Information specification during singing: A theoretical approach to music performance

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Published 16 December 2021; https://doi.org/10.18061/FDMC.2021.0039
Author video presentation and/or other conference material: https://doi.org/10.17605/OSF.IO/3VPZQ

Abstract

Self-organized systems emphasize Gibson's (1966) proposal that organisms and the environment are one coupled system. As a result, energy flow throughout the system allows its subsystems to utilize it in a meaningful way. Specifically, emergent collective organization provides information about and specific to the world around us. During music performance, this is especially important for both performers and listeners alike. This theoretical proposal discusses how we can consider examining ecological physics and the theory of the global array through music performance. If we consider a group of singers as a self-organized system, it opens the door to understanding the dynamics and information flow within and around it. The goal of this paper is to explore an unorthodox approach to examining the perception of music performance.

KEYWORDS: *collective organization, ecological psychology, emergent dynamics, energy flow, information, music performance, perception and action*

Ecological Framework

The field of ecological psychology, brought to the forefront by J. Gibson, emphasizes the epistemology and intentionality of organized systems through perception-action coupling. Gibson (1966) noted that the appropriate scale of investigation for living organisms in their environment is structured differently at each level – from microscopic amoeba to entirely coordinated animal herds. Importantly, organisms in their environment are not isolated from it, and for a system to maintain its organization, energy must always be expended or dissipated (Gibson, 1966; Walton et al., 2014). The self-organizing system demonstrates the necessity of energy flow throughout the system which allows its subsystems to utilize it in a meaningful way.

Anytime an open non-equilibrium system does work, energy dissipates through the system and provides constraints in a reciprocal manner – this affords self-organization (Walton et al., 2014). When many of these systems (or subsystems) maintain each other's mutual constraints, it is considered an *autocatakinetic system* where circular causality and emergent collective organization occurs (Swenson, 1997).

One such example of this phenomenon could be theorized as a group of singers. If we consider each singer individually as an open non-equilibrium subsystem that transforms energy throughout an intentional performance, emergent collective organization occurs as each person constrains the other in unique ways that result in a dynamic yet synchronized performance. This paper is meant to bring attention to the possible theoretical consideration of a music performance as part and parcel of an emergent collective organization. First, let's discuss the properties of emergent collective organization that provide the means for information flow.

Open Systems and Ambient Energy Arrays

Energy expenditure is the fundamental foundation of nonlinear system dynamics. Ecological physics, similarly, defines the nature of the organism-environment interaction and how it is specified to an organism. Gibson (1966) introduces *ambient arrays* as a source of information – structured energy by the animal-environment interaction governed by physical laws which give rise to unique structures and patterns of ambient energy (Stoffregen & Bardy, 2001). This structuring of energy specifies information to an organism because each particular pattern defines a unique relationship between the organism and their environment. *Specification* is described as a lawful, 1-to-1 relationship between patterns in ambient energy arrays and aspects of the organism-environment interaction that give rise to them (Shaw et al., 1982; Stoffregen & Bardy, 2001).

When considering the perceptual system, the orthodox perspective is that different stimuli in the environment activate specific sensory receptors which then send signals to the central nervous system where meaning is then interpreted (i.e., Dewey, 1896). Gibson

(1986), on the other hand, argued that perception is based on ambient energy where the variations in sensory information are related directly to physical reality through natural law. Further, Stoffregen and Bardy (2001) make the argument that behavior is perceived and controlled relative to *real* and *lawful* aspects of the animal-environment system rather than sensory representations or internal models. By introducing ecological physics, we can move away from the focus on how the world around us becomes structured *inside* the brain or nervous system. Instead, the activity of an organism can be understood in relation to many independent referents that result in various patterns of ambient energy arrays which provide information that is inherently structured (Stoffregen et al., 2017).

Gibson (1966) originally described each sensory system to be stimulated by specific forms of energy (i.e., the auditory system stimulated by an acoustic ambient array). However, it has been theorized that direct perception must be based on sensitivity to emergent higher order patterns of *multiple* ambient energy arrays because perceivers seek information about behavior relative to multiple referents at once **(**Stoffregen et al., 2017**)**. Thus, because perception is not comprised of multiple, distinct sensory systems that respond to a only one distinct form of energy, we can instead conclude that there is only one irreducible perceptual system where information is specified by a single, global energy array.

Theory of the Global Array

To better understand the theory of a global array as information that specifies the system-environment relationship of a system, let's assess the act of walking as an example. If multiple ambient arrays were sources of specific sensory information (i.e., the eyes respond to the ambient light array or the ears respond to the acoustic array), what happens if what we perceive is not *consistent* across all ambient arrays? When a person walks, footfalls compress receptors on the feet (mechanical) but there is a very different pattern of stimulation on the vestibular system (proprioceptive) and through optical changes in the layout of the environment (visual) without stimulation on the mechanical or vestibular systems. Here, it would not be feasible for there to exist a 1-to-1 specification of "walking" in a *single* ambient array since each one is specifying unique information. The act of perceiving must provide rich information about aspects of the animal-environment system relevant to a specific action (Stoffregen et al., 2017).

