Lectures on Ecological Psychology

Presented to Japanese Society for Developmental Psychology 2004

Dr. Paul Treffner

metaffordance.com

Session 1

Physical self-organization as the basis of biological coordination and control

In this lecture I will introduce the *physical* basis of biological coordination and control. This is known as self-organization. This is an idea opposed to the notion that control of the "self" comes from a higher, non-physical source (e.g., from a so-called "motor program", "executive", or "little man in the head" – the *homunculus*). The modern theory of biological control and coordination reformulates the mind-body problem by realizing that there is really no such thing as "the mind" – at least not in the original sense of this word as introduced by Descartes as meaning, literally, the *soul*. Such dualisms as between mind and body are untenable.

Descartes' notion of the soul was given some degree of respectability when the technical term of "mind" was introduced to replace the religious concept of "soul". But careful analysis shows that to somehow separate the physical (body) from the non-physical (mind) is nonsense. What if, as modern physical science shows, all behaviour can be understood not by reduction to matter, but reduction to *principles*? Such "principled reductionism" is how the theory of pattern formation and self-organization can be used to successfully address issues of body morphology and behavioural patterns in time.

In this lecture I will introduce the paradigmatic example of physical self-organization—Bénard convection, and also demonstrate the development of spiral waves and temporal rhythmic beating patterns (like a heart beat) using nothing but a few chemical compounds in a glass bowl—the so-called Belousov-Zhabotinsky (B-Z) reaction. These patterns—generated by principles of physical self-organization (not "programs") can be described by the new geometry and mathematics of fractals, chaos, and dynamical systems. The key concept used here is *pattern stability*.

I will then move on to describe such patterns using very simple and easy-to-understand mathematical concepts such as the potential well model of pattern stability (e.g., visualize hills and valleys and little balls—the tops of hills are unstable points or *repellors*, and the bottoms of valleys are stable points or *attractors*). This will form a basis for understanding Scott Kelso's (and Michael Turvey's) development of the potential well model to understand complex biological movement patterns.

Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Boston, MA: MIT Press.
[Chapter 1: How nature handles complexity]
Glass, L., & Mackey, M. C. (1988). *From clocks to chaos: the rhythms of life*.
[Chapter 2: Steady states, oscillations, and chaos in physiological systems]
Davies, P. (1988). *The cosmic blueprint*. New York, NY: Simon & Schuster.
[Chapter 4: Chaos]

Liebovitch, L. S. (1998). *Fractals and chaos simplified for the life sciences*. New York, NY: Oxford University Press.

Mandelbrot, B. (1990). Fractals—a geometry of nature. *New Scientist*, 15th September, 38-43.

Goldberger, A. L., Rigney, D. R., & West, B. J. (1990). Chaos and fractals in human physiology. *Scientific American*, February, 43-49.

Session 2

Dynamical systems approach to coordination and control

In this lecture I will continue the development of Kelso's dynamical systems model of human movement. The model was developed to describe the fundamental phenomenon of self-organization—the *phase transition*. In the early 1980s, Scott Kelso discovered that as he wiggled his two index fingers (of his left and right hand) faster and faster, they spontaneously changed their pattern of coordination from same direction (different muscles activated; *anti-phase*) to opposite directions (same muscles activated; *in-phase*). After seeking theoretical advice from and working with German Prof. Hermann Haken, the theoretical physicist in Stuttgart who developed the theory of the laser (recall the incoherent-to-coherent atomic vibration phase transition in the laser), Kelso was able to show that the transition from anti-phase to in-phase wiggling of the two index fingers was strictly analogous to a physical phase transition between two patterns—one that lost stability (anti-phase) and spontaneously gave rise to another (in-phase). The subsequent paper by Haken, Kelso, and Bunz in 1995, a classic in the field, gave rise to the HKB equation. The transition may be the same as the switch from a trot to a gallop in a horse, sitting to standing in a child's development, and even, from confusion to understanding with respect to our cognitive experience.

