

## Who, What, and When: Skinner's Critiques of Neuroscience and His Main Targets

Diego Zilio<sup>1</sup>

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**Abstract** Skinner is commonly accused of being against neurophysiological explanations of behavior. However, in his writings, he did not criticize neuroscience itself as an important independent field from behavior analysis. The problem was in how some authors were using a pseudo-physiology in the explanation of behavior. Skinner was explicit in showing which authors and theories were using physiology incorrectly. Therefore, my goal is to present an analysis of the main targets of Skinner's critiques against neurophysiological explanations of behavior. This analysis will be divided as follows: (a) the targets of Skinner's critiques, (b) when the critiques were presented, and (c) the specific critiques that were made. The analysis was based upon 73 papers written by Skinner that were selected through keywords related to the issue. When placed in proper historical context, Skinner did not criticize neuroscience, but the misuse of pseudo-physiological theories in the explanation of behavior.

**Keywords** B. F. Skinner · Radical behaviorism · Physiology · Neuroscience · Conceptual nervous system · History

B. F. Skinner (1904–1990) is well known for his allegedly *anti-physiological* position regarding explanations of behavior. Negative and misinformed reactions

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✉ Diego Zilio  
dzilioufes@gmail.com

<sup>1</sup> Department of Social and Developmental Psychology, Federal University of Espírito Santo (UFES), Fernando Ferrari Ave, 514. Goiabeiras, Vitória, ES 29075-910, Brazil

to his view started to appear in the literature in the late 1930s with the publication of *The Behavior of Organisms* (e.g., Jones 1939; Loucks 1941) and, apparently, never stopped (e.g., Machamer 2009; Panksepp 1990). However, Skinner was not criticizing neuroscience<sup>1</sup> as an independent field from behavior analysis, a field that could also present means for achieving more effective ways of prediction and control of behavior (Moore 2002; Zilio 2013a). In other words, Skinner never denied that neuroscience could also contribute to the explanation of behavior. He even claimed that explanations based on the real (as opposed to conceptual or inferred from behavior) physiological processes that mediate behavioral relations would be preferable: "...independent information about the second link [neuroscience] would obviously permit us to predict the third [behavior] without recourse to the first [history of interactions with the environment]. It would be a *preferred type of variable* [emphasis added] because it would be non-historic" (1953/1965, p. 34). Skinner consistently repeated the same idea in other works (1969b, p. 24; 1974, pp. 214–216; 1983a, p. 239; 1988, pp. 302, 344–345).

For Skinner, the real problem was how some authors were misusing physiology in the explanation of behavior. One important point about this is that Skinner was usually explicit in showing which authors and theories were using physiology improperly. An analysis that takes into account the criticisms made by Skinner over the course of his career from the 1930s to the 1990s, along with his main targets, seems to be an important contribution in showing that Skinner was not anti-neuroscience, but only against some particular ways of doing neuroscience. Therefore, my goal here is to present an analysis and a historical context of the main targets of Skinner's criticisms against neurophysiological explanations of behavior. This analysis will take into account the authors and theories criticized by Skinner, the specific critiques made against those authors and theories, and the period of time when Skinner presented his critiques.

I used Morris et al. (2004) references as a starting point for the present analysis. They "reviewed the 289 primary-source works Skinner published over the course of his career" (p. 154), focusing on the ones in which Skinner addressed issues related to "biological participation in behavior" (p. 154). However, because they analyzed only primary-source works and "coded only Skinner's constructive comments on biological participation, not his critiques" (p. 154), additional secondary-source works (mainly Skinner's collections of papers, like *Cumulative Record* and *Recent Issues in the Analysis of Behavior*) were added to the present analysis. Also, I did not restrict the selection to constructive comments only. On the contrary, the focus was on Skinner's critiques. As a result, I started the analysis with a total of 148 texts, including books, chapters, and articles. The first reading (titles, abstracts, and the text itself) was to select a material that contained keywords related to neuroscience (see Table 1).

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<sup>1</sup> Skinner used different terms such as *physiology*, *neurology*, and *neural science* when referring to the sciences dedicated to studying the physiological mechanisms related to behavior. I chose to use *neuroscience* here because it is the most common term used in contemporary literature on the subject.

