Consciousness and Cognition 56 (2017) 77–90

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Rhythms of the body, rhythms of the brain: Respiration, neural oscillations, and embodied cognition

Somogy Varga[a,*], Detlef H. Heck[b,*]

[a] Dept. of Philosophy, University of Memphis, Memphis, TN 38152, United States
[b] Dept. of Anatomy and Neurobiology, University of Tennessee Health Science Center, Memphis, TN 38163, United States

ARTICLE INFO

Keywords:
Neural oscillation
Coherence
Synchrony
Embodied cognition
Sensory afference
Respiration
Gesture

ABSTRACT

In spite of its importance as a life-defining rhythmic movement and its constant rhythmic contraction and relaxation of the body, respiration has not received attention in Embodied Cognition (EC) literature. Our paper aims to show that (1) respiration exerts significant and unexpected influence on cognitive processes, and (2) it does so by modulating neural synchronization that underlies specific cognitive processes. Then, (3) we suggest that the particular example of respiration may function as a model for a general mechanism through which the body influences cognitive functioning. Finally, (4) we work out the implications for EC, draw a parallel to the role of gesture, and argue that respiration sometimes plays a double, pragmatic and epistemic, role, which reduces the cognitive load. In such cases, consistent with EC, the overall cognitive activity includes a loop-like interaction between neural and non-neural elements.

0. Introduction

The emergence of cognitive science in the second half of the twentieth century offered a broad theoretical framework for understanding cognition. While its initial focus on abstract formal descriptions shifted to connectionist approaches based on neural models of cognitive architecture (Bermúdez, 2014; Haugeland, 1995; Thagard, 2013), standard cognitive science shares a fundamental "locational" commitment: whether mental processes are best seen as abstract formal processes (though exclusively realized in the brain), or as activation patterns in neural networks, they unfold in the brains of cognizers and can be adequately described in abstraction from the body (Clark, 2008; Rowlands, 2004; Shapiro, 2012).

In contrast, the relatively recent research program "embodied cognition" (EC) opposes the "locational" commitment, holding that at least some cognitive processes are best comprehended in terms of a dynamic interaction of bodily (non-neural) and neural processes (Foglia & Wilson, 2013). EC is not a unified area of research, and the various research projects usually subsumed under the EC label lack homogeneity, established definitions (Wilson, 2002), and clarity about whether EC is conceived as complementing or providing an alternative to standard cognitive science.

Central claims of EC are based on findings in several disciplines, including psychology, robotics, and neuroscience (see Barsalou, 2010). To mention a few instructive examples, researchers have demonstrated that sensorimotor variables can influence cognitive tasks (Barsalou, 2008; Hegarty, 2004; Rubin, 2006; Wilson & Knoblich, 2005; Zwaan, 2004), that gesturing can support the comprehension of number concepts and calculations (Andres, Olivier, & Badets, 2008; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001; Goldin-Meadow & Wagner, 2005; Sweetser & Goldin-Meadow, 2004), and that some higher-level cognition is founded on modal systems (Martin, 2007; Pulvermuller, 2005).

* Corresponding authors.
E-mail addresses: svarga@memphis.edu (S. Varga), dheck@uthsc.edu (D.H. Heck).

http://dx.doi.org/10.1016/j.concog.2017.09.008
Received 8 May 2017; Received in revised form 8 August 2017; Accepted 25 September 2017
1053-8100/ © 2017 Elsevier Inc. All rights reserved.

The results of relevant research have given rise to different EC accounts that all reject the "locational" commitment, but adopt more or less radical formulations of the basic idea. While this is not the place to identify fine-grained differences between them, according to what we could call a *weak formulation of the EC hypothesis*, the body exerts a significant and often unexpected influence on cognitive processing, to the extent that failing to include bodily aspects leads to accounts of cognition that are at best incomplete. In contrast, the *strong formulation of the EC hypothesis* states that the body acts as a (partial) realizer of cognitive processing that is distributed across neural and non-neural entities.[1]

What we propose in this paper is consistent with the weak formulation of the EC hypothesis. We draw attention to respiration and respiratory muscle activity, a constantly active and unique bodily and neural process that has not received attention in the EC literature. The absence of systematic interest in respiration is somewhat curious, as the characteristic rhythmic contraction and relaxation of the body that gives rise to the continual flow of air through the mouth or nose is uniquely situated at the intersection of body and mind. On the one hand, quite similar to other vital functions (e.g. digestion, endocrine and cardiovascular functions) breathing operates autonomously, adapting to environmental demands and maintaining homeostasis. On the other hand, unlike these latter functions, respiration allows conscious top-down control: not only do cognitive states modify respiratory rate and volume, but breathing can also be brought under conscious control, for example, during speech production or the playing of a wind instrument.