The key notion is that these are pattern dynamics and a mathematical description is a powerful and perhaps the best way to define the phenomena. Importantly, these are *informational dynamics*—the phenomena are described at the level of wholistic patterns. Gestalt psychology was in many ways a good theory. A molecular or atomic level of analysis is simply irrelevant to capturing these kinds of phenomena. New laws are needs—the laws of pattern stability and pattern change. Haken introduced the relevant terms to describe these patterns—terms such as "order parameter: (to describe the pattern; e.g., such as in-phase or anti-phase) and "control parameter" (to refer to the state that when changed brings about a *spontaneous* change in pattern; e.g., such as rate of movement).

Such notions of pattern-based self-organisation are now well-known in the new physics. Within quantum mechanics, a level of analysis many consider difficult to apply to everyday experience, there are similar concepts that not only explain the microscopic level of analysis but, importantly, how the microscopoic is related to the macroscopic. Concepts such as David Bohm's theory of the "implicate order" which is ultimately a theory of how information interacts with and guides matter (by the so-called "quantum potential"). In this theory macroscopic states are irreducible and coherent wholes that involve principles of connection that are difficult to understand but provide considerable insight into the nature of "pattern".

The mathematical description of such physical phenomena are paradigm-shattering and should be considered carefully by all scientists purporting to have an interest in psychological matters where by "psychological" phenomena, we necessarily, mean *information-based*. From this view, psychology is the science of *how information shapes behaviour*.

Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Boston, MA: MIT Press.
[Chapter 2: Self-organization: The basic picture]
Turvey, M. T. (1990). Coordination. *American Psychologist, 45*, 938-953.
Reed, E. S. (1996). *Encountering the world: Toward an ecological psychology.* New York: Oxford.
[Chapter 4: The importance of information.]

Session 3

Asymmetry, laterality, and handedness

The functional asymmetry of the upper limbs and of the cerebral mechanisms that subserve them is well known. For most people there is a bias toward using the right hand for manual tasks, and although the two hands undoubtedly work together as a synergy, in both unimanual and bimanual tasks performance distinctions between the upper limbs can be readily observed. Although few distinctions can be stated formally in strictly quantitative terms, it is apparent that any asymmetry found in right-handed (RH) people tends to be in the opposite direction in left-handed (LH) people, although they are not simple mirror-images of each other. The degree of laterality expressed is, however, as always a function of the particular task constraints (or as Gibson called them, the *affordances*). For example, musicians who play keyboard instruments (which necessarily permit greater independence of the hands), express a greater degree of handedness than do musicians who play strings and woodwinds (which necessarily require integrated movements). Although moving the two limbs together in a 1:1 manner is easy and almost all children can do it, it is known that the hands can, with some training, learning, and/or development, produce more complex, nonisochronous rhythms such as 1:2 or 2:3. These are known as resonances and their pattern stability is related to music theory, chords, harmony, and the perception of patterns as pleasing (i.e., aesthetics; Treffner & Turvey, 1993). Performance in this case is optimal provided the preferred hand implements the faster rhythm. This requirement has been interpreted in terms of the degree of attention which can be directed at the preferred or nonpreferred hand (Amazeen, Amazeen, Treffner, & Turvey, 1997; Riley, Amazeen, Amazeen, Treffner, & Turvey, 1997).

In this lecture I will develop the HKB theory to address *asymmetrical* patterns of performance (such as due to handedness) and show how the phenomenon of attention can be addressed and incorporated in a principled way into the theoretical model.

Amazeen, E., Amazeen, P., Treffner, P. J., & Turvey, M. T. (1997). Attention and handedness in bimanual coordination dynamics. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 1552-1560.

Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Boston, MA: MIT Press.
[Chapter 3: Self-organization of behavior: First steps of generalization.]

Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Boston, MA: MIT Press.
[Chapter 4: Extending the basic picture: breaking away.]

Riley, M. A., Amazeen, E. L., Amazeen, P. G., Treffner, P. J., & Turvey, M. T. (1997). Effects of temporal scaling and attention on the asymmetric dynamics of bimanual coordination. *Motor Control, 1*, 263-283.

Treffner, P. J., & Turvey, M. T. (1993). Resonance constraints on rhythmic movement. *Journal of Experimental Psychology, 19,* 1221-1237.

