

Two Theories of Responsiveness

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Abstract

Organisms are responsive—they respond to stimuli. This is a unique mode of causation that we usually only ascribe to organisms. What does it amount to? In this talk, I propose two candidate theories of responsiveness. The first is a functional pathway theory according to which organisms that are responsive are organisms with a certain kind of physiologically realized functional architecture. The second is a vital-integrative theory, according to which responsiveness is a capacity of whole organisms to integrate their activity with the environment in such a manner that their needs are met. I will explain the two views and their underlying rationales. Finally, I will argue that these two theories attribute different kinds of causal structure to the organism, and say divergent things about how their activity is organized. Adjudicating between these views could help to resolve a deeper, older debate between mechanistic and organicist theories of the organism. Therefore, we should find ways to test these theories of responsiveness.

What is Responsiveness?

Organisms are *responsive*—they respond to stimuli. What does this mean?

It cannot *mean* simply that they can be causally impacted by things. Billiard balls can be impacted by other billiard balls and caused to move, but the collision of a moving ball is not a *stimulus* to which the stationary ball *responds*. Nor is it sufficient for the impacting body and the impacted body to be putative responders—two armadillos or pill-bugs could undergo the same communication of motion, and these would not be response phenomena either. So what differentiates response phenomena from this pattern of simple cause-and-effect?

On the other hand, philosophers often distinguish between passive and active movements of organisms (e.g. Dretske 1988). There is a difference between something happening to an organism, and the organism *doing* something. It is common for accounts of the active/passive distinction to identify active behaviour with internally caused movement. Consider: an armadillo goes for a walk. Here, the activity seems to have been initiated spontaneously by the armadillo. In the situation's stipulated simplicity, no externalities are cited—the armadillo forms a desire to go for a walk, and then this state initiates the walking. The chain of causation seems to start in the organism.

This cannot be an account of responsiveness either, for two reasons. The first, more obvious reason is that some responses are instances of reflex action, which on most accounts is not something an organism actively does. But more fundamentally, responses are responses-*to* stimuli. We would not call a behaviour or change in bodily state a response if it truly were initiated without any essential connection to things outside of the organism. A tendency to spontaneously behave in ways that show *no* contingency on externalities would not be responsiveness.

So responsiveness seems to lie somewhere in the crux between these two paradigms of causation—the mechanical cause-and-effect picture, and the internally-caused movement accounts of agency. Like the paradigm of simple cause-and-effect, the response is in some way causally contingent upon the stimulus. But like the paradigm of activity, the response is something the organism does and not something that happens to it. Neither of these concepts are sufficient as an analysis of responsiveness; it needs an analysis of its own. So what essentially is responsiveness?

In this talk I will propose that in psychology there have been two basic underlying theories of responsiveness—a functional pathway theory of responsiveness and a vital-reorganizational theory of responsiveness. I will explain the two views and their underlying rationales. Finally, I will argue that adjudicating between these views could help to resolve a deeper, older debate between mechanistic and organicist theories of the organism. Therefore, we should find ways to test these theories of responsiveness.

The Functional Pathway Theory of Responsiveness

On the functional pathway conception of responsiveness, the stimulus is to be identified with energy applied to parts of an organism called its *receptors*, and the response is to be identified with activity at other parts of the organism called its *effectors*. This input theory of the stimulus and output theory of the response presupposes an input-output conception of the organism.

This scheme for understanding responsiveness has been the dominant causal theory of responsiveness since Descartes' description of the reflex arc, and it will likely be recognizable to the point of seeming truistic today. It is a

broadly mechanistic theory, and is deeply embedded in the protocols of experimental psychology. Because of its general acceptance I will explicate it by first briefly describing its development in the history of experimental psychology (I have drawn largely from Boring's 1932 history) and philosophy of mind. Then I will give a formalized statement of it.

