

This article was downloaded by: [University of Connecticut]

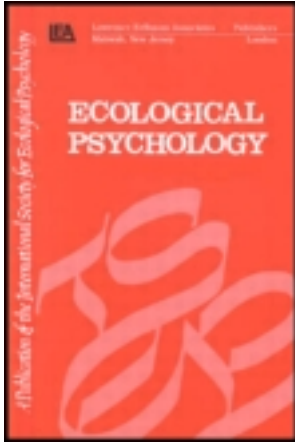
On: 09 August 2013, At: 16:16

Publisher: Routledge

Informa Ltd Registered in England and Wales Registered Number: 1072954

Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

1737



Ecological Psychology

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/heco20>

The Surprising Nature of the Reaction Time Task

Michael T. Turvey^a & Claudia Carello^b

^a Center for the Ecological Study of Perception and Action University of Connecticut Haskins Laboratories

^b Center for the Ecological Study of Perception and Action University of Connecticut

Published online: 26 Jul 2013.

To cite this article: Michael T. Turvey & Claudia Carello (2013) The Surprising Nature of the Reaction Time Task, *Ecological Psychology*, 25:3, 226-232, DOI:

[10.1080/10407413.2013.810483](https://doi.org/10.1080/10407413.2013.810483)

To link to this article: <http://dx.doi.org/10.1080/10407413.2013.810483>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

The Surprising Nature of the Reaction Time Task

Michael T. Turvey

*Center for the Ecological Study of Perception and Action
University of Connecticut
Haskins Laboratories*

Claudia Carello

*Center for the Ecological Study of Perception and Action
University of Connecticut*

At one level, the scientific enterprise engaged in by Guy Van Orden was about how to analyze reaction time data. At another level it was an attempt to understand the kind of system that one is dealing with in a reaction time (RT) experiment—the system that accords with the instructions that the experimenter gives, produces the responses to the particular class of stimuli that the experimenter presents, at latencies that the experimenter measures and analyzes. That there can be any question about the essential nature of the system under study is perhaps surprising given the long and influential history of RT research and the relative simplicity and transparency of the RT task. In this brief note we hope to show that the question is deserved and that on close inspection the nature of the RT task is, indeed, surprising.

THE SURPRISING NATURE OF THE REACTION TIME TASK

Conventional wisdom holds that the performance of a reaction time (RT) task comprises a sequence of events bridging stimulus and response, with the princi-

Correspondence should be addressed to Michael T. Turvey, Center for the Ecological Study of Perception and Action, U-1020, 406 Babbidge Road, University of Connecticut, Storrs, CT 06269.
E-mail: michael.turvey@uconn.edu

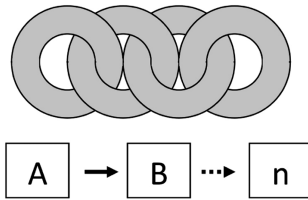
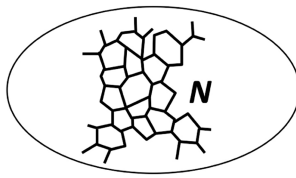
pal events being those in the brain. These two convictions readily constrain the identification of the system under study.¹ The sequence starts with a “stimulus” (e.g., a flash of light, a brief tone, a string of letters) describable in conventional physical terms and ends in a “response” (e.g., a key press) describable in conventional physical terms. Mediating the stimulus and the response is a series of physical events of different kinds (e.g., electromechanical, electrochemical) at the start and finish and mental events of different grades (e.g., sensations, inferences) sandwiched between them and entailing different areas of the brain (e.g., visual cortex, motor cortex).

