

Presence and Pleasure: The Funk Grooves of James Brown and Parliament (Music/Culture)

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Rhythmic complexity and predictive coding: a novel approach to modeling rhythm and meter perception in music

Peter Vuust^{1,2} and Maria A. G. Witek^{1*}

¹ Center of Functionally Integrative Neuroscience, Aarhus University Hospital, Aarhus, Denmark

² Royal Academy of Music, Aarhus/Aalborg, Denmark

Edited by:

Jessica A. Grahn, University of Western Ontario, Canada

Reviewed by:

Shinya Fujii, Sunnybrook Research Institute, Canada

Richard Ashley, Northwestern University, USA

*Correspondence:

Maria A. G. Witek, Center of Functionally Integrative Neuroscience, Aarhus University Hospital, Nørrebrogade 44, Building 100, 8th Floor, 8000 Aarhus C, Denmark
e-mail: maria.witek@fnua.dk

Musical rhythm, consisting of apparently abstract intervals of accented temporal events, has a remarkable capacity to move our minds and bodies. How does the cognitive system enable our experiences of rhythmically complex music? In this paper, we describe some common forms of rhythmic complexity in music and propose the theory of predictive coding (PC) as a framework for understanding how rhythm and rhythmic complexity are processed in the brain. We also consider why we feel so compelled by rhythmic tension in music. First, we consider theories of rhythm and meter perception, which provide hierarchical and computational approaches to modeling. Second, we present the theory of PC, which posits a hierarchical organization of brain responses reflecting fundamental, survival-related mechanisms associated with predicting future events. According to this theory, perception and learning is manifested through the brain's Bayesian minimization of the error between the input to the brain and the brain's prior expectations. Third, we develop a PC model of musical rhythm, in which rhythm perception is conceptualized as an interaction between what is heard ("rhythm") and the brain's anticipatory structuring of music ("meter"). Finally, we review empirical studies of the neural and behavioral effects of syncopation, polyrhythm and groove, and propose how these studies can be seen as special cases of the PC theory. We argue that musical rhythm exploits the brain's general principles of prediction and propose that pleasure and desire for sensorimotor synchronization from musical rhythm may be a result of such mechanisms.

Keywords: rhythm, meter, rhythmic complexity, predictive coding, pleasure

INTRODUCTION

Music can move us, both emotionally and corporally. It can send shivers down our spines and make us tap our feet in time with the beat. How does the brain facilitate the rich and complex experiences we have of rhythm in music? Here, we propose the theory of predictive coding (PC) as a framework for understanding the ways in which complex rhythms are processed in the brain and discuss why we derive pleasure from rhythm in music. First, we point to the theories of rhythm and meter which allow for hierarchical and computational modeling. Second, we present the theory of PC, which posits a hierarchical organization of neural functioning, reflecting fundamental mechanisms associated with predicting future events. The theory puts forward that perception and learning occurs in a recursive Bayesian process by which the brain tries to minimize the error between the input and the brain's expectation. Third, we view rhythm perception in light of this theory as an interaction between what is heard ("rhythm") and the brain's anticipatory model ("meter"). We describe the experience of rhythm in music as depending on the degree of tension or discrepancy between rhythm and meter. Finally, we review some empirical studies of different forms of tension between rhythm and meter—syncopation, polyrhythm and groove—and propose that these can be seen as special cases of PC. Our examples illustrate a number of fundamental principles of its

mechanisms: the effects of prior experience, model comparison, and the relationship between prediction error and affective and embodied responses.

HIERARCHICAL MODELS OF RHYTHM AND METER

Theories of rhythmic perception often contrast rhythm with meter. Broadly, *rhythm* is a pattern of discrete durations and is largely thought to depend on the underlying perceptual mechanisms of grouping (Fritsch, 1963, 1967, 1968; Clarke, 1999). Meter, again broadly, is the temporal framework according to which rhythm is perceived. More specifically, as defined by London (2012, p. 4): "meter involves our initial perception as well as subsequent anticipation of a series of beats that we abstract from the rhythmic surface of the music as it unfolds in time." At the most basic level, the perception of meter involves a sense of pulse, i.e., a pattern of beats at isochronously spaced intervals (Honing, 2012, 2013). When such beats are hierarchically differentiated into strong and weak accents, it is thought that we perceive meter (Lerdahl and Jackendoff, 1983; London, 2012). Because of its hierarchical nature, meter allows for rhythmic expectations in music (Large and Kolen, 1994; Jones, 2009; Ladning et al., 2009; Rohrmeier and Kollsch, 2012). In other words, meter provides the listener with an expectancy structure underlying the perception of music according to which each

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