From discrete structures to localized functions

The first point is that when we examine our anatomy, we find it comprised of conspicuously distinct discrete structures—we have structures at our extremities which we call *receptors* or sense-organs, which are connected to distinct long cord-like structures called nerves, which are connected to a brain, which is connected to more nerves, which finally terminates in muscles and viscera. It is natural to ask of all these distinct structures what they do and how they work. Nerves all share the same gross basic anatomical features, but Bell and Magendie experimentally demonstrated that they have different functions in the organism in virtue of what they are connected to. Sensory nerves connect sense organs with the brain; motor nerves connect the brain to muscles.

From local function and forward direction of nervous impulse to the reflex arc

Furthermore, there seems to be a *forward direction* in the nervous system—impulses travel in only one direction in each neuron, and the nervous system is just a complex network of these neurons. There may be refferent connections within the brain, but especially *between* the functional parts of the arc impulses that begin at the receptors travel in a sequence through an arc. So it seems that the whole sequence that culminates in movement follows an *arc*, or a functional pathway.

This distinction of sensory and motor nerve function was used to explain reflex movements. If you remove the brain of a vertebrate but leave the spinal cord, that vertebrate is still capable of reflex activity. In these cases the functional pathway that produces the reflex movement is something like this: sense receptors lead to sensory nerves, which lead to spinal interneurons, which lead to motor nerves, which lead to effector organs. This sequence is called the *reflex arc*. When the brain is not bypassed, another central component is added. The brain, being an elaborate network of more neurons, has its function circumscribed for it by its place in the functional pathway. It needs to produce outputs which culminate in responses on the basis of inputs which come from transduced energy at the receptors. Whatever intellectual, emotive, and volitional capacities there are, they need to be assimilated to a structure whereby impulses enter and exit.

From the reflex arc to the organism as an input-output machine

In philosophy of mind, at the start of the cognitive revolution, there was a movement confoundingly named “functionalism” according to which the physiological structures which gave rise to the reflex arc were seen to be mere *implementation*

details. The basic feedthrough conceptual model of the reflex arc was retained, but without essential reference to the physiological structures which gave rise to it. Take Putnam's early arguments against identity theory and formulation of his alternative *machine functionalism* (1967). Putnam explicitly takes the Turing machine as a “model of the organism.” Creatures with mental states, on this theory, could be modeled as Turing machines that A) were probabilistic, and B) implemented certain transition tables. The particular physiological facts which gave rise to the reflex arc—the neurons with their forward motion, the central parts with local functions—were abstracted away from the model of the organism, but fundamentally the transition tables are a function from inputs and internal state variables to internal state variables and outputs. The mediating mechanisms may be unspecified, but the fact remains that they are *mediating mechanisms*—mechanisms that produce movements at local functional parts called effectors on the basis of other local functional parts called receptors (or “sensors.”)

Formalizing the input-output machine: the functional pathway theory of responsiveness

So there are three conceptual parts to an organism considered as an input-output machine: the input, central processor or controller, and the output. These parts have localized functions and are connected in a sequence via input-output relations, so they can be considered components of a componential mechanism. What must each of these components be?

First, there is the *sensor*. The sensor needs to do two things. First, it needs to *transduce* energy—convert heat, light, or something else that can locally affect a sensory structure of the relevant modality into a format compatible with the next component. Second, it needs to *transmit* this signal to the next part of the functional pathway. Both of these facets are necessary. Disrupt the sensor's transducing function, and it will not produce informative input signals; disconnect the sensor from the sensory nerve or the central component and no amount of transduction will constitute an input. The sensor needs to *play its role in the functional pathway*; it needs to be adjusted appropriately to the central component for it to be a source of input.

Second, there is the *effector*. The effector also needs to do two things. First, it needs to receive output from the central component as input. Second, it needs to transform its input signal into some kind of motion (an “effect”). The obvious example in an animal is a muscle cell that contracts. A robot car's motor would be another example. Again, both of these conditions need to be met for an effector to be an effector; if it does not receive input from the central component (or at least from upstream in the functional pathway!) it is not functioning as an effector, and if its movement is not a function of that input, it is not motor *output*.