It is the case, however, that several strands of contemporary psychology are inclined toward a rethinking of RT and the system to which it refers (Järvillehto, 1998). The strands in question are those that promote a broadening of the basis for theorizing about cognition, strands such as “situated cognition” (e.g., Clancey, 1997); “embedded, embodied cognition” (e.g., Beer, 2006; Clark, 1999; Gibbs, 2005; Pfeifer & Scheier, 2001); “ecological psychology” (e.g., Gibson, 1979/1986; Michaels & Carello, 1981; Richardson, Shockley, Riley, Fajen, & Turvey, 2006; Turvey & Shaw, 1995, 1999); “dynamical systems theory” (e.g., Kelso, 1995; Thelen & Smith, 1994); “probabilistic epigenesis” (e.g., Gottlieb, 1997); and “enactive psychology” (e.g., Varela, Thompson, & Rosch, 1991). For the preceding orientations to cognition and its science, the identity of the system under study in the RT task is not so obvious.

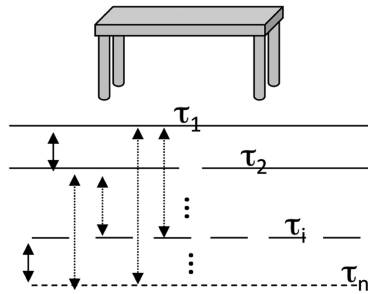
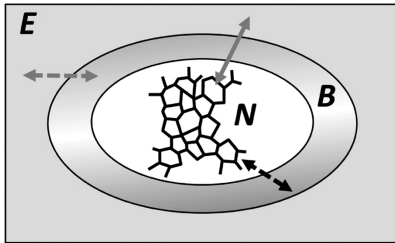
Figure 1a schematizes the historical perspective on the RT task: it is primarily a matter of processes within the central nervous system, interpretable as a causal lineage. Figure 1b schematizes a possible alternative perspective on the RT task: it is a matter of processes within the participant-environment system, interpretable as a causal organization (cf. Turvey, 2004; Turvey & Moreno, 2006). A *chain* metaphor is at work in Figure 1a (each causal component is like a link in a chain); a *support* metaphor is at work in Figure 1b (each causal influence is like a leg of a table).

In a nontrivial sense, the historical perspective confines system identification to the temporal course of an individual trial. The only processes admitted into system identification are those that could possibly occur within the single-trial timescale and then only those processes that occur within the nervous system. In contrast, the alternative perspective anchors system identification (minimally) to the temporal course of the experimental session. The processes admitted into

¹*System identification* is a technical term referring to an ideally formal process by which a dynamical model (linear or nonlinear) is crafted for a phenomenon of interest on the basis of available measures. Here, the phenomenon of interest is performance in the RT task. Van Orden’s argument was that the required dynamical model is not attainable by measures that fail to incorporate (explicitly or implicitly) the multiple tasks and time scales that embed the individual occurrences of expeditious responding to a presented stimulus item (e.g., Van Orden, Holden, & Turvey, 2005; Van Orden, Hollis, & Wallot, 2012; Wijnants, Cox, Hasselman, Bosman, & Van Orden, 2012).



(a)

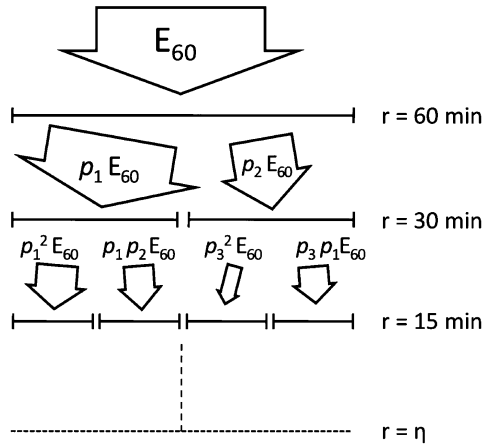


(b)