**Table 1** Keywords and parts of words related to neuroscience

Keywords	Parts of words <sup>a</sup>
Anatomist	Anato
Antiphysiological	Physio
Autonomic nervous system	Bio
Biological	Brain
Black box	Cerebral
Black-box	Inner
Biochemical system	Internal
Biological	Inside
Body-cum-brain	Neur
Bodily state(s)	Nerv
Body state(s)	Physico
Brain	Synap
Brain science	Stor
Central nervous system	Copy
Central processes	Proprio
Cerebral	Intero
Cerebral cortex	Mechani
Conceptual nervous system	
Cortex	
Cortical states	
Inner state(s)	
Internal states(s)	
Inside story	
Mechanisms	
Neural	
Neural events	
Neural homunculus	
Neural science	
Neural structure	
Neuro	
Neurologist	
Neurology	
Neurological	
Neurones	
Neuroscience	
Neuropsychology	
Neurophysiology	
Neuroanatomy	
Nerve(s)	
Nerves going to the right places	
Nerve impulse	

**Table 1** (continued)

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Nervous
Nervous impulses
Nervous system
Three nervous systems
Physiological
Physiologist(s)
Physiology
Physico-chemical neurology
Physical or chemical
Psychobiology
Psychopharmacology
Psychophysiology
Sensory nerve(s)
Synapse(s)
Synaptic
Reflex physiology
Representation
Storage
Copy theory

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<sup>a</sup> Used to account for possible variations related to one single keyword

From the 148 texts,<sup>2</sup> 73 contained these keywords (see [Appendix](#)). A second reading of the remaining 73 texts was made in order to select passages containing critiques against neuroscience or neuroscientific explanations of behavior that explicitly identified the targets of the critiques. The final result was a selection of 36 texts of Skinner, which are included in the “Reference” section of this paper. With the exception of Skinner (1950), all of the references for Skinner’s writings were used in the present analysis.

After selecting the sources for analysis, the resulting material was organized according to the following categories: (a) which/who: the authors and theories criticized by Skinner; (b) when: the period of time when Skinner presented his critiques against those authors and theories; and (c) what: the specific critiques made against those authors and theories.

### The “What”: Skinner’s Criticisms

Based on a more detailed analysis of Skinner’s views on neuroscientific explanations of behavior (Zilio 2015), I divided the critiques into three categories: (a) definition of behavior, (b) theory and explanation, and (c) centrism. Each category was divided into sub-categories associated with specific critiques. Although these critiques overlap to

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<sup>2</sup> It is important to note that I only used the material present in the bibliography section of Morris et al. (2004). Although their analysis started with 289 texts, only a part of this material was selected for analysis and therefore mentioned in the bibliography. That is the reason why the present analysis was conducted with a smaller number (148) of texts.

some degree, the division into categories and sub-categories nevertheless provided an analytical tool that served the purpose of classification and organization of the selected material. All the critiques presented by Skinner are summarized in Table 2.

## Definition of Behavior

**Relational Definition of Behavior** Skinner wrote more than once that we should study behavior in its own terms. In his historical analysis, Skinner (1931/1961a) presented an alternative definition of the reflex concept that used no physiological terms. Reflex was defined as observed correlations between stimuli and responses, and Skinner argued that this should be the proper use of the concept in the domain of behavior analysis. In Skinner's words:

We must not, however, fail to recognize a well-grounded distinction between the two fields [physiology and behavior analysis], which is based primarily upon a difference in immediate purpose. The one seeks a description of the reflex in terms of physico-chemical events, the other a description of behavior in terms of the reflex. (1931/1961a, p. 336)

The relational definition of reflex provided the basis to define the subject matter of behavior analysis without any mention of physiological processes. By not relying on physiological terms, the result was a definition of behavior in its own terms. Knowing

**Table 2** Skinner's critiques of pseudo-physiology

Categories	Sub-categories
1. Definition of behavior	1.1 Relational definition of behavior. 1.2 Neuroscience may restrict the definition of behavior.
2. Theory and explanation	2.1 Theorizing: "any explanation of an observed fact which appeals to events taking place somewhere else, at some other level of observation, described in different terms, and measured, if at all, in different dimensions" (Skinner 1950, p. 193). 2.2 Conceptual nervous system. 2.3 "Thermodynamics" of brain function: disregard for how the brain actually works. 2.4 Mind-brain identity: avoiding dualism. 2.5 Refusal to recognize the possibility of an independent science of behavior.
3. Centrim	3.1 Leads to the search for the wrongs things inside the nervous system. 3.2 Use of metaphors: e.g., brain as a computer, memory and storage, information process, representation. 3.3 Introspection: methodological limitation (private events). 3.4 Introspection: structural limitation (we don't have nerves going to the right places). 3.5 Mereological fallacy: behavior is a property of the whole organism and not something that brain does. 3.6 Agency: it's not real explanation (homunculus); shifts the focus away from environmental variables; neurophysiological processes are not "agents" responsible for the control of behavior; behavior is not only an effect or symptom of what happens inside the organism; neurophysiological processes are not responsible for the origins of behavior.

that Skinner initially used the term *reflex* to describe behavior in its most general sense and not only as synonymous for *respondent* (Skinner 1979, 1980, 1998), we can assume that the relational definition is not only about reflex but can be extended to all behaviors. Later, Skinner abandoned the term reflex and described different kinds of behavioral relations (mostly operants and respondents). In sum, the problem was to assume that reflex (and by extension *behavior*) has the same meaning in behavior analysis and physiology. Skinner's criticism consisted of pointing out that we should not define reflex or behavior using physiological or structural terms. Behavior should be viewed as a relational (functional) term.

