

**CLPS 1500 Ecological Approach to Perception and Action**  
**Fall, 2012-13**  
**Prof. William Warren**

- Course Website:** <https://canvas.brown.edu/courses/755816>  
(Unregistered students have access through shopping period)
- Class:** Tu, Th 2:30-3:50  
Metcalf 105
- Office Hours:** Wed. 1:00-2:00 (or by appointment), x3980  
Metcalf 257
- Required Text:** Gibson, J.J. (1979) *The ecological approach to visual perception*. Boston: Houghton Mifflin.
- Rec. Texts:** Kelso, J.A.S. (1995) *Dynamic patterns: The self-organization of brain and behavior*, Cambridge, MA: MIT Press.  
Camazine, et al. (2001) *Self-organization in biological systems*. Princeton University Press.

**Course Requirements**

This is a seminar that combines discussion and lecture. The first 20-30 min of each class will be reserved for discussion of the topic I introduced in the previous class. We are all grown-ups, and I expect you to take responsibility for your part in the course:

- 1. Do the reading.** The *Reading* is required – do the reading after the introductory lecture and before the next class, and come prepared to discuss it. *Going further* is optional reading, useful for background or term papers.
- 2. Daily blog post.** Post one written question or comment about each reading by 12:00 noon the day of the discussion, and bring it to class. Click link on Assignments page.
- 3. Report & Debates.** You will present a 10-min report on a journal article to the rest of the class. We will also have two official debates, complete with teams.
- 4. Short essays.** There will be four 3-page essay papers on specified topics, which must be uploaded by midnight of the day the paper is due.
- 5. Term paper.** There will be a 10-page term paper on a topic of your choice derived from the course, due at the end of the semester.

**Grading:** Essays 10% each, term paper 30%, report 10%, daily blog 5%, discussion 5%, debates 5% each.

**WARNING:** Academic dishonesty such as plagiarism, copying material from the web, or submitting work that is not your own is a serious offence, and can result in an NC for the course or dismissal from Brown. Read the Academic Code and follow these guidelines:

- Cutting and pasting from websites is plagiarism. Wikipedia etc. may be useful to get oriented to a topic and find relevant articles, but *they are not valid sources*.
- Word-for-word quotation from any source **MUST** be in quotation marks and the source must be cited in the text. *Do not copy other people's work*.
- Paraphrasing or summarizing the contents of another work is OK, but the source must be cited in the text. *Credit other people for their ideas*.
- *All sources used in writing an essay must be cited in the text and listed in a References section at the end of the paper.*

## Part I. The Controversy

### Sept. 6 Indirect perception 1: The constructivist tradition

*Background reading for first class:*

Gibson (1979) Introduction & Ch. 1. (Scan Ch. 2 & 3).

### Sept. 11 Indirect perception 2: Computational approaches

*Reading for discussion of "The constructivist tradition":*

Proffitt, D. (1999) Inferential vs. ecological approaches to perception. In R.J. Sternberg (Ed.), *The nature of cognition*.

Rock, I. (1983) *The logic of perception*. Ch. 1 & 2 (p. 28-40).

*Going further:*

Gregory, R.L. (1980) Perceptions as hypotheses. *Philosophical Transactions of the Royal Society of London, B*, 290, 181-197.

Palmer, S.E. (1999) *Vision science: Photons to phenomenology*, Ch. 1 and 2. MIT Press.

### Sept. 13 Direct perception

*Reading for discussion of "Computational approaches":*

Johnson-Laird, P. (1988) *The computer and the mind*. p. 57-80, 103-120.

Searle, J. (1990) Is the brain's mind a computer program? *Scientific American*, 262(1), 26-31.

Knill, D.C., Kersten, D., & Yuille, A. (1996) A Bayesian formulation of visual perception. In Knill, D. & Richards, W. (Eds.) *Perception as Bayesian inference*, p. 1-21.

*Going further:*

Chemero, A. (2009) Theories of representation. Ch. 3 of *Radical embodied cognitive science*. Cambridge: MIT Press.

Searle JR (1980) Minds, brains, and programs. *Behavioral and Brain Sciences*, 3, 417-457.

Marr, D. (1980) Visual information processing: The structure and creation of visual representations. *Phil Trans of the Royal Society of London B*, 290, 199-218.

Kersten, D. & Yuille, A. (2003) Bayesian models of object perception. *Current Opinion in Neurobiology*, 13, 150-158.

Ernst, M. & Banks, M. (2002) Humans integrate visual and haptic information in a statistically optimal fashion. *Nature*, 415, 429-433.

Tassinari, Domini, & Caudek (2008) The intrinsic constraint model for stereo-motion integration. *Perception*, 37, 79-95.

## Part II. Perceiving the Environment

[Sept. 17 Mon. 1:00 Talk: John Jeka, "The many roles of vision during locomotion," Metcalf]

### Sept. 18 Information 1: Ecological optics

*Report:*

Geisler, W.S., Perry, J.S., Super, B.J., & Gallogly, D.P. (2001) Edge co-occurrence in natural images predicts contour grouping performance. *Vision Research*, 41, 711-724.