Third, we have the *central component*. The central component takes inputs from the sensors, transforms or assimilates them somehow, and produces outputs for the effectors. No further *conceptual* requirements are strictly necessitated by the general input-output conception of the

organism, but the adaptive or plastic qualities of responsiveness can be explained in terms relating inputs to outputs—perhaps in computational terms.

Responsiveness as activity produced by a functional pathway

With the functional pathway conception in place, we can now state what responsiveness, stimulus, and response are. On the functional pathway theory of responsiveness, then, a response is an activity produced by effectors, where those effectors receive inputs from a central processor, and that central processor receives inputs from sensors. In this view, a stimulus is an application of energy to the sensor. An organism is responsive when at least some of its activities are responses defined in this sense.

The Vital-Integrative Theory of Responsiveness

The *vital-integrative* theory of responsiveness has it that responsiveness is an attribute of a whole, intact organism whereby it establishes and maintains functional relationships with its environment in a manner that meets its vital needs; a *stimulus* is a breakdown of the organism's integration with its environment consisting of a noticed threat or opportunity that the organism has not adapted to. This is the beginning phase of a coordination; a *response* is the final phase of that coordination which establishes a new state of integration with the environment incorporating the stimulus. I will explain each of these features in turn.

Starting with the whole organism in its conditions of living

The second theory of responsiveness begins to be expressed after the development of the reflex arc scheme with psychology's second school, the Functional Psychologists. It was expressed in part and with varying degrees of explicitness by others as well, including American pragmatists, organismic theorists, and some humanistic psychologists. These schools of thought were broadly united in their methodological commitments, with emphases on the pattern of life of the whole, intact organism (e.g. Holt 1915, Goldstein 1934, Maslow 1943a, 1943b) and the ways in which the organism adapts and integrates into its conditions of living (e.g. Dewey 1896, Angell 1903, Goldstein 1934, Maslow 1943c). Because of their shared methodological commitments, these schools are largely compatible with each other, but collectively fell out of fashion around the end of the Second World War. It is difficult to find an explicit formulation of this theory that synthesizes across these schools, but their insights could be recovered and synthesized to form a second theory of responsiveness, which could be descriptively named a vital-integrative theory of responsiveness. I will describe some of the principles it offers for understanding responsiveness and gesture towards possible ways in which they could be integrated into a resuscitated 21st century theory.

Organisms have needs, and survival requires meeting them

Darwin's theory of natural selection starts with populations of reproducing organisms. It explains the origin of *species*—that is, the emergence of particular *kinds* of organisms over time. Its operands are organisms that survive, vary, and reproduce. Before it can be used to explain the emergence of more complex forms of responsiveness, there needs to be a population of organisms that vary, reproduce, and inherit. What can be said in general about what an organism is, and what it means for an organism to *survive*?

One proposed general feature of organisms that has been relatively uncontroversial at least since Schrodinger's essay (1944) has been the fact that they seem to resist entropy. They persist as complex objects in a way that seems to subvert generalizations of statistical physics, namely, the tendency towards maximum entropy. Organisms don't just resist breakdown, they even repair themselves and *grow*. This is generally accomplished by "drinking orderliness," i.e. taking in nutrients that can be converted into usable energy and assimilated into the organism's own body. These assimilative processes are given the name *metabolism*, and metabolism is a necessary condition of living. When these vital processes stop, the organism *dies*, and while they are operating, the organism is *alive*.

Organisms are not just alive—which they could be while under artificially contrived conditions of life support. They *survive*, which means that they *stay* alive despite obstacles, struggles, and dangers from without, and the consequences of their own metabolic processes from within. And in any realistic environment there are many such dangers. Walter Cannon described the exceedingly narrow parameters under which an organism's vital processes can operate (Cannon 1932). If an organism's internal temperature leaves this narrow range, or if there is a deficiency of some nutrient, or if there is not enough water, it *dies*. This is what a *need* is--a necessary condition for the organism's vital processes to continue, i.e. for the organism to continue surviving. When needs are met, we say that the need is *satisfied*. (Thus defined, the notions of need and satisfaction are not anthropomorphic, but organismic.)