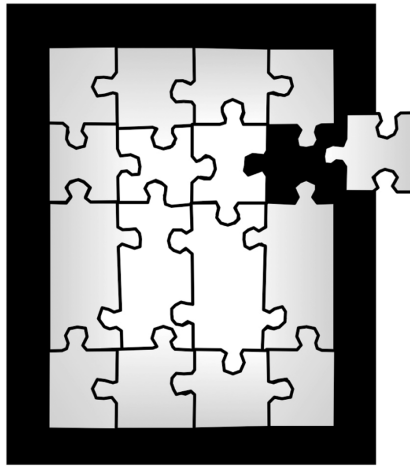
FIGURE 1 (a) An isolated nervous system that suggests the causal view of component processes as links in a chain. (b) An embodied, embedded nervous system that suggests the supportive view of mutually interacting processes at different timescales with (c) a multifractal experimental analog. (d) A developing organization of an event such as an experimental trial is completed by the arrival of the target. Figure 1c adapted from Figure 3 of Meneveau and Sreenivasan (1987) with permission. *(continued)*

identifying the system in question are those that can be postulated at timescales that are nested within, and inclusive of, the timescale from the start to the end of the experiment. They are processes that do not necessarily abide the putative boundaries of brain, body, and environment and do not necessarily affect the individual RT directly.

In terms of the timescales of human actions identified by Allen Newell (1990) in *Unified Theories of Cognition*, an RT experiment of an hour or more would span processes over seven orders of magnitude, from 10^{-2} to 10^4 s, encompassing bands of biological activity (upper bound of 10 ms), cognitive activity (upper bound of 10 s), and rational activity (upper bound of many hours). Relating slower and faster timescales presents a major challenge for a comprehensive account of cognitive performance (Anderson, 2002). Figure 1b identifies the relation as one of mutual interactions. Faster processes affect slower



(c)



(d)

FIGURE 1 (Continued).

processes and slower processes affect faster processes. Such interdependence of long and short timescales characterizes self-organizing complex systems (Haken, 2004). Figure 1c could be taken as a minimal multifractal perspective (see Kelty-Stephen, Palatinus, Saltzman, & Dixon, 2013) on an RT experiment of 60 min

duration equivalent, say, to 300 responses per participant. The total sample of RTs is iteratively split at each successive level into two samples of nonequal proportions p_1 and p_2 (with all samples at a level summing to 1.0) until a limiting interval (η) is reached. When formalized, Figure 1c is consistent with the interactivity of Figure 1b. The sample proportions at each of Figure 1c's cascading levels reflect the succession of multiplicatively interacting random perturbations across Figure 1b's scales (Kelty-Stephen et al., 2013).

Elaborating the rational band in Newell's (1990) scheme aids our understanding of the relation of timescales and gives insight into how RT variability might be conveyed over the course of an experimental session. At this band of timescales (from 10 s to hours), the appropriate descriptor is *task*. Processes within the biological and cognitive bands are so composed (or constrained) as to fit (or realize) this or that task structure. For the RT experimental session, task structures include "keep the right hand with index finger lightly on the response key ready to respond" and "keep the eyes focused on the screen so as to see the stimulus when it occurs." Other such tasks with longer or shorter timescales can be easily imagined and readily understood as nested and mutually interactive in the manner depicted in Figure 1b. The interdependence of timescales means that trial-to-trial fluctuations in RT and, perforce, in activities at 10^{-2} to 10^1 s, would be felt by the rational band. Indeed, if a particular relation, a so-called scaling or allometric relation (West, 2006), constrained the mutual interactions, and if the timescale of one or more rational processes approximated the experimental session, then the statistics of rational band fluctuations and RT fluctuations would be closely similar.

Of special interest are the task structures of the rational band when RT is employed in the form of lexical decision or rapid naming. For lexical decision, the task structure is "respond to a letter string on the screen by pressing the *yes* key if it is a recognizable word and the *no* key if it is not." The experimental participant qua language processor is a system of considerable detail that ordinarily analyzes and produces, online, multiple embeddings of linguistic structures of different grains. The task structures of lexical decision RT and rapid naming RT are *alternative descriptions* (Pattee, 1970, 1972, 1973) of the complexity of the language processor. These alternative (simpler) descriptions make explicit some small part of the detailed processing that is implicit in ordinary sentence comprehension.

