Title: What should a “Gibsonian neuroscience” look like? Introduction to the Special Issue.

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Abstract:
Ecological psychology has been criticized for ignoring the brain in its theory formation. In recent years, however, a number of researchers have started asking ecologically-inspired questions about the ways in which not only the embodied activity of the organism in its environment, but also the particulars of the organism's nervous system matter. This work has typically appeared in neuroscience journals, thereby potentially escaping the attention of ecological psychologists. The current article introduces a Special Issue of *Ecological Psychology* that aims to correct this problem. This Issue brings together one empirical and six theoretical articles that develop ideas about the contributions of the nervous system to perception-action. We briefly review each of the articles, identify common themes, and point out the surprising variety in theoretical positions. It is hoped that this Special Issue will help guide discussions amongst
ecological psychologists and (ecological) neuroscientists as they confront the question “What should a ‘Gibsonian neuroscience’ look like?”

A psychology cannot be explained by a physiology until one has a psychology to explain. (Tolman, 1958, p. 118)

Ecological psychology has been criticized for ignoring the brain in its investigations of how perception and action come about, treating it as “wonder tissue, resonating with marvelous sensitivity to a host of sophisticated affordances” (Dennett, 1998, p. 204). Indeed, barring some notable exceptions (e.g., Kelso, 1995, 2008; Reed, 1989, 1996; van der Meer, Fallet, & van der Weel, 2008; Van Orden, Hollis, & Wallot, 2012; Wang & Frost, 1992), over the last few decades ecological psychologists have generally followed Mace's (1977, p. 43) dictum of “Ask[ing] not what's inside your head, but what your head's inside of”. During much of this time disembodied and disembedded accounts of perception and action were clearly dominant, and the focus on studying the sensitivity of active organisms to information in the environment – at the expense of studying the neural contributions to this process – was therefore a natural one. In addition, most neuroscientific studies were (and unfortunately still are) guided by the mechanistic and cognitivist assumptions that ecological psychology disputes, and hence ill-positioned to guide ecological theory formation. Finally, it can be argued that the right conceptual framework needs to be in place before one can study the neurophysiological contributions; obviously, questions about what an animal does have to precede questions
about how the animal is doing it (e.g., Reed, 1989; see also Jirsa, McIntosh, & Huys, this issue).

Now that several decades have passed in which ecological psychologists have worked on the conceptual framework, one might ask whether the time is ripe to include a neuroscience branch. Indeed, a number of ecological theorists and, to a lesser extent, experimentalists have recently begun asking questions about the ways in which the particulars of the organism's nervous system matter (e.g., Agyei, van der Weel, & van der Meer, 2016; Bruineberg, Kiverstein, & Rietveld, 2016; Bruineberg & Rietveld, 2014; de Wit, de Vries, van der Kamp, & Withagen, 2017; de Wit, van der Kamp, & Withagen, 2016; Dotov, 2014; Favela, 2014; Fultot, 2017; Raja, 2018; Seifert, Komar, Araújo, & Davids, 2016; Teques, Araújo, Seifert, del Campo, & Davids, 2017; van der Meer, Svantesson, & van der Weel, 2013). However, this work has often been published in neuroscience venues, thereby potentially escaping the attention of ecological psychologists. This Special Issue aims to correct this problem. It brings together seven articles that develop (and, in one case, empirically tests) ideas about the workings of the nervous system and its role in perception-action. Each article, in one way or another, engages with one or more of Gibson's (1966, 1979/1986) concepts of perceptual systems, direct perception, and affordances, and in several cases also with ideas from related fields such as dynamical systems theory (DST), pragmatism, and phenomenology. As will become clear, the articles present a large variety of approaches and perspectives. We will return to this point and to what it might signify at the end of the editorial.

**Overview of the Special Issue**
In the framework presented by Jirsa and colleagues, brain networks can be decomposed into probabilistic task-specific "functional modes" that operate temporarily and continually appear and disappear, in a way that is similar to the concept of muscle synergies in movement coordination (Bernstein, 1967). It is argued that, as organisms switch between behaviors, slow order parameter dynamics govern the appearance and disappearance of the functional modes, of which the task-specific fast dynamics underlie perceptual-cognitive-behavioral functioning such as, e.g., the direct perception of a particular affordance.

Raja and Anderson also present an account of neural synergies, but stress that a complete account of synergies will typically span brain, body, and environment (i.e., exist at the ecological scale). Raja and Anderson furthermore develop the argument that a non-computational version of Anderson's (2014) increasingly influential theory of neural reuse is a good candidate for developing a Gibsonian neuroscience (see also de Wit et al., 2016, 2017).