**Neuroscience May Restrict the Definition of Behavior** Apart from the preference for a relational (functional) definition of behavior, per se, Skinner argued that a definition based on structural or physiological terms was too restrictive. Behavior should be viewed as a process defined and classified functionally through an analysis of the correlations between stimuli (antecedent and consequent) and responses; that is, it should be viewed through the study of contingencies. Neurophysiological structures and processes that may correlate to behavioral relations under analysis should not be used to define those relations, since it would impose restrictions to the definition. If we define a behavioral relation of the *X-type* according to the correlated activity of the neural mechanism *Y*, then we could only say that a behavior of *X-type* is occurring when the mechanism *Y* is active. Functional aspects of behavior become secondary. It does not matter if we find behaviors functionally similar to the *X-type*, and those would not be described as *X-types* because they are not accompanied by the activation of the neural mechanism *Y*. For instance, there is a problem in restricting the concept of *fear behavior* to the cases where the amygdala is activated, since there are cases in which fear behavior occurs without the participation of the amygdala (cf. Adolphs 2013; Feinstein et al. 2013; LeDoux 2013). About this restriction, Skinner (1931/1961a) wrote that

The physiological study of the reflex supplements and restricts our definition. It begins by identifying and describing certain of the events which intervene typically between stimulus and response, and it then *arbitrarily restricts* [emphasis in original] the use of the word reflex to correlations which employ that kind of event. (pp. 335–336)

## Theory and Explanation

**Theorizing** This sub-category relates to Skinner's famous critique of "any explanation of an observed fact which appeals to events taking place somewhere else, at some other level of observation, described in different terms, and measured, if at all, in different dimensions" (Skinner 1950, p. 193). This critique only makes sense in the light of the phenomenon under investigation. A problematic theory would be one that attempts to explain behavior by describing events that are not part of the behavioral relation such as physiological and mental events. The same goes for the level of observation. To be at different levels of analysis means to be controlled by different kinds of variables (i.e., objects of study). Neuroscience and behavior analysis are at two different levels because they study different variables: physiological events (brain activity, action

potential, protein synthesis, and so on) and behavioral events (functional relations between stimuli and responses). If we assume that scientific terms, laws, and concepts are established by contingencies related to a scientist's verbal behavior (mainly tacts) and environmental conditions that control its emission (Lee 1985; Moore 2010), then different subject matters (i.e., environmental conditions) lead to laws, terms, and concepts pertaining to different levels of analysis. For Skinner, to use terms, concepts, and laws of a different level in the explanation of behavior is not useful because they are not about behavior at all. Skinner consistently mentioned neuroscientific explanations while talking about these kinds of theories. For instance:

Synaptic connections are made or broken, electrical fields are disrupted or reorganized, concentrations of ions are built up or allowed to diffuse away, and so on. *In the science of neurophysiology statements of this sort are not necessarily theories in the present sense [emphasis added]. But in a science of behavior [emphasis added], where we are concerned with whether or not an organism secretes saliva when a bell rings, or jumps toward a gray triangle, or says bik when a card reads tuz, or loves someone who resembles his mother, all statements about the nervous system are theories in the sense [emphasis added] that they are not expressed in the same terms and could not be confirmed with the same methods of observation as the facts for which they are said to account.* (Skinner 1950, p. 193)

**Conceptual Nervous System** This is perhaps the most recurrent critique in Skinner's texts (1931/1961a, pp. 319, 335; 1938/1966b, pp. 419–427; 1944, pp. 277–279; 1946 pp. 167–168; 1950, p. 194; 1953/1965, p. 54; 1956, pp. 223, 227, 231; 1966a, pp. 76–77; 1966c, p. 217; 1969a, pp. vii, 28; 1974, pp. 6, 213, 217–218; 1975, p. 45; 1979, pp. 68, 166–167, 269; 1980/1998, p. 291; 1983a, p. 367; 1986a, pp. 208–209; 1988, pp. 67, 101–103, 470). It is closely tied to the *theorizing* criticism discussed earlier. In addition to explaining behavior by talking about something else (theorizing), this *something else* is a purely conceptual model or hypothetical construct inferred from data about behavior. For instance, although Pavlov (1927/1960, 1934/1955) was not studying the real nervous system, but mostly respondent relations, he nonetheless developed a complex model of how the brain functions (what he called “higher nervous activity”), to the point of even proposing theories of personality and psychopathology based solely on a conceptual nervous system inferred from reflex studies. In Skinner's words:

He [Pavlov] turned too quickly to inferences about the nervous system. The subtitle of the Anrep translation is “An investigation of the Physiological Activity of the Cerebral Cortex”. Pavlov never saw any of that activity; he was studying merely what he took to be its products. His facts were about behavior, and his effort to represent them as facts about the nervous system interfered with his reports and must have affected the design of his experiments. (1966a, pp. 76–77)

