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Special issue:
"In memory of Michael Turvey"

More than science: A systems approach inspired by Michael T. Turvey

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HIGHLIGHTS

- M. T. Turvey impacted our study of perception and action significantly.
- Ecological psychology is nested under a broader systems perspective.
- Context dependence inherent to systems facilitates understanding of any phenomenon.
- Systems necessarily include contemporaneous multiscale and historical influences.
- Systems thinking extends beyond academic study to teaching and mentoring.

ABBREVIATIONS

ASU	Arizona State University
CESPA	Center for the Ecological Study of Perception and Action
DPAC	Dynamics of Perception, Action, and Cognition
EEG	Electroencephalography
UConn	University of Connecticut

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ABSTRACT

This year, we lost a giant in the field of perception and action, Michael T. Turvey. This special issue is dedicated to the impact that he made on his students and the field. I learned about ecological psychology just as I was headed to graduate school in 1990. Through Michael's teachings and my own academic career that followed, I recognized that the inseparability of organism and environment that was fundamental to ecological psychology was part of the larger story of a systems perspective that itself helped to frame questions of causality from Aristotle and the problematic division of subject and object inherited from Descartes. In this mini-review, I identify fundamental concepts in systems science from an academic perspective, but I extend that same reasoning to life beyond science. Together with his wife, Claudia Carello, who was also the director of the Center for the Ecological Study of Perception and Action (CESPA) at the University of Connecticut, Michael taught, mentored, and cared for his students within the same systems framework. It is that broader lesson for how to teach and mentor students that I offer to honor his memory today.

KEYWORDS: Turvey | Ecological psychology | Dynamical systems | Systems approach | Perception-action

A theme will no doubt emerge in the collection of articles submitted for this special issue, that Michael T. Turvey was a giant in the field, someone who influenced the trends and general approach to the study of perception and action over the past 50 years and who will, through his writings and his students, continue to influence the field long past his time here with us. The contributors to this special issue were charged with the monumental task of discussing Michael's influence on our scientific careers. I chose to write about Michael's ultimate gift to me as being a *systems approach*, the belief that everything is connected, not simply in the academic sense but also as foundational to teaching and mentoring. As I write about the importance of preserving the integrity of the system in seeking causal explanation, I have to acknowledge not only Michael, but Claudia Carello and other faculty, fellow students and other alumni from the Center for the Ecological Study of Perception and Action (CESPA) at the University of Connecticut (UConn), and as well as CESPA's constant flow of visitors over the years, that all helped to shape my scientific career. In this article, I will identify other lines of thinking from across the sciences and philosophy that reflect Michael's mentorship in multidisciplinary thinking and contribute to my broader understanding of a systems perspective.

I believe that a reasonable approach to reading the articles in this volume will be to take them in chronological order from the earliest students to the most recent. I was a student at CESPA somewhere in the middle of that timeline, during the early 1990s and shortly after the introduction of dynamical systems to psychological questions, starting with motor coordination. Kugler and Turvey [1] had just introduced the hand-held pendulums paradigm, and Schmidt, Carello, and Turvey [2] had just demonstrated that the same dynamics held both within and across people. The principle of dynamical similitude—that the same behavior could be observed in very different looking systems–captivated me, and I was lucky enough to build on that social coordination research [3,4] and to contribute to the first book on *Dynamical Systems in Social Psychology* [5,6]. Dynamics became the central focus of my own scientific career. I named my lab at Arizona State University (ASU) the Dynamics of Perception, Action, and Cognition (DPAC) lab and have conducted a multidisciplinary

graduate seminar by the same name for over 23 years.

A SYSTEMS PERSPECTIVE: EVERYTHING IS CONNECTED

It may surprise the reader, then, to hear that I am not going to focus on dynamics itself as Michael's central influence on my career. Instead, I think that his greatest influence was the adoption of a systems perspective. In the search for an explanation for behavior, a systems perspective considers everything—both contemporaneous and historical influences—that might influence the phenomenon of interest. I explain it to students as *drawing a circle* around everything that might possibly play a role in producing that phenomenon. Ecological psychology's emphasis on the organism embedded in its environment is necessarily a systems perspective.