Evidently, these alternative descriptions, these language-related task structures of the rational band, must be in place and organized together with related task structures and the relevant compositions of processes of the neural and cognitive bands for one to respond quickly with a letter string's lexical status or pronunciation. Only this organization of causal support across multiple interacting timescales makes the required result possible. When a letter string is presented, it completes an organization that preceded it, much as the final piece of the

jigsaw puzzle shown in Figure 1d completes the picture. The letter string closes a system, the whole activity of which results, after a brief interval of time, in a lexical decision or name (Järvilehto, 1998).

It is worth noting that a broader take on the interrelatedness of timescales can be found in the homeokinetic notion of the *behavior modes* that constitute an organism's "factory day" (Bloch et al., 1971; Iberall & McCulloch, 1969; Iberall & Soodak, 1987). These manifestations of metabolic and physiological processes (expressed in activities such as eating, drinking, voiding, sleeping, posture-shifting, etc.) distribute ergodically throughout the day. The "thermodynamic 'engine' cycles" (Bloch et al., 1971) that operate in the functional factory day of an experimental session—Van Orden's explanatory target (e.g., Holden, Van Orden, Turvey, 2009; Wijnants et al., 2012)—demand that certain modal activities have to be repeated with their characteristic frequency.

In summary, Guy Van Orden sought and provided evidence that panels b, c, and d of Figure 1, rather than panel a, identify the system under study in linguistic RT experiments. He hoped that such evidence would invite new lines of research and theory directed at the conditions and organizations implied in those figures. He believed that such evidence would, on a longer timescale, revolutionize the content and conduct of cognitive science.

REFERENCES

- Anderson, J. R. (2002). Spanning seven orders of magnitude: A challenge for cognitive modeling. *Cognitive Science*, 25, 85–112.
- Beer, R. (2006). Dynamics of brain-body-environment systems: A status report. In P. Calvo & T. Gomila (Eds.), *Elsevier handbook of new directions in cognitive science (Section I: The embodied architecture of cognition. Conceptual issues)*, pp. 99–120. Amsterdam, The Netherlands: Elsevier.
- Bloch, E., Cardon, S., Iberall, A., Jacobowitz, D., Kornacker, K., Lipetz, L., . . . Yates, F. E. (1971). *Introduction to a biological systems science* (NASA Contractors Report, CR-1720). NASA: Washington, DC.
- Clancey, W. J. (1997). *Situated cognition: On human knowledge and computer representations*. Cambridge, UK: Cambridge University Press.
- Clark, A. (1999). *Being there: Putting brain, body, and world together again*. Cambridge, MA: MIT Press.
- Gibbs, R. W. (2005). *Embodiment and cognitive science*. Cambridge, UK: Cambridge University Press.
- Gibson, J. J. (1986). *The ecological approach to visual perception*. Hillsdale, NJ: Erlbaum. (Original work published 1979)
- Gottlieb, G. (1997). *Synthesizing nature-nurture: Prenatal roots of instinctive behavior*. Mahwah, NJ: Erlbaum.
- Haken, H. (2004). *Synergetics: Introduction and advanced topics*. Berlin, Germany: Springer-Verlag.
- Holden, J., Van Orden, G., & Turvey, M. T. (2009). Dispersion of response times reveals cognitive dynamics. *Psychological Review*, 116, 318–342.
- Iberall, A., & Soodak, H. (1987). A physics for complex systems. In F. E. Yates (Ed.), *Self-organizing systems: The emergence of order* (pp. 499–520). New York, NY: Plenum Press.