**“Thermodynamics” of Brain Function** Some conceptual nervous system theories intended to be heuristic models to be used in guiding research on the real nervous system or simply placeholders for a future explanation based on the real nervous system. Skinner (1974) was particularly critical of this strategy:

Another way of dealing with inference is to give it respectability by converting it into an explicit model or system. There has arisen a kind of *thermodynamics of the nervous system* [emphasis added], in which general laws or principles with little or no reference, direct or inferred, to the parts of the nervous system involved. Information theory and cybernetics both contributed to this kind of speculation about what is going on inside the head. Such a model or system could apply to either the mental or physical worlds or even to both, and the problem of dualism therefore seems to be avoided. Will a model of the nervous system not serve until physiology is more advanced? (p. 217)

Briefly, thermodynamics is the branch of physics that studies heat and its relations with work and energy. Variables, such as volume, pressure, and temperature, are macroscopic. In thermodynamics, the molecular and atomic properties of those processes are not taken into account (Fermi 1956). According to Skinner’s analogy, the conceptual nervous system theories propose models of the mind-cognition-brain function (i.e., *thermodynamics*) inferred from behavior, disregarding completely how the real brain actually works. This is the defining feature of the thermodynamics critique. However, one may argue that its role in guiding research of how the real brain works (i.e., *molecular physics*) would justify this practice. But Skinner (1988) was skeptical about this heuristic value:

I doubt that the conceptual nervous systems constructed to explain sensory, motor, and associative processes have a valuable heuristic role. Instead, they have generally led the neurologist to look for the wrong thing - for example, the supposed copies or representations which are said to be constructed in the nervous system when a person perceives a situation or remembers it later. (p. 67)

**Mind-Brain Identity: Avoiding Dualism** Skinner directly criticized authors who defended some kind of identity relation between their conceptual models inferred from behavior and the brain as a way of avoiding the accusation of dualism. Here is an example in which Skinner (1983b) discussed cognitive psychology and Freud:

That does not mean that cognitive psychologists have abandoned the brain. A touch of physiology seems to save them from dualism, and many of them use ‘brain’ and ‘mind’ interchangeably. Freud took a similar position much earlier. He assumed that we should some day know what the ego, superego, and id, the conscious, preconscious, and unconscious, and all the dynamisms really were in neurological terms. (p. 10)

Skinner’s core problem with the thermodynamics of the nervous system, as well as mind-brain identity, seems to be in assuming that if we accept those arguments as valid,



then we would have carte blanche to propose hypothetical models of mental processes inferred from behavior without any concern about validation and parsimony. After all, they are about the brain and not something else (mind-brain identity) and they will serve later as heuristic guides (thermodynamics) for the study of how the brain actually works.

**Refusal to Recognize the Possibility of an Independent Science of Behavior** In explanations based on inferred constructs, behavior is not taken as an object of study in its own right. The search for its causes always focuses on elements from another domain—mind, cognition, or brain. In this situation, an independent science of behavior that is not dependent on theorizations about internal processes seems to be impossible. A focus of Skinner’s arguments in favor of an independent science of behavior was to show that a purely behavioral science was indeed possible (Zilio 2015).

### **Centrism**

I define *centrism* as any kind of organism-centered explanation of behavior; in other words, it is the practice of providing explanations of behavior solely in terms of internal/intermediate events, whether purely conceptual (e.g., mind/cognition) or real (e.g., brain). That is the main characteristic of mentalistic explanations of behavior (Moore 1981, 2008; Schnaitter 1984; Zilio and Carrara 2008). Skinner discussed extensively the presence of centrism in neuroscientific explanations of behavior, and he was often explicit about the targets of his critiques. Here, I present them briefly.

**Search for the Wrong Things Inside the Nervous System** This first problem with centrism derives from its association with mentalism. Skinner was skeptical about approaching the conceptual nervous system as a heuristic theory that will eventually guide the research of the real nervous system. The practice of proposing theories about one domain (in this case, cognition or brain) through inferences from data of other domains (in this case, behavior) can weaken the connection between theory and phenomena to be explained. This occurs because the scientists’ theorizing behavior is being controlled by other variables than the phenomena itself, which increases the probability of faulty inferences, misconceptions, and conceptual confusion. Based on Schnaitter (1986), Moore (2008) described this as the problem of “intraverbal distance” between theory and phenomena: “as the amount of verbal behavior intermediating between the world and a conclusion about the world increases, the opportunity for a faulty inference increases” (p. 305). In the context of centrism plus mentalism in neuroscience, for instance, if a theory of brain inferred solely from behavioral data is used as a heuristic guide for future research, it can end up leading neuroscientists to the search for the “wrong things” in the nervous system. In Skinner’s (1969b) words: “Rather than attack mentalistic concepts by examining the behavior that is said to be explained by them, the physiologist is likely to *retain the concepts and search for their physical bases* [emphasis in original]. ... The unhappy

result is that physiologists usually look into the black box for the wrong things” (p. 282).