Our paper aims to investigate respiration from an EC perspective by substantiating three hypotheses.

(1) *The influence hypothesis:* besides its vital function of supplying oxygen and removing carbon dioxide, respiration exerts significant and unexpected influence on movements, sensory perception, and cognitive processes.
(2) *The mechanism hypothesis:* via respiration-driven sensory inputs, respiration influences cognition by modulating neuronal oscillations, which in turn influence the generation of action potentials that realizes specific cognitive processes.
(3) *The general (speculative) hypothesis:* neural synchronization through oscillations might be modulated by sensory inputs from all sensory modalities, as well as proprio- and interoceptive sensory inputs, suggesting a general mechanism through which the body influences cognitive functioning.

If (1) is true, then it is also true that a comprehensive account of cognition cannot be attained in abstraction from the respiratory activity of the body, which would lend additional support to the weak formulation of the EC. If (2) is also true, then not only is (1) further strengthened, but we have also taken initial steps towards support for the admittedly speculative (3).

To support our three theses, we draw on the emerging interdisciplinary field that investigates "neuronal oscillations" (for a review, see Buzsaki & Draguhn, 2004), and in particular on electrophysiological studies linking oscillatory neuronal activity to the performance of sensory, motor, and cognitive tasks (Buzsaki, 2006; Buzsaki & Watson, 2012; Ward, 2003). We start with (1) offering support for the first hypothesis by providing evidence for the interaction between respiration and motor, sensory, emotional, and cognitive processes. Then, (2) we explain how neural oscillations are implicated in the synchronization of neuronal activity underlying cognitive functions and discuss evidence for a specific neuronal mechanism through which respiration influences cognitive function. Subsequently, (3) we offer support for the hypothesis that the mechanism uncovered in (2) may represent a general mechanism through which the body influences cognitive processes. Finally, in the last part of the paper (4), we work out the implications for EC, draw a parallel to the role of gesture in thinking, and argue that respiration sometimes plays a double role, executing both a pragmatic and an "epistemic action" that offers a cognitively significant contribution. In such cases, the overall cognitive activity includes a loop-like interaction between neural and non-neural elements.

1. Support for hypothesis (1): Respiratory function beyond gas exchange

While the exchange of oxygen for carbon dioxide in the lungs is the most important physiological function of respiration, there are many known effects of breathing on motor, sensory, and cognitive functions that cannot be explained by the physiology of gas exchange. In the following we describe examples for each category. Before doing so, we find it useful to point out how the research described here differs from much earlier studies that have investigated links between cardiovascular activity with respiration and with slow oscillations of brain activity measured with EEG (Birbaumer, Elbert, Canavan, & Rockstroh, 1990). Those studies were conducted at a time where high frequency oscillations were not yet considered as functionally relevant brain activity patterns, and the changes in brain activity measured in those studies were often linked to states of sleep or arousal (Dworkin & Dworkin, 2004). There is a known influence of respiration on heart-rate and heart-rate variability (respiratory sinus arrhythmia) (Berntson, Cacioppo, & Quigley, 1993) which indirectly links breathing to blood flow changes through the brain as well as blood pressure changes which are signaled to the brain by baroreceptors and will result in changes in brain activity (Rau, Pauli, Brody, Elbert, & Birbaumer, 1993). Those forms of respiratory influence on brain activity may affect cognitive functions, but they would do so on a time scale slower than the one we are considering. Moreover, most central to our argument, those changes in brain activity are not directly linked to voluntary body movements. Our argument centers on the role of direct sensory feedback from movements of the body, and we are basing it on findings linking sensory feedback from respiration to instantaneous changes in high frequency brain activity that has been widely linked to respiration.

[1] More radical approaches maintain that in some cases, not only non-neural, but also non-bodily realizers can be seen as constitutive for cognitive processing (Clark, 2008; Clark & Chalmers, 1998).

Download English Version:

https://daneshyari.com/en/article/7288252

Download Persian Version:

https://daneshyari.com/article/7288252

Daneshyari.com