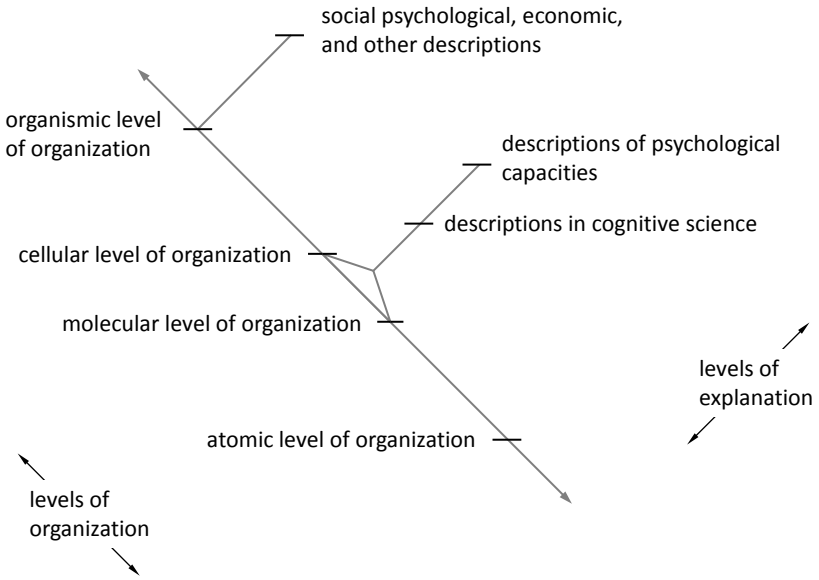

Figure 8: In this diagram the lowest level of explanation for psychological capacities intersects with both the cellular and the molecular levels of organization. See text for further explanation.

a particular set of resources and, hence generate a particular kind of description. But they are, nonetheless, just descriptions of those activities that occur at the cellular level of organization. The psychological capacities that are described in cognitive psychology may seem distinct from the activities found at the cellular level of organization, but they are not, and moreover, they cannot be. For it to be otherwise, psychological capacities would either have to occupy their own level of organization or they would have to be unconnected from the activities that occur in nature.

A caveat is now in order. While Figure 7 illustrates the significant features of this account, a more complete model should indicate that some aspects of psychological capacities are carried out by activities at the molecular level of organization. Molecular activity gives rise to the plasticity that occurs at the cellular level, and this does bear on the execution of psychological capacities. In the more detailed model, the intersection of levels of explanation and levels of organization is split between the cellular and the molecular levels of organization (figure 8).

6 Conclusion

The goal in this paper has been to outline an alternative model for understanding the relationship between psychological capacities and neurobiological activities. Several as-

pects of this model have been explained rather quickly. A more complete account should include a fuller discussion of the nature of psychological capacities, as well as a further defense of the claim that it is the activities at the cellular level of organization that primarily carry out psychological capacities. Nevertheless, what has been put forward here is a useful alternative to an account (such as Lycan's) that locates psychological capacities and neurobiological activities on a single hierarchy of levels.

Based on this new model, it is clear that the psychological is not a part of nature in the way that Lycan suggests: the psychological is not one of the many types of things that occupy the various levels of organization. This model also indicates that the relationship between the psychological and the neurobiological is not analogous to the relationship between chemical entities and processes and those of basic physics. Instead of having a composition relationship, psychological capacities are only a certain type of description of neurobiological processes. This is a type of description that is useful and has been widely adopted. But because it is only a certain type of description, the psychological is not separable from the neurobiological in the same way as the chemical is separable from basic physics.

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