**Use of Metaphors** The increase of metaphorical vocabulary is another possible consequence of the intraverbal distance between theory and phenomena. The scientists’ verbal behavior is not necessarily under control of the phenomena they are trying to explain when they propose cognition-brain-mind theories solely from inferences based on behavioral data. As a consequence, they may start using vocabulary of other domains to describe elements of the inferred theory. For instance, Fernandez-Duque and Johnson (2002) discuss the problem of different metaphors guiding the research on *attention*:

This fact is quite evident in the field of attention research, in which even a cursory survey reveals that there is no general agreement about what a theory of attention ought to explain. Different theories have different views of what counts as attention. ... Is it a cognitive system made of interacting subcomponents discretely localized in the brain? Or is attention a pool of resources we allocate to effortful tasks? ... there is no way to identify attention independent of some theory of attention, and we argue that theories of attention are structured largely by conceptual metaphors. (p. 153)

This brief example shows how metaphors can lead to faulty inferences, misdirection, and conceptual confusion by providing different meanings for the same term (i.e., its use being controlled by different variables).

**Introspection: Methodological Limitation** Skinner criticized the idea of using introspection as a method for the study of nervous system. In behavior analysis, introspection is best described as verbal responses under discriminative control of private events (Moore 1994; Zuriff 1979). It is not a way of revealing the structure of mind or cognition. It is a behavioral relation between private stimuli and verbal responses. We are essentially dealing with behavioral data. But introspection has its own particular problem: Introspective knowledge is defective because private events are inaccessible to the verbal community that teaches us to talk about them, which means that they must rely on public behavioral events that may be associated with the occurrence of private events. As a consequence, contingencies that bring up this particular kind of discriminative behavior are limited (cf. Moore 2008; Skinner 1974).

**Introspection: Structural Limitation** The second problem associated with introspection implies an anatomical-physiological limitation: Skinner (1980, p. 180; 1983a, pp. 194–195; 1989c, p. 17; 2009, p. 69) often said that we “don’t have the nerves going to the right places.” This means that when we respond discriminatively to private events (i.e., introspection), we are not accessing it as brain processes, per se, but as more stimuli or responses, that is, as behavioral events. The only way to access internal events as brain processes is by using our exteroceptive nervous system, which is the same way we contact the world outside the skin and the way neuroscientists should access their object of study. In sum,

introspection is not a suitable method for neuroscience because when responding discriminatively to private events, we only access more behavior and not neurophysiological events as such:

To agree that what one feels or introspectively observes are conditions of one's own body is a step in the right direction.... *But what is felt or introspectively observed is not an important part of the physiology which fills the temporal gap in a historical analysis* [emphasis added]. A severe limitation is to be seen in the organs a person uses in observing himself.... He does not make contact with that vast nervous system that mediates his behavior. He does not because he has no nerves going to the right places. Trying to observe much of what is going on in one's own body is like trying to hear supersonic sounds or see electromagnetic radiation beyond the visible range. (Skinner 1974, pp. 216–217)

**Mereological Fallacy** Although the term *mereological fallacy* was never used by Skinner, it accurately describes another critique present in his writings (cf. Burgos and Donahoe 2006; Schaal 2005). According to the mereological principle (Bennett and Hacker 2003), it is inappropriate to attribute psychological predicates to the brain. It is not the brain that *thinks, perceives, attends, feels, or has consciousness*, but the organisms that possess a brain (and other relevant parts). The fallacy consists in attributing those processes to the brain instead of the whole organisms. For Skinner, mental or cognitive processes are not to be associated with brain activities but to the behavior of whole organisms. In his words: “Cognitive psychologists like to say that ‘the mind is what the brain does,’ but surely the rest of the body plays a part. The mind is what the *body* [emphasis in original] does. It is what the person does. In other words, it is behavior” (1987, p. 784).

**Agency** One of the main problems with centrism is that neurophysiological processes are not “agents” responsible for the control of behavior. The use of psychological vocabulary in reference to cognitive or brain processes (mereological fallacy) associated with centrism can turn the brain into a “homunculus,” the agent responsible for causing behavior: “Both the mind and the brain are not far from the ancient notion of a homunculus—an inner person who behaves in precisely the ways necessary to explain the behavior of the outer person in whom he dwells” (Skinner 1974, p. 117). There are at least five problems with a homunculus point of view: (a) it does not provide a real explanation because the homunculus used to explain also needs explanation, (b) it shifts the focus away from environmental variables that are paramount to the explanation of behavior, (c) it leads to the assumption that this inner agent (homunculus) is in some way *free* or *autonomous* from controlling variables, (d) behavior tends to be viewed as only an effect or symptom of the processes that we really should be studying: mental-cognitive-brain processes, and (e) the origin of behavior (or *originary causes*) is not to be found inside the organism, but in organisms’ phylogenetic and ontogenetic histories. For Skinner, centralistic explanations do not provide details about initial causes of behavior:

What is wrong with all of this is not what philosophers, psychologists, brain scientists, and computer scientists have found or will find; it is the direction in which they are looking. *No account of what is happening inside the human body, no matter how complete, will explain the origins of human behavior. What happens inside the body is not a beginning* [emphasis added]. (1989c, p. 18)

## The “Who” and “When” of Skinner’s Critiques

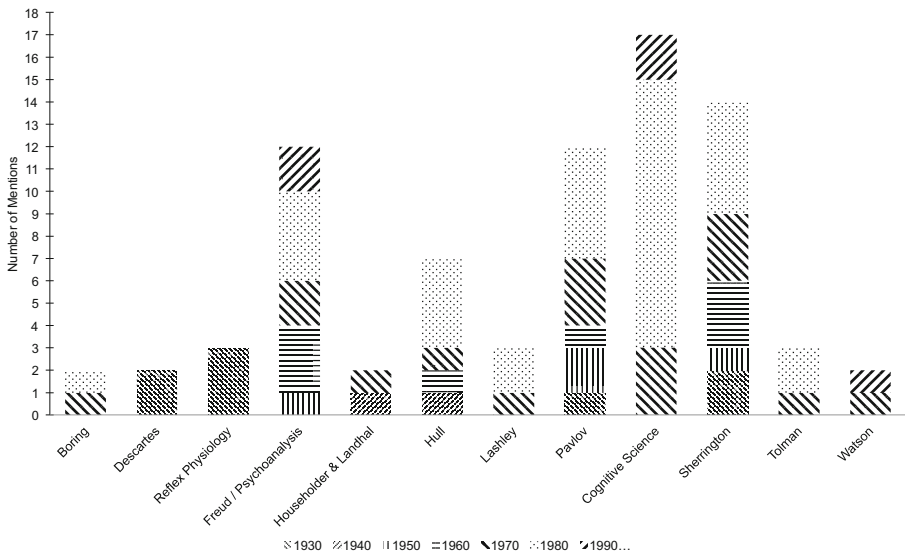
As noted earlier, from the 148 texts analyzed, only 36 contained critiques related to neuroscience with the targets clearly described. The data gathered from this analysis are organized in Tables 2 and 3 and Fig. 1. Table 3 presents the targets (*who* column), the texts in which Skinner criticized them (*when* column), and the specific critiques directed to them (*what* column). The *what* column contains the sub-categories of classification code presented in Table 2.

For instance, it is possible to gather from the information in Tables 2 and 3 that Skinner criticized Descartes in two texts (1931/1961a, 1938/1966b) and the critiques were about the conceptual nervous system and the thermodynamics of the nervous system. Quoting Skinner (1931/1961a):

Descartes was, as Foster has said, a ‘retrograde’ physiologist, who accepted the more convenient theory, as against the more accurate, for the sake of a broader

**Table 3** The “who” (Skinner’s targets), “when” (Skinner’s texts), and “what” (Skinner’s critiques)

Who	When	What
Boring	1979; 1983a	2.1; 2.2; 2.4; 2.5; 3.3
Descartes	1931/1961a; 1938/1966b	2.2; 2.3
Reflex physiology	1931/1961a; 1935/1961b; 1938/1966b	1.1; 1.2; 2.1; 2.2
Freud (psychoanalysis)	1954; 1966c; 1969b; 1969c; 1971; 1974; 1983b; 1985; 1987; 1988; 1990; 2009	2.1; 2.2; 2.4; 3.3; 3.4; 3.6
Housenholder and Landhal	1946; 1979	2.1; 2.2; 2.5
Hull	1944; 1969a; 1979; 1983a; 1986a; 1987; 1988	2.1; 2.2; 3.6
Lashley	1979; 1983a; 1987	2.2; 2.4
Pavlov	1938/1966b; 1953/1965; 1956; 1966a; 1974; 1975; 1979; 1983a; 1986b; 1987; 1988; 1989a	2.1; 2.2; 2.4; 2.5; 3.2; 3.6
Cognitive science	1974; 1975; 1977; 1980; 1983a; 1983b; 1984; 1985; 1986a; 1986b; 1987; 1988; 1989b; 1989c; 1989d; 1990; 1993	2.1; 2.2; 2.3; 2.4; 3.1; 3.2; 3.3; 3.4; 3.5; 3.6
Sherrington	1931/1961a; 1938/1966b; 1956; 1966a; 1967; 1969a; 1974; 1975; 1979; 1980/1998; 1983a; 1987; 1988; 1989a	1.1; 1.2; 2.1; 2.2; 3.6
Tolman	1979; 1986a; 1987	2.2; 2.2; 3.6
Watson	1974; 1993	2.5