Treffner, P. J., & Turvey, M. T. (1995). Handedness and the asymmetric dynamics of bimanual rhythmic coordination. *Journal of Experimental Psychology: Human Perception and Performance, 21*, 318-333.

Treffner, P. J., & Turvey, M. T. (1996). Symmetry, broken symmetry, and handedness in bimanual coordination dynamics. *Experimental Brain Research, 107*, 463-478.

Turvey, M. T., & Carello, C. (1996). Dynamics of Bernstein's level of synergies. In M. L. Latash and M. T. Turvey (Eds.), *Dexterity and its development* (pp. 339-376). Mahwah, NJ: Erlbaum.

Session 4

Dynamical systems approaches to learning and development

The HKB model can be extended to address issues of learning. Building upon material covered in the preceding lectures, I will describe and explain the work of Kelso, Zanone, and colleagues. In this research, it was shown that learning a new behavioural pattern involves creating new stable states in the dynamical system—states known as attractors. Imagine creating a new “valley” in the potential well model that describes the overall macroscopic organization of one’s neuromuscular system. When a new attractor is installed, then because of the existence of mathematical symmetries, additional new stable states and attractors will automatically be introduced. For example, it was shown that learning a 90 degrees coordination pattern between the fingers (right finger leading) automatically allowed the person to produce –90 degrees (left finger leading). (This is like a “galloping horse” sound if tapped on the table!). So the new pattern is inherited—for free—as a consequence of the mathematical patterns underlying the organization of the behaviour. The relation of learning to development will also be introduced.

Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Boston, MA: MIT Press.
[Chapter 6: Learning dynamics]

Newell, K. M. (1996). Change in movement and skill: learning, retention and transfer. In M. L. Latash and M. T. Turvey (Eds.), *Dexterity and its development* (pp. 393-429). Mahwah, NJ: Erlbaum.

Session 5: Open Public Lecture

Gestural coordination and direct perception as a foundation of communication

Paul Treffner with Dr. Mira Peter

The last decade has witnessed a dramatic rise in research investigating the common neural and functional basis for speech perception, speech production, and manual gestures. Indeed, interest is rapidly growing in the hypothesis that natural language emerged from a more primitive set of linguistic acts based primarily on manual gestures (Corballis, 2003).

Gestures emerge in children even before they start to speak and are produced by speakers from all cultural backgrounds. They are observed in speakers even when they are alone as well as in blind speakers when speaking to other blind persons. Thus, gestures seem to be tightly coupled to the speaking process. Given that gestures and speech are the foundation of human communication and that human communication is rhythmic in nature, one issue that we explored was how speech gestures are synchronized and coordinated with accompanying hand gestures.

We approach the issue of speech-hand coordination from both a dynamical systems perspective and a direct perception (i.e., ecological) perspective (Gibson, 1979/1986). Of special interest in how attention and laterality entail stability and function. Given that both speech perception and production have origins in the dynamical generative movements of the vocal tract, known as articulatory gestures, the notion of a “gesture” can be extended to both hand movements and speech articulation. The generative actions of the hands and vocal tract can therefore provide a basis for the (direct) perception of linguistic acts. Such gestures are best described using the methods of dynamical systems analysis since both perception and production can be described using the same language.

In one set of our experiments we used a phase transition paradigm to examine the coordination of speech-hand gestures in both left- and right-handed individuals. We explore coordination (in-phase vs. anti-phase), hand (left vs. right), lateralisation (left vs. right hemisphere), focus of attention (speech vs. tapping), and how dynamical constraints provide a foundation for human communicative acts (Treffner & Peter, 2002).

Results revealed that right-handers and left-handers showed striking similarities in coordination of in-phase and anti-phase speech-hand movements when using their right hand. The observed differences were mostly restricted to the left hand under anti-phase coordination. Additionally, it was observed that participants actively stabilised their speech-hand coordination patterns prior to the transition to in-phase primarily by utilising factors such as intention, attention, perceived synchrony, and laterality. The model we propose provides motivation for an asymmetric potential equation that can encompass cognitive factors in a straightforward manner and adds to increasing efforts to include aspects of psychological phenomena often assumed unapproachable from a dynamical systems perspective.