Furthermore, physiological needs like the above are not the only kinds of needs. *There are as many kinds of needs as there are ways to thwart the vital processes in a particular environment*. So in addition to parameters of the internal milieu that may be controlled by internal regulative mechanisms and feeding, drinking, or expulsive behaviours, there are also necessary parameters for the external milieu. (Goldstein 1934). If there are predators which can consume the organism, that organism now additionally has *safety needs* that can be met by, in one way or another, avoiding being eaten by these predators. If the organism's form of life is social and its survival depends on its standing in a community, then it will also have social needs (Maslow 1943b). From the intrinsic vulnerability of the metabolic process and the complexity of the environment, the variety and extent of needs *balloons*. How is the organism to negotiate its standing amidst this seemingly endless set of dangers, and opportunities? This

question can be partially addressed from observing their activity. When we do that, we notice that the vital processes themselves incorporate aspects of the environment.

Life processes constitutively involve pivotal outer objects

The reflex arc model itself is *internalist*—it explains responsiveness in terms of processes solely inside the organism. But Holt stresses that behaviour is organized around a *pivotal outer object*. The organism, Holt says, “while a very interesting mechanism in itself, is one whose movements turn on objects outside of itself, much as the orbit of the earth turns upon the sun; and these external, and sometimes very distant, objects are as much constituents of the behaviour process as is the organism which does the turning” (1915). To even characterize what a response is, he argues, you need to ask what aspect of the world that response is an adjustment to.

What this means is that the vital-integrative theory of responsiveness is not purely internalist. But neither is it purely *externalist*. It is rather that the physiological principles are *relational* in nature and involve organizing to or around external things. The external things can thereby become constituents of the vital processes themselves.

This either allows us to extend our conception of the vital processes beyond metabolism, or to extend our conception of metabolism out into the world. As Dewey puts it, we can conceive of the processes of living as “enacted by the environment as truly as by the organism; for they *are* an integration.” (1938)

If vital processes *are* an integration with their environments, and activity can be a function of arbitrarily distal, complex, and abstract features of the environment, then perhaps they could approach the task of meeting the organism’s ballooning set of needs. Here is an example of Holt applying this logic to a bee:

The fact is that the specific object on which the bee’s activities are focused, and of which they are a function, its ‘home,’ is a very complex situation, neither hive, locality, coworkers, nor yet flowers and honey, but a situation of which all of these are the related components. In short we cannot do justice to the case of the bee, unless we admit that he is the citizen of a state, and that this phrase, instead of being a somewhat fanciful metaphor or analogy, is the literal description of what the bee demonstrably is and does (1915).

As Holt notes, there is a tendency to read such a claim as that the bee integrates into its home is a mere whimsical description. But on the contrary, if the vital-integrative theory is correct, it is actually a direct statement of a complex relational biological causal process. Perhaps it is a shorthand of an organicist equivalent of a mechanism sketch.

So if the activities of an organism are a kind of integration, what are the stimulus and the response? What does responsiveness amount to?

Life processes are directional

On the vital-integrative theory, responsiveness takes place against the backdrop of the ongoing, total integration an organism has with its environment. Living is described as a process of integration with environmental need-satisfiers and threats. One way that this could work would be akin to early descriptions of homeostatic processes—just as nutrient concentrations, temperature, and the like need to be held constant, so, we might think, an organism might act to keep all of its relationships with important aspects of its environment about the same.