**Fig. 1** Skinner’s targets and number of mentions from the 1930s to the 1990s. The ellipsis is used after the “1990s,” it is to indicate that every text published after 1989 was added to this period (including the ones published posthumously)

consistency. His interest was ultimately philosophical, even in his physiological explanations, and *he did not attempt to discover the true action of the nervous system* [emphasis added]. (pp. 323–324)

In this passage, Skinner is talking about how Descartes ignored physiological data available in his time in order to maintain the consistency of his conceptual nervous system model. This passage also justifies placing Descartes as one of the targets of the thermodynamics critique, since the defining feature of this critique is the disregard for how the brain actually works. The analysis of all 36 texts was conducted in this way. Unfortunately, it is not feasible to present all the passages analyzed. But it is possible to pinpoint the exact texts, targets, and critiques of Skinner in Table 3. Figure 1 presents Skinner’s targets and the number of times they were mentioned throughout the decades.

We can gather from Fig. 1 and Tables 2 and 3 that the main targets of Skinner’s critiques were cognitive science, Sherrington, Pavlov, and Freud or psychoanalysis, as those are the only targets mentioned more than 10 times. Sherrington was criticized for his organism-centered orientation (centrism), non-relational (functional) account of behavior, and as a consequence, for restricting its definition. But he was criticized mainly for proposing a conceptual nervous system with the concept of *synapse*. Pavlov was criticized mostly because of his explanations (theorizing) based on an organism-centered and metaphoric conceptual nervous system model of brain function. Skinner also criticized Pavlov for using this strategy as a way of avoiding the dualism present in the psychology of his time, failing to recognize the possibility of an autonomous science of behavior. Freud and psychoanalysts, in general, were criticized for theorizing about mental events by inferences from behavioral data, proposing a conceptual nervous system, using neurophysiology in order to escape the charge of dualism, and

for mentalism (problems with introspection and centrism) in his theories. Cognitive science (a general term for cognitive psychology, computational cognitive science, and cognitive neuroscience) was a target for almost all criticisms. The exceptions were 1.1 (relational definition of behavior), 1.2 (neuroscience may restrict the definition of behavior), and 2.5 (refusal to recognize the possibility of an independent science of behavior). Cognitive science was also the main target when Skinner criticized mentalism in neurophysiological explanations.

Skinner changed his targets through the decades. In the 1930s, the main targets had some relation to physiological theories of reflex (e.g., Descartes, reflex physiology, Sherrington, and Pavlov). Also in the 1930s, Skinner emphasized the relational definition of reflex as opposed to pseudo-physiological accounts. In the 1940s, the main targets were Hull and Housenholder and Landhal. In this case, the critiques were directed towards specific books published by those authors: Hull's *Principles of Psychology* (published in 1943) and Housenholder and Landhal's *Mathematical Biophysics of the Central Nervous System* (published in 1946). The main criticisms were theorizing and proposing a conceptual nervous system. Although Pavlov was mentioned in two papers in the 1950s, the main target in this decade was Freud (and psychoanalysis). Skinner dedicated one entire paper (1954) to the problems of Freudian theory. In the 1960s, Skinner maintained criticisms against Freud and psychoanalysis (3 mentions) but also focused on Sherrington (3 mentions), Pavlov (1 mention), and Hull (1 mention). The only criticisms during this decade is about theorizing and proposing conceptual nervous systems.

New targets appeared in the 1970s: Tolman, Watson, Lashley, and Boring, each being mentioned once. However, the most important target to appear in the 1970s was cognitive science, which was mentioned in three texts (1974, 1975, 1977). Cognitive science would become the main target of Skinner's criticisms from the 1970s until the end of his career. Almost every sub-category of criticism was present in this decade, except for 1.2 (neuroscience may restrict the definition of behavior) and 3.5 (mereological fallacy). It is also in the 1970s that criticisms directed towards centrism started to appear in a more systematic way (before that centrism had only two mentions in the 1950s).

Continuing with the tendency started in the 1970s as the predominant target of Skinner's critiques, cognitive science was by far the main target of Skinner's criticisms in the 1980s and 1990s with 14 mentions. Skinner also focused on Sherrington (5 mentions), Pavlov (5 mentions), and Hull (4 mentions), but mostly in texts in which he was presenting a retrospective of his views on diverse topics (e.g., 1980/1998, 1983a, 1988). Freud and psychoanalysis were discussed as well, but at this time, Skinner established parallels between the problems of Freudian theory and cognitive science by showing similarities in the development and practice of these two fields.