Given that our data indicate that the dynamics of coordinated speech-hand movements may play a significant role in conveying the essence of an utterance as well as clarifying the intentions of a speaker, we investigated the effect of speech-hand gesture synchronization on *perceived* meaning of a sentence. In addition, we explored the role of context on the perceived meaning given that from an ecological perspective issues of meaning must be “bound to” and “grounded” within the organism-environment context (Shaw, 2003).

We created an animated male human character who uttered the sentence: “Put the book there now.” The sentence was without any prosody [multimedia animations will be shown during presentation]. The temporal alignment of an accompanying “beat” gesture (i.e., hand in front of the chest that extends and flexes at the wrist) was modified such that it could occur at one of 23 different locations in the utterance. A table in the background was included in half the trials. There were two control conditions where no gesture was present (with and without table).

Results revealed that coordinating a hand gesture with different points in an utterance influences the perceived meaning of a sentence. Thus, hand gesture (^) may provide prospective (and retrospective) information about a speaker's intentions and thus the meaning of an utterance (e.g., "put the *bo^ok* there now" = definite perceived focus on "book"). Importantly, environmental context affects the clarity (i.e., understanding) of the perceived intentions of a speaker, such that when a perceived environmental affordance is compatible with the speaker's utterance, clarity and understanding increases (e.g., table in background + "put the book ^*there* now" = definite perceived focus on "there"). These results suggest that embodiment (gestures) and environment (affordances) are both essential for grounding language in a dynamic meaningful environment.

Corballis, M. C. (2003). *From hand to mouth*. Princeton, NJ: Princeton University Press.

Gibson, J. J. (1979/1986). *The ecological approach to visual perception*. Mahwah, NJ: Erlbaum.

Shaw, R. E. (2003). The agent-environment interface: Simon's indirect or Gibson's direct coupling? *Ecological Psychology, 15*, 37-106.

Treffner, P. J., & Peter, M. (2002). Intentional and attentional dynamics of speech hand coordination. *Human Movement Science, 21,* 641-697.

Session 6

Dynamical systems approaches to learning and development

In this lecture I will provide my perspective on the relation between dynamical systems approaches to learning and the theory of development as outlined by Esther Thelen and colleagues. Clearly much is to be learned form the self-organization paradigm when asking questions about the "causes" of development—or more generally—of pattern emergence and pattern change. The self-organization approach clearly questions assumptions that material causes lead to pattern emergence. *It is not all in the genes!* It can not be the case. Worse, it is even more confounding as self-organization theory shows that pattern change is a macroscopic phenomenon. It can not be *reduced* to material substance. If anything, genes must act as just another constraint, and is probably best characterised as shaping the overall informational constraint on the material substructure of molecules and atoms.

As James Gibson is responsible for showing, psychological phenomena (both explicit behavioural patterns and implicit experience) must fundamentally require an *information-based* (not sensation-based) explanation. Just as my perception of a chair can not simply be *in* my head (for then how explain the phenomenological experience of the chair as *out* there, not in here?), so too the explanation of overt patterns of behaviour can not simply be due to the stuff *in* there (the genes). It is, surely, an ecology (Gibson), a synergy (Haken), a Gestalt (Koffka), a coalition (Shaw & Turvey), a communion (Buddhism)—a deep and inextricable interaction between organism and environment (if such a distinction is accepted, for reasons of scientific analysis). We may not yet fully understand development and learning as it is perhaps the "holy grail" for behavioural science, but we must at least try and get the framework and paradigm correct within which to start a search for an answer to the mysteries of growth, development, and (goal-directed) change.