Let us first consider contemporaneous influences. Whenever I teach dynamical systems to graduate or undergraduate students, I start with a lecture entitled *Everything is Connected*. As you sit in your chair reading this, lift the leg that sits on the same side as your writing hand and draw circles in a clockwise direction as if you were tracing them in sand on the ground. Now draw a big number 6 in the air with your preferred hand. What happens? Your leg reverses direction and starts to move counter-clockwise. Despite being distally related, located at different ends of our bodies, our limbs are connected; they influence each other and cannot move at will in opposite directions without sufficient practice. This was Bernstein's context conditioned variability [7]. Every movement occurs in—and its outcome is dependent upon—context. Bernstein goes on to explain in his explanation of the degrees of freedom problem the impossibility and unnecessary computational burden of considering the control of movements in isolation, apart from context [8]. Behavior, after all, never occurs in isolation.

Bernstein [9] emphasized the role of given forces in the control of bodily movements: we can either consider commands that work in a vacuum, building an intended movement from scratch, or supplement given dynamics, for example, gravity and springlike properties of muscles, to solve a much easier problem. If we harness the given dynamics, molding them to our will, then we are working with the natural dynamics of a system and do not have to build it up from scratch - which, because the given forces will still be there - won't work. Thelen and colleagues [10,11] induced stepping and walking behavior in babies by providing the context in which those behaviors could emerge. They induced stepping behavior in infants as young as three months old by submerging their lower bodies in water to lessen the impact of baby fat. They encouraged slightly older babies who could not yet walk on their own to demonstrate walking behavior on a treadmill where the springlike forces in the muscles produce the leg swing that is characteristic of walking. In the spirit of this research, I ask my own students whether they are walkers or crawlers... and then I show them a picture of a steep slope that they might be asked to climb. In context, even grown adults capable of walking necessarily become crawlers. To quote Alicia Juarrero [12] in her latest book, *Context Changes Everything: How constraints create coherence*.

We acknowledge the importance of context in ecological psychology when we take as foundational the inseparability of organism and environment. Classically, from Gibson [13], we know that direct perception is facilitated by the preservation of the organism-environment relationship. Meaning exists in the relation between organism and environment, with no primacy given to either the organism or environment alone. As we all learned in Michael's Perception class, preserved for posterity in Turvey's [14] *Lectures on Perception: An Ecological Perspective*, if we separate the organism from the environment by considering the retinal image as the point of division, then we face the insurmountable task of adding meaning back into that impoverished point of contact. This is not a new idea: Our scientific tradition inherits from Descartes a division not just of mind and body but of subject and object [15]. If we as subjects are separate from the objects that we wish to consider in our surrounding world, then we face the tremendous task of explaining how to stitch the two back together.

Scientists who dichotomize nature and nurture face similar battles. In his book, *The Dependent Gene*, Moore [16] addresses causality using memorable examples of the inseparability of gene and environment. One of my favorites is the example of chicks with teeth. Wait, you say, chicks don't have teeth... but they do in context! A chick's beak develops out of a particular layer of embryonic tissue; Moore conveniently labels it Layer 1. If mouse cells are transplanted into the layer behind that beak-developing layer, into what might be labeled Layer 2, then the cells in Layer 1, still the chick cells, develop into teeth. It isn't those Layer 1 cells that contain the information about the structure that emerges but the cells in Layer 1 plus the environment of Layer 2 that constrain what emerges. One does not take primacy over the other.

The previous examples are limited to contemporaneous context, but behavior similarly occurs in historical context. As scientists, we have inherited a tendency to look for (Aristotle's) efficient cause [17], a type of causality that has been likened to a "billiard ball" effect, where we look for some event that immediately preceded the behavior that we are trying to explain. That is a limited view of history. In fact, most behaviors are multiply-caused by events both proximal and distal to the observed behavior. What caused you to start reading this article? Was it that you saw it in your email? Was it a future-oriented goal, that you hoped to learn something? Was it oriented further in the past, that you hoped to read something that reminded you of your own interactions with Michael Turvey? We know from the immense literature on long-range correlations [18] that it is not just the immediately preceding event that is correlated with the present. Autocorrelations of a value greater than one are the more likely case, with events correlated across both proximal and distal points in time.

Inseparable from this issue of causality is the idea that there are always multiscale explanations of "why" [19]: Did you start reading because your eyes started moving over the words or because you are interested in the topic? Both answers are correct, but they exist at different levels of analysis. One of my favorite examples comes from the study of postural control [20]: Across short time windows, postural deviations from vertical are positively correlated; because that would cause us to topple over the long term, postural deviations from vertical are negatively correlated at larger window sizes. Both regions are integral to the control of upright posture.