We can notice from Table 3 and Fig. 1 that, although Skinner added new targets through the decades (cognitive science in the 1970s being the most significant addition), the critiques remained essentially unchanged. The main criticisms were 2.1 (theorizing) and 2.2 (conceptual nervous system), both having occurrences from the 1930s through the 1980s. The only significant change was the increase of criticisms in the 1980s against centrism on neuroscientific explanations, the main target being cognitive science, possibly because of the so-called *cognitive revolution*, that, even though it is said to be started in the 1950s, only gained force during the decades that

followed, particularly in the 1980s (Baars 1986; Miller 2003). In addition, it was only in the 1980s that the collaboration between cognitive science and neuroscience was strengthened, which resulted in the foundation of a new discipline called *cognitive neuroscience* (Gazzaniga et al. 2002). However, we can find passages in which Skinner criticized the cognitive science misuse of neuroscience in publications that date as early as 1974 (Skinner 1974, p. 213), and he used the term *cognitive neuroscience* while criticizing cognitive science in 1987 (Skinner 1987, p. 784). Both considerations suggest that Skinner was aware of the changes happening in the field of psychology during his later years.

## Concluding Remarks

Skinner did not criticize neuroscience, per se, but instead criticized how his targets were misusing neurophysiology in pseudo-explanations of behavior. One indication of the misuse of neuroscience is that the majority of Skinner's targets were actually studying behavior, not neural processes. For instance, although Pavlov was a physiologist and used physiological techniques (e.g., fistulas), he was essentially studying respondent behavior. The same goes for Boring, Descartes, reflex physiology, Freud, psychoanalysis, Housenholder and Landhal (in the particular book reviewed by Skinner), Hull, cognitive science, Tolman, and Watson.

Nevertheless, two of Skinner's targets (Sherrington and Lashley) were conducting actual neuroscientific studies; that is, they manipulated real neurophysiological variables. This poses the question of the relevance of Skinner's criticisms when directed towards scientists who studied (and studies) the real nervous system, even though by proposing conceptual constructs when doing so. Sherrington is an exemplar case. In this context, I think Skinner's arguments are not free from criticisms and deserve a more careful analysis, since the strategy of theorizing about how neurophysiological mechanisms work without having direct access to it was and still is a very important part of neuroscience:

...the synapse was conceived by Sherrington as a theoretical entity in 1897, before it was observed directly with the electron microscope 50 years later. ... During that time the concept of the synapse was forming increasing rich relations with anatomical and physiological observations in the context of the neuron theory. *This is a good example of the importance of unobservable entities* [emphasis in original] (i.e., entities that were not observable with techniques available at the time) in the construction of the central theory of neuroscience. (Jacobson 1993, p. 22)

As we saw earlier, when Skinner criticized Sherrington, he was talking about his synaptic theory. There were two main points in Skinner's criticism: first, the concept of synapse was a construct. Sherrington never saw a synapse (Finger 2000; Robinson 2001). As Finger (2000) stated: "...Sherrington looked upon the synapse as a physiological construct, since neither he nor his contemporaries could see the gap in the pre-electron-microscope era" (p. 222). Second, Sherrington's synaptic theory was inferred from behavioral data and not from physiological data. The synapse was a

hypothetical entity proposed by Sherrington in order to explain the data obtained from reflex experiments. However, Sherrington is also viewed as one of the main figures responsible for establishing the foundations of modern neuroscience. Sherrington was strictly under the control of experimental data when he proposed the construct of a synapse. His verbal behavior of theorizing about the existence of synapses was being controlled by behavioral (reflex delay) as well as anatomical and physiological data (the work of Ramón and Cajal on the microscopic structure of the nervous system, and his own works on the degeneration patterns of nerve cell and on the patellar reflex mechanism) showing that neurons were intact cells (completely surrounded by an unbroken membrane) that formed tiny gaps with neighboring neurons (Zilio 2013b). In his book about the history of molecular and cellular neuroscience, Robinson (2001) wrote that “a half century after his death in 1952, Sherrington’s influence continues to pervade the field of neuroscience” (p. 35). That being the case, to what extent is Skinner’s criticism pertinent, or even fair, when directed towards Sherrington’s way of doing science?

Skinner’s critiques should neither be viewed as barriers to establishing dialogues between behavior analysis and neuroscience, nor as rigid guidelines for a proper way of doing science. Skinner (1956) himself opposed attempts to restrict scientific practice with preconceived rules or maxims. When placed in historical context, Skinner did not criticize neuroscience, he criticized the misuse of pseudo-physiological theories in the explanation of behavior. In addition, Skinner assumed that many questions about behavior, from the mechanisms of reinforcement and motivation to perceptual processes and private events, would be at least in part explained by neuroscience (Zilio 2013a). Neuroscience is not necessarily mentalistic or a purely conceptual effort; the proper study of the nervous system can (and indeed does) provide relevant explanations of behavior in the sense of providing information about variables necessary for its production (Donahoe and Palmer 1994; Marr and Zilio 2013; Moore 2002; Schaal 2005; Thompson 2007). Here, we find the *gaps* of behavior analysis.

## Appendix

### Skinner’s Texts Containing Keywords Related to Neuroscience

- Skinner, B. F. (1933). The measurement of “spontaneous activity”. *Journal of General Psychology*, 9, 3–23.
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