Stoffregen and Bardy (2001) maintain that emergent, higher order patterns across multiple forms of ambient energy are all that meet the criteria for lawful 1-to-1 specification. The global array offers a solution to this discrepancy. Here, information exists as high order invariant relations between other ambient energy arrays (Stoffregen et al., 2017). Accordingly, while single ambient arrays may provide specification of a particular form of energy in relation to the actor, the global energy array provides unique specification of all possible ambient arrays in relation to each other *and* to the actor. The global array is an inherently compound invariant that emerges from patterns of single-energy arrays which are, by nature, irreducible and directly perceivable (Stoffregen et al., 2017).

This theory is consistent with Gibson's (1966) claim as follows: "If the invariants in this structure can be registered by the perceptual system, the constants of neural input will correspond to the constants of stimulus energy. […] The brain is relieved of the necessity of constructing such information by *any* process" (pp. 267). Thus, we rid ourselves of the necessity for integration or computation within the perceptual system through the coupling of the system to the global energy array embedded in lawful physical relations.

Proposed Experimental Application

While the existence of a global array has much theoretical support from an ecological perspective, research conducted to test this theory is severely lacking. Many questions remain as to what features of the global array allow us to specify relational information in the world around us, as previous research on the topic emphasizes single forms of energy stimulating specific, isolated sensory systems. The current proposed experimental application offers an applied approach to understanding how the perceptual system might access specific information in structured energy emergent in the global array.

Emergent Collective Organization in Choir

Musical Semiotics

Considering a group of singers as a self-sustaining system which has emergent collective organization has often been discussed in terms of *musical semiotics* (Walton et al., 2014). Musical semiotics, as defined by Tarasti et al. (1996), is music production as a system of signs where others seek to understand how sound events come to signify musical meaning through their relationship with instruments and other performers. As Rappaport (1974) expertly notes, communication not only includes what is said, but also includes certain sorts of 'doing' as well. This coincides with Pierce's (1960) classification of indexicality - where an action is caused by part of what it indicates (Rappaport, 1974). For example, a singer performs a piece which, in turn, embodies the meaning of that piece. Sawyer (1995) notes that a musician's actions within a performance contribute to the *evolving emergent* – the musical output of that interaction, which reciprocally constrains the performance. More specifically, there are kinesthetic constraints that affect the ways that the performance is generated and able to be interpreted by both the audience and other performers (Walton et al., 2014).

Perception-Action Coupling During Performance

Music performance, like other behavior, involves both perception and action couplings continuously informed by specific and lawful information. While auditory information seems to be primarily what we perceive, it is *affordances* that are the true objects of perception according to Gibson (1986). Affordances are possibilities (or lack thereof) for action specified by lawful and relational information structured in patterned energy. In a musical performance, for example, the information indicating the dynamics of the performance specify the affordances for continuing to perform (i.e., speeding up or getting softer). It is clear why this relationship is circularly causal and impredicative.

In the framework of Stoffregen et al.'s (2017) theory of the global array, we can conceive that the information specified during music performance is much richer than the single-energy array containing acoustics. Windsor and de Bezenac (2012) explain that the significance of music, or any sound, does not lie in an abstract, auditory phenomenon but instead lies in the *manner* in which it directly specifies interactions among people in the environment.

Group music performance, in particular, requires excellent coordination and regulation of action among members to achieve a common goal, a property of self-organizing systems (Kugler & Turvey, 1988). Behaviors of each individual solicit particular patterns of behavior in others. Interacting musicians are not motivated and constrained only by the *sound* produced by other musicians, but also by the specific actions and gestures that provide richer information about the performance. Windsor and de Bezenac (2012) go further to note that, "Music presents a limitless array of highly structured information about the bodies and environments of those that produce it" (pp. 111). The musical performance itself may encompass its own global array that captures *all* dynamics of the system.

As discussed by Schögler and Trevarthen (2007), there has been research that demonstrates how an expressive musical performance can provide perceptual information in various modalities through physical movement (Juslin & Sloboda, 2001; Todd, 1994). When singing or performing with others we inform others about our action in how we move, which can act as an invitation for others to join in (Schögler & Trevarthen, 2007). This information that specifies the possible intent of other performers must be of various modalities, not simply auditory or visual. Thus, an expressive musical performance is a complex array of energy as emphasized by the theory of the global array.