- Iberall, A. S., & McCulloch W. S. (1969). The organizing principle of complex living systems. *Journal of Basic Engineering, ASME, 91*, 290–294.
- Järvillehto, T. (1998). The theory of the organism-environment system: I. Description of the theory. *Integrative Physiological and Behavioral Science, 33*, 321–334.
- Kelso, J. A. S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Cambridge, MA: MIT Press.
- Kelty-Stephen, D., Palatinus, K., Saltzman, E., & Dixon, J. (2013). A tutorial on multifractality, cascades, and interactivity for empirical time series in ecological science. *Ecological Psychology, 25*, 1–62.
- Meneveau, C., & Sreenivasan, K. R. (1987). Simple multifractal cascade model for fully developed turbulence. *Physical Review Letters, 59*, 1424–1427.
- Michaels, C. F., & Carello, C. (1981). *Direct perception*. Englewood Cliffs, NJ: Prentice-Hall.
- Newell, A. (1990). *Unified theories of cognition*. Cambridge, MA: Harvard University Press.
- Pattee, H. H. (1970). The problem of biological hierarchy. In C. H. Waddington (Ed.), *Towards a theoretical biology 3* (pp. 117–136). Chicago, IL: Aldine-Atherton.
- Pattee, H. H. (1972). Laws and constraints, symbols and languages. In C. H. Waddington (Ed.), *Towards a theoretical biology 4* (pp. 248–258). Chicago, IL: Aldine-Atherton.
- Pattee, H. H. (1973). The physical basis and origin of hierarchical control. In H. H. Pattee (Ed.), *Hierarchy theory: The challenge of complex systems* (pp. 73–108). New York, NY: Braziller.
- Pfeifer, R., & Scheier, C. (2001). *Understanding intelligence*. Cambridge, MA: MIT Press.
- Richardson, M. J., Shockley, K., Riley, M. R., Fajen, B. R., & Turvey, M. T. (2006). Ecological psychology: Six principles for an embodied-embedded approach to behavior. In P. Calvo & T. Gomila (Eds.), *Elsevier handbook of new directions in cognitive science (Section I: The embodied architecture of cognition. Conceptual issues)*, pp. 161–187). Amsterdam, The Netherlands: Elsevier.
- Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: Bradford Books/MIT Press.
- Turvey, M. T. (2004). Impredicativity, dynamics, and the perception-action divide. In V. K. Jirsa & J. A. S. Kelso (Eds.), *Coordination dynamics: Issues and trends. Vol. 1. Applied complex systems* (pp. 1–20). New York, NY: Springer-Verlag.
- Turvey, M. T., & Moreno, M. (2006). Physical metaphors for the mental lexicon. *The Mental Lexicon, 1*, 7–33.
- Turvey, M. T., & Shaw, R. E. (1995). Toward an ecological physics and a physical psychology. In R. Solso & D. Massaro (Eds.), *The science of the mind: 2001 and beyond* (pp. 144–169). Oxford, UK: Oxford University Press.
- Turvey, M. T., & Shaw, R. E. (1999). Ecological foundations of cognition: I. Symmetry and specificity of animal-environment systems. *Journal of Consciousness Studies, 6*, 95–110.
- Van Orden, G., Holden, J., & Turvey, M. T. (2005). Human cognition and $1/f$ scaling. *Journal of Experimental Psychology: General, 134*, 117–123.
- Van Orden, G., Hollis, G., & Wallot, S. (2012). The blue-collar brain. *Frontiers in Physiology, 3*(article 207), 1–12.
- Varela, F. J., Thompson, E., & Rosch, E. (1991). *The embodied mind*. Cambridge, MA: MIT Press.
- West, B. J. (2006). Control from an allometric perspective. In D. Sternad (Ed.), *Progress in motor control: A multidisciplinary perspective* (pp. 57–82). New York, NY: Springer-Verlag.
- Wijnants, M. L., Cox, R. F. A., Hasselman, F., Bosman, A. M. T., & Van Orden, G. (2012). A trade-off study revealing nested time scales of constraint. *Frontiers in Physiology, 3*(article 116), 1–15.