Van der Weel, Agyei, and van der Meer contribute the sole empirical article to the Issue. Inspired by Reed (1996) and Anderson (2014), they re-analyze infants' brain responses to looming objects reported in van der Weel and van der Meer (2009) and find that presentation of the same looming object yields highly variable patterns of neural connectivity from trial to trial, consistent with the notion that many different sets of neurons can temporarily assemble to accomplish the same task (i.e., degeneracy; Edelman & Gally, 2001).

Bruineberg and Rietveld argue that an account of organisms' context-sensitive responsiveness to affordances requires the incorporation of an ecological-enactive

Fultot, Frazier, Turvey, and Carello present a detailed discussion of the rich capacities for perception and action of organisms without nervous systems. Against this backdrop, and recapitulating the ecological disaffection with representations and computations, they consider what advantage is conferred by having a nervous system. The authors argue for anchoring perception-action capabilities in thermodynamics, whether those capabilities are achieved by unicellular organisms that realize different functions through temporary morphological changes, or multicellular organisms that rely on a process of neural synergy assembly for their ability to be multiply poised.

Golonka and Wilson take things in a rather different direction by arguing that ecological psychology does not yet actually have an account of "representation-hungry" problems (cf. Bruineberg, Chemero, & Rietveld, 2018; Kiverstein & Rietveld, 2018; van Dijk & Withagen, 2015). They propose that the neural activity that accompanies information detection can be de-coupled from the information, and that this is what is required for an ecological understanding of organisms' ability to engage with temporally-distal objects and events.

Van Dijk and Myin, lastly, warn ecological psychologists making forays into the field of neuroscience against the danger of ascribing psychological functions to neural processes, i.e., reification; it is the organism-environment system that resonates, and not the nervous system. Taking this view one step further, neuroscientific explanations are
considered in an ecological vein—as phenomena of humans attuning to sociomaterial practices. Only by thus keeping neuroscience within the human environment, it is argued, can neuroscience in turn explain non-vacuously some of the conditions that enable a resonating organism-environment system.

**Common themes but different perspectives**

It is hopefully clear even from the above brief descriptions that there are a number of common themes to several of the articles, suggesting there is at least some agreement in their approaches. A number of authors apply the notion of *synergies* to the nervous system (e.g., Fultot et al.; Jirsa et al.; Raja & Anderson), and stress that these are task-specific and typically *softly-assembled* (e.g., Fultot et al.; Jirsa et al.; Raja & Anderson; van der Weel et al.). It is also commonly noted that there often is *degeneracy* in the way nervous systems support tasks (e.g., Bruineberg & Rietveld; Jirsa et al.; Raja & Anderson; van der Weel et al.) and, relatedly, that nervous systems often display *neural reuse*—the involvement of neural resources in multiple assemblies, potentially playing a different role from assembly to assembly (e.g., Bruineberg & Rietveld; Raja & Anderson, van der Weel et al.).

At the same time there is also great variability among the contributions. Some try to develop a Gibsonian neuroscience by drawing upon dynamical systems theory (Jirsa et al.), while others additionally focus on Anderson’s theory of neural reuse (Raja & Anderson; van der Weel et al.), Friston’s theory of free energy (Bruineberg & Rietveld), or principles of thermodynamics (Fultot et al.). And although there might be some overlap between the approaches, there are also fundamental points of disagreement. An
issue that divides authors is what drives coordination or control. Some authors explicitly follow Gibson in asserting that control cannot be localized in the brain or nervous system (e.g., 1979/1986, p. 225), while others are more ambiguous on this issue or even seem to disagree with Gibson on this point (cf., e.g., Bruineberg & Rietveld; Fultot et al., Golonka & Wilson; Jirsa et al.; Raja & Anderson; van Dijk & Myin). Relatedly, while the Special Issue as a whole is clearly skeptical of neurocentrism, individual contributions vary quite strongly in the strength of their rejections (cf., e.g., Fultot et al.; Golonka & Wilson; Jirsa et al.; Raja & Anderson, van Dijk and Myin).

What is causing this variability in positions? One option, which relates back to the epigraph with which this Introduction began, is that ecological psychology has not yet maturated enough to provide neuroscience with a clear explanandum—the variability might simply reflect the variability that exists in ecological psychology itself. After all, after Gibson’s death, different theorists (e.g., Costall, Heft, Reed, Shaw, Turvey) developed his ecological framework in fundamentally different ways. However, it is unlikely that these approaches will converge anytime soon, and one may question whether such a convergence would even be desirable (e.g., Dale, Dietrich, & Chemero, 2009).

Regardless of where one stands on this issue, there is clearly no shortage of ideas on the workings of the nervous system and its role in perception-action in the ecological community. Consequently, we suspect that this Special Issue will contain a lot for the readership of Ecological Psychology to disagree with, but perhaps also something to agree with. In any case, we hope that this Special Issue will inspire fruitful discussion about whether we need a “Gibsonian neuroscience” and if so, what it should look like.
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