Evidence has shown that movement is more strongly associated with the auditory system than the visual system (Patel et al., 2005). In addition, other research has emphasized the temporal patterns of musical performance giving rise to beat perception. For example, Toiviainen et al. (2010) conducted a kinetic analysis of peaks in mechanical energy during music listening which showed that participants embodied the musical stimulus on multiple metrical levels. This provides further evidence that there are various ways to parse information specific to a music performance.

Research is warranted to explore the information that *emerges* among a group of performers. The various possibilities of information coupling may offer enhanced information about the piece being performed (i.e., acoustical timbre, stylistic details, variations in breath control). Experiments that involve music listening offer insight into how it is heard, but when manipulating sound production and feedback in real-time we can uncover if changes in coupling strategies impact information flow.

One previous study by D'Amario and colleagues (2019) manipulated visual contact among singers and used the audio recordings as stimuli for listeners. Results demonstrated that participants listening to the recordings were able to perceive differences in synchrony in correspondence with the visual contact conditions (D'Amario, Daffern, & Bailes, 2019). This finding demonstrates the possible suggestion that manipulating information available to the singers in each condition changes how that performance was perceived by listeners.

The research application discussed here offers an empirical lens to investigate how changing the structured information of the performers' global array may change how they perform, how synchronized they perform, and how the performance is perceived by listeners.

Proposed Study

The current proposal aims to investigate how mechanical coupling affects listeners' perception of a performance using a similar paradigm as D'Amario and colleagues (2019). However, in addition to visual coupling, a subsequent question of interest is whether varying *mechanical coupling* among singers will produce similar results.

Experiment 1

Four singers will be recruited from the University of Connecticut to partake in the study. The participants will be members of an already existing performance group that have a simple chorale or carol in their repertoire that they can perform comfortably acapella. They will be positioned so each singer can see and reach each other during baseline (a small square).

The performance conditions will be as follows:

1. Visual contact (eyes open)
    a. No mechanical coupling
    b. Holding hands
2. No visual contact (eyes-closed)
    a. No mechanical coupling
    b. Holding hands

Audio recordings will be recorded for each condition and serve as stimuli for *Experiment 2.* Additionally, movement data will be recorded and analyzed to examine the impact of the visual and/or mechanical manipulations on movement synchrony of the singers during the performance. Singers will also be asked to rate their performance after each condition as to how well they did to gauge perceptions in real-time. All data will be used to compare relationships with participants' perceptual ratings of each performance condition during *Experiment 2.*

We predict that movement during the visually and mechanically coupled condition will result in the most synchrony between singers (and best performance ratings), while the least synchronized condition will be the performance with no mechanical coupling with eyes closed (and least performance ratings).

Experiment 2

Using the recordings from *Experiment 1*, we will recruit students from the University of Connecticut participant pool to come into the lab and listen to all of the condition recordings. The order of the audio files will be randomized to avoid any order bias. We will ask participants to rate how well each performance was performed, how synchronized they thought each performance was, and other exploratory questions (i.e., "How many singers did you hear?").

In conjunction with the data collected from the performance in *Experiment 1,* we will analyze the effect of condition on listeners' ratings and compare the results to the movement data collected from the singers. This will provide evidence, if any, of coherence in ratings and the mechanical or visual coupling manipulations.

We predict that perceptual ratings of each performance should correspond with the motion synchrony of each condition. Further, we predict that mechanical coupling may provide richer information for performers and listeners alike, which may influence listeners to have more aligned ratings with the performance data for the mechanically coupled conditions.

Discussion

The results of this research will contribute to our understanding of how performance manipulated by mechanical or visual coupling may specify information about the performance to listeners. Further, it is of interest to theorize how information contained in the global energy array may or may not be limited when compressed into a different domain – auditory listening. Future research may consist of *Experiments 1 and 2* concurrently and capture the performer-audience dynamic.

The proposed study will provide much needed empirical data to explore the global array while adding to the vast amount of existing literature on synchrony during music performance. If participants' experience listening to each performance recording reflects our coupling manipulation, it would provide quantitative evidence that *mechanical* information can be picked up in the *auditory* domain. Thus, individual single-energy arrays would be affecting each other in an interactive way – evidence for an emergent global array, rather than individualized sensory pathways.

Conclusion

An empirical approach to investigating the dynamics of group singing embedded in a noteworthy theoretical framework provides a novel way to quantify the complexities of the shared collective experience. Ecological physics and the theory of the global array has not received much attention from experimental work. However, the benefits of examining real-world experiences like group singing from an ecological physics perspective allows for us to explore the rigor of proposed theories and move research on music cognition forward in an innovative way.

Acknowledgements
Thank you to the Center for the Ecological Study of Perception and Action for providing me with the perspective that inspired the ideas explored herein.

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