But organisms do not just maintain a static form of integration. Another general feature of organic activity is its *direction*, which Goldstein claims is “the essential characteristic of every vital phenomenon” (1934). This direction manifests itself markedly in at least two ways—first, in the tendency of organisms to *recover* from injuries, which radically alter their state of integration with the environment. When this previously established pattern of living is disrupted by a brain injury, the organism tends to re-establish a *new* total pattern of integration with its environment consistent with meeting as many needs as it can (this process is described in great detail in Goldstein’s 1934 book *The Organism: A Holistic Approach to Biology Derived from Pathological Data in Man*). The second way that direction is manifest in organisms concerns the sheer complexity of the problem of meeting their many needs in their specific environments. This seems to improve over the course of an organism’s life; Dewey and Maslow call this process *growth*. Not all needs are equally crucial for survival, and from this fact it is predictable that a hierarchy of “prepotent” needs would emerge—wherein some needs are more basic than others, but once they are adequately met, the organism becomes motivated to satisfy the less-crucial needs. The process of meeting increasingly many needs is the process of integrating more and more with one’s environment.

So living is integrating with the environment in a manner that meets the organism’s needs. Armed with this conception of the life process, we may be in a good position to interpret Dewey’s pregnant but somewhat obscure alternative to the reflex arc in his famous “The Reflex Arc Concept in Psychology” (1896).

Stimulus and response as phases of adaptation

Dewey argues that it was a failure of interpretation to assign psychological notions like perception, cognition, and action to local activities of the reflex arc analysis’ component mechanisms. *Sensation* or *perception* are not names of transduction at sensor surfaces; *cognition* is not a name for an associative or integrative process carried out in a central nervous system, and *action* is not a name for movement generated at effectors. In Dewey’s memorable phrase, this leaves the organism “a patchwork of disjointed parts, a mechanical conjunction of unallied processes”. (Dewey 1896). Instead, perception, cognition, and action are “divisions of labour, functioning factors within the single concrete whole.”

As an illustration, consider the act of *chasing*. Is this activity motor? Certainly—a chaser needs to move. But chasing

is also sensory. If it were not, in which direction would one chase? Without the perceptual guidance inherent to chasing, one may dart away from one's chaisee, rather than towards them. And what if the chase involves some tact, wile, and prediction of the chaisee's behaviour? Then the whole activity would be cognitive as well. The "single concrete whole" that has perceptual, cognitive, and motor functionality is what Dewey calls a *coordination*; another term he uses for this unit is "act".

Stimulus and response don't take place at different parts of the organism either. All of the organism is stimulated, and all of the organism responds. They, too, are teleological distinctions, or "parts played with reference to reaching or maintaining an end" (Dewey 1896). What they describe are *stages* in the process of adapting the organism's functional relationships with the world. What are these stages?

Prior to stimulation, the organism has a certain standing in its environment—it is well-fed, or safe, or otherwise is not motivated by any needs related to the stimulus. When the organism is stimulated, some aspect of the situation becomes *problematized* to the organism—that is, there is some aspect of the situation that is pertinent to its ability to meet its needs that it has become aware of. From the moment of stimulation, the organism begins to coordinate with the stimulus. Through a process that Dewey calls "inquiry" in the human case, but ascribes to all responsive entities as well, the organism determines the means of adapting to the stimulus. In the response stage, those means are executed, and the organism thereby establishes an integration with the stimulus such a way that its needs problem is solved and the discomfort dissipates. At the end of the whole sequence of events, the organism has an enlarged total coordination with the environment.

So which theory of responsiveness is better?

The functional pathway theory of responsiveness and the vital-integrative theory of responsiveness describe and explain responsiveness in fundamentally different ways. The functional pathway view seems to follow a *mechanistic* style of explanation, where parts of an organism are decomposed into components with relatively localized functions. The nature of and prospects for mechanistic explanations in the life sciences and cognitive science have been a topic of intense interest in recent history. (Craver 2007; Bechtel & Richardson 2010). The vital-integrative view, in contrast, seems to be committed to a kind of *organicist* and processual biology, which have both seen some recent interest (e.g. Gilbert & Sarkar 2010; Nicholson & Dupre 2018).

One might still wonder: do these theories fundamentally clash, or are they in any way reconcilable? Might these be different ways of describing the same phenomenon, or orthogonal but equally valid kinds of explanation?