When we sever those multiscale contemporaneous and historical connecting bonds through the practice of reductionism, we lose information both at the macroscopic level and at the microscopic level. An understanding of team behavior, for example, requires that we understand the team dynamic, not just the members of the team, and not just their interactions, but the dynamic that emerges through the interaction of all of those team members [21,22]. That team dynamic is broken when we consider each individual in isolation. Similarly, and this is not something we usually consider, when we study the individual, we necessarily lose information about the impact on individual behavior of the team of which they are a part. This circular causality is what makes explanations centered around efficient cause both inaccurate and hopeless [23].

It sounds like an insurmountable problem - how else are we to conduct our science? - until we realize that we can take advantage of that vastly interconnected system to understand phenomena beyond what we are measuring. One of my favorite findings was that we could build up an understanding of team-level experience through analysis of electroencephalography (EEG) signals recorded from individual team members [24]. Such an understanding is only possible with the understanding that *Everything is Connected*.

SYSTEMS IN LIFE

I could keep talking about the systems perspective in science alone, but that would be only half of the story. For the science that we conduct in a lab and that we record in papers is only part of a broader system of science education and lifestyle. Michael and Claudia exemplified the systems perspective when they took care of the entire student: academically, financially, and socially. It is beyond the scope of this scientific journal to identify all of the personal stories and ways in which they enriched the lives of their students. However, I feel that it is appropriate to tell a few stories to illustrate this point.

Those of us who remained in academia recognize how hard it is to secure funding for our labs and for our students. Michael and Claudia would go into intensive writing mode before grant deadlines to secure the funding that allowed us, as students, to dedicate ourselves fully to our research, to be as productive as we could be during our graduate career so that we could secure jobs of our choice afterwards. Claudia would ask me about the cost of everything—my rent, my electric bill, how much I paid for food—so that she could make sure that I had just enough to live on. Even at that time, but particularly after years of worrying about funding for my own graduate students, I recognize that this particular dedication to the financial lives of their students was special.

Part of taking care of us financially was taking care of our social life. We didn't have extra funds to go out and socialize, so Michael and Claudia hosted us... all of the time. They hosted speakers and guests and invited us all over to eat and to socialize with people who were so very important in our field. That practice was fun for us socially, but it also helped us to build our network of professional contacts and, in some cases, including my own, find researchers that would serve as postdoctoral supervisors or references for job hunts and promotions. Michael and Claudia hosted us for every holiday: Fourth of July? You knew to be prepared for a quiz on the Constitution and its amendments. Christmas shopping? Expect to help Michael fulfill Claudia's list and to help Claudia buy gifts for all of the front office staff. New Year's Eve? Borrow a gown, put on some makeup, and expect to dance to Glenn Miller. And Friday nights? Every Friday night, expect to be invited into Sweet William's Pub, the Irish pub that they built in their basement, to unwind from the week, to bond, and to get a little push on the plan for what you should accomplish before Monday morning. Decades have passed since my graduation, and yet I still remember the words to all of the Irish pub songs; I still remember the sausages, Coleman's mustard, and perhaps some Hungarian brandy that made their appearance after midnight. Decades after graduation, I knew that I could still turn to Michael and Claudia for support.

Like an approach to science, this consideration of the entire student in teaching and mentorship is central to a systems perspective. You cannot divide out the students' academic progress from their financial concerns, their need for a social outlet and long-term support. Michael, Claudia, and the entire CESPA system provided that to all of us.

DON'T MIMIC BUT FOLLOW THE SPIRIT OF THE LESSON

Finally, part of a systems approach is recognizing that behavior emerges from the particulars of its components. Most of my early mistakes in teaching came from trying to mimic Michael's teaching style a little too closely. I recall putting together my very first graduate class on dynamical systems as an assistant professor. The material imitated Michael's format and style a little too closely, to the extent that I found myself explaining, in a lecture on Rayleigh-Bénard convection, "the salsa [that's what saucer sounded like to me when Michael said it in his British accent] is heated from below". It was clear that I had to find my own voice, quite literally. I know now that what my students like most about my teaching style is that it reflects who I am, just as Michael's style truly reflected him.

There are far more stories that I could share that were eliminated from earlier drafts. Admittedly, this was an overly emotional paper to write. But all good things must come to an end, and so I only wish to say Thank You, Michael. I honestly would not be where I am today—or be who I am today—without you.

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