Thelen, E. (1995). Motor development: A new synthesis. *American Psychologist, 50,* 79-95.
Thelen, E. & Smith, L. B. (1995). *A dynamical systems approach to the development of cognition and action.*

Session 7

Direct perception and locomotion

In this lecture I will describe recent research we have conducted into the role of ecological information in the control of driving and locomotion. James Gibson was the first psychologist to say anything sensible about locomotion and indeed Gibson and Crooks (1938) still reveals ideas that are not clearly understood today but seem to make much good sense (Warren, 1998). Ideas such as the "field of safe travel" around a car and driver that effectively protects them—in a *functional* sense—from colliding with other vehicles. The field, perhaps although originally based on loose intuitions related to Einsteinian fields in physics, is clearly well conceived today as a Gibsonian perceptual field that specifies affordances—a medium consisting of a structured energy field that has different intensities in different directions. This is another *macroscopic* concept that is an attempt to show that macroscopic patterns of behaviour have a commensurate or corollary description in macroscopic patterns of light in the case of visual perception (or sound in the case of audition). The ecological approach to perception and action is about showing that perception-action is a function of an organism-environment interaction based on macroscopic patterns of energy distributions (e.g., light) (Turvey, Carello, & Kim, 1990). Most importantly, the psychological concept of meaning is explained in a Gibsonian framework by realising that information specifies or "points to" *affordances*. Affordances are the meaningful properties of the environment that potentially afford actions to the organism. Gibson had to invent a term such as affordance to capture the fact that perception is inherently meaningful in the same way that an organism is inherently a part of an environment. This is a Darwinian notion and Gibson based his ideas strongly on Darwin's theory of natural selection. So too have neo-Gibsonians (e.g., Reed, 1996). As Gibson said, perception is *not based on sensations* although sensations are a mere side effect of the process. Rather, perception (and action) is *based on information*. It was Gibson's genius, far ahead of his time, to see this and to conduct experiments that showed that the resultant behaviour could not be reduced and explained by "parts"—it was the *whole pattern* of light that mattered (he worked with the Gestalt psychologist Koffka in the US for a few years but extended Gestalt notions of the causes inside the brain to encompass causes in the environment).

I will also describe our research into locomotion using virtual reality. At the Complex Active Visualisation (CAV) lab at Griffith University in Australia, we have a treadmill set up in front of large 2.5 m x 5 m screens. We can create virtual walking (or running) experiments. I will show that safe driving and locomotion is based on *stability*—just as a dynamical systems account of behaviour is based on an understanding of the creation of functionally stable states (Treffner & Kelso, 1999). By increasing postural stability in the car (e.g., by bracing a knee against a door and foot against footrest) one's perceptual sensitivity increases and so control is improved (Treffner, Barrett, & Petersen, 2002). I will also discuss classic issues such as time-to-contact (the "tau" variable) and how one can perceive the timing of events directly—as Gibson long ago intuited—and so control one's actions in a *direct* manner. For example, one can *see* the future when driving a car and can *see* when to begin to apply the brake for a gentle deceleration so as to avoid a crash—it is a function of current optical expansion patterns (not thoughts or concepts). Driving is a *perceptual* process not a conceptual one. That's why it is not good to think too much while driving. Our experiments on hands-free mobile phones show that engaging in a conversation is very bad for the control of driving as it compromises one's attention to the perceptual information for control (Treffner & Barrett, 2004). Perception and action are intimately coupled—it is the concept of "perception-action" that we, as ecological psychologists, are trying to understand.

Gibson, J. J., & Crooks, L. E. (1938). A theoretical field-analysis of automobile driving. *American Journal of Psychology, 51,* 453-471.

Reed, E. S. (1996). *Encountering the world: Toward an ecological psychology.* New York: Oxford. [Chapter 1: Regulation versus construction.]

[Chapter 3: Affordances.]

Turvey, M. T., Carello, C., & Kim, N.-G. (1990). Links between active perception and the control of action. In H. Haken and M. Stadler (Eds.), *Synergetics of cognition* (pp. 269-295). Berlin: Springer.

Treffner, P. J., & Barrett, R. (2004). Hands-free mobile phone speech while driving degrades coordination and control. *Transportation Research, Part F: Traffic Psychology and Behaviour, 7,* 229-246.

Treffner, P. J., & Kelso, J. A. S. (1999). Dynamic encounters: Long-memory during functional stabilization. *Ecological Psychology, 11,* 103-137.

Treffner, P. J., Barrett, R., & Petersen, A. J. (2002). Stability and skill in driving. *Human Movement Science, 21*, 749-784.

Warren, W. H. (1998). Visually controlled locomotion: 40 years later. Special issue of *Ecological Psychology, 10,* 177-219.