One thing is clear. These two theories ascribe causal patterns with radically different profiles to the organism.

They also make divergent prescriptions for experimental psychology. The functional pathway picture is concerned with how application of energy at one part of the organism propagates through the system and culminates in movements at another part of the system. This means that we can precisely control the properties of the stimulus. It also means that stimuli can be *applied to* an organism. It does not matter what state the organism is in, or whether the stimulus culminates in a response. As long as the components of the functional pathway are working, an application of energy at the receptors counts as a stimulus. The responses, likewise, are patterns of effector activity that can be described without any essential reference to their stimuli or their manipulanda. The causal pattern described is between activity at sensors and activity at effectors, with intervening activity in the central component. No essential reference is made to the needs of the organism (though it can be an additional fact that the central processes modulate their output in a manner that represents those needs, or happens to conduce to meeting them.) This is not to say that an input-output machine could not meet its needs in virtue of operating as an input-output machine, but that need-satisfaction is incidental to the *causal* structure of responsiveness.

On the vital-integrative picture, on the other hand, it is more difficult to precisely control whether something is a stimulus. Only if something induces the organism to modify its relationships with the need-relevant affordances in its world is that thing a stimulus, and the activities of the organism a response to it. Accordingly, stimuli cannot just be *applied to* an organism. The only way to design a stimulus for an organism is to know something about its needs, its means of attaining those needs, and its disposition to employ them. The causal pattern described is one that is distributed broadly throughout the organism and involves understanding how the organism is integrating itself into its world, and integrating the world into itself in a manner that meets its needs.

How would you synthesize responsiveness?

Which theory of responsiveness we adopt determines what sorts of entities we are trying to make, what their essential organization is, and how we might go about making them. I will say a brief word about what it would mean to create artificial responsiveness according to both theories.

Artificial functional pathways

At the outset, it is clear that the functional pathway system not only follows a familiar style of explanation (i.e. mechanistic), but synthesizing an entity with a fully operational functional pathway also is a familiar process. Any robotic system which has distinct sensors, effectors, and central components that are appropriately wired to each other instantiates this functional architecture. It has a number of advantages. First, the parts can be manufactured and calibrated independently, and assembly would involve connecting these components. Importantly, the outputs of earlier parts of the functional pathway need to be

adjusted to the inputs of the next part—so if the central component performs an information processing function, it needs to accept the format of the sensor output; and likewise, the effectors need to accept the format of the output from the central system.

What would be the asymptotic limit of success with such an approach? It would be to implement any possible function between energy at receptors and movement at effectors.

Artificial vital integrators

It is clear at the outset that the vital-integrative theory claims that responsiveness requires a kind of organization that is atypical of current artifacts (although perhaps that could change!) The first thing to do is create an entity with a metabolism that *survives*. Since we are designing these entities, perhaps that gives us some freedom to diverge from the vital processes we are familiar with on earth. But survival at the very least means persisting against the forces of entropy, which means that they, like us, need to be able to take in sources of energy and use that energy. They also need to be able to assimilate this material into their own body.

Once we have an entity with artificial metabolism, we have ipso facto created an entity with *needs*. Those needs already include at least physiological needs and safety needs. To create minimal responsiveness, all we need to do is alter the matrix of vital processes so that its activity is a function of its needs in a manner that conduces to meeting them. That may not require much—perhaps it is a matter of swimming around randomly until the enviroing nutrient gradient is sufficient (which may work in a relatively limited milieu). Or maybe that requires sensitivity to information in the ambient array that specifies need-satisfying affordances, and coordinated exploratory movements towards them (which may work in a relatively expansive milieu.) We can be as creative and elaborate, or as frugal and ad hoc as the evolutionary process is allowed to be. The ground truth is in whether the organism survives in an environment full of dangers and opportunities.

What would be the asymptotic limit of success for such an approach? This being would meet all of its needs, and thereby survive in its environment.

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