*Reading for discussion of "Direct perception":*

Gibson (1959) Perception as a function of stimulation. In S. Koch (Ed.), *Psychology: A study of a science, v. I*, pp. 456-473 only.

Warren, W.H. (2005) Direct perception: The view from here. *Philosophical Topics*, 33, 335-361.

Going further:

Shaw, R. E., Turvey, M. T., & Mace, W. M. (1981). Ecological psychology: The consequence of a commitment to realism. In W. Weimer & D. Palermo (Eds.), *Cognition and the symbolic processes, II* (pp. 159-226). Hillsdale, NJ: Erlbaum.

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

Huemer, M. (2001) *Skepticism and the veil of perception*. Lanham, MD: Rowman and Littlefield.

## Sept. 20 Information 2: Sensory ecology

**ESSAY 1 DUE** - upload PDF file to the course website by 11:59 pm

Reports:

Carew, T.J. (2000) Echolocation in bats. *Behavioral Neurobiology*, Ch. 2, p. 35-58.

Von der Emde, G. (1999) Active electrolocation of objects in weakly electric fish. *Journal of Experimental Biology*, 202, 1205-1215.

Reading for discussion of "Ecological optics":

Gibson (1979) Ch. 4 & 5

Going further:

Sedgwick, H. A. (1986) Space perception. In K.R. Boff, L. Kaufman, & J.P. Thomas (Eds.) *Handbook of perception and human performance*. New York: Wiley, p. 21.1-21.57.

## Sept. 25 Perception of layout: Air theory vs. Ground theory

Reading for discussion of "Sensory ecology":

Mandik, P. & Clark, A. (2002) Selective representing and world-making. *Minds and Machines*, 12, 383-395.

Chemero, A. (1998) A stroll through the worlds of animats and humans: Review of *Being there* by Andy Clark. *Psyche*, 4, 1-10 (esp. p. 5-7).

Going further:

Au, W.W.L. & Simmons, J.A. (2007) Echolocation in dolphins and bats. *Physics Today* (Sept.), 40-45.

von Uexküll, J. (1934) A stroll through the worlds of animals and men. In K. Lashley (Ed.), *Instinctive Behavior*, New York: International Press.

Varela, F., Thompson, E., & Rosch, E. (1991). *The embodied mind*, Ch. 3, 5, 7-9. Cambridge, MA: MIT Press.

Chemero, A. (2007) Toward a situated, embodied realism. *Cognition and Behavior*

## Sept. 27 Perception of shape 1: Euclidean structure

Report:

Sinai, M.J., Ooi, T.L., & He, Z. (1998) Terrain influences the accurate judgment of distance. *Nature*, 395, 497-500.

Ooi, T.L., Wu, B., & He, Z.J. (2001) Distance determined by the angular declination below the horizon. *Nature*, 414, 197-200.

Reading for discussion of "Perception of layout":

Gibson (1979) Ch. 9

Loomis, J.M., da Silva, J.A., Philbeck, J.W., & Fukusima, S.S. (1996) Visual perception of location and distance. *Current Directions in Psychological Science*, 3, 72-77.

Going further:

Loomis, J.M. & Philbeck, J.W. (2008) Measuring spatial perception with spatial updating and action. In R. Klatzky, B. MacWhinney, & M. Behrmann (Eds.), *Embodiment, ego-space, and action*. New York: Psychology Press, 1-43.

## Oct. 2 Perception of shape 2: Affine structure

*Report:*

Todd, J.T. & Perotti, V.J. (1999) The visual perception of surface orientation from optical motion. *Perception & Psychophysics*, 61, 1577-1589.

*Reading for discussion of "Shape 1: Euclidean structure":*

Gibson (1979) Ch. 10 & 11

*Going further:*

Warren, W.H. (2012) Does this computational theory solve the right problem? Marr, Gibson, and the goal of vision. *Perception*, in press.

Ullman, S. (1979) The interpretation of structure from motion. *Proceedings of the Royal Society of London, B*, 203, 405-426.

Braunstein, M.L., Litter, J.C., & Tittle, J.S. (1993) Recovering three-dimensional shape from perspective transformations and orthographic rotations. *Journal of Experimental Psychology: Human Perception and Performance*, 19, 598-614.

Norman, J.F., Todd, J.T., Perotti, V.J., & Tittle, J.S. (1996) The visual perception of three-dimensional length. *Journal of Experimental Psychology: Human Perception and Performance*, 22, 173-186.

## Oct. 4 Perception of shape 3: Topological structure

*Reading for discussion of "Shape 2: Affine structure":*

Todd, J.T. (2004) The visual perception of 3D shape. *Trends in Cognitive Sciences*, 8, 115-121.

Tittle, J.S., Todd, J.T., Perotti, V.J., & Norman, J.F. (1995) Systematic distortion of perceived three-dimensional structure from motion and binocular stereopsis. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 663-678.

*Going further:*

Todd, J.T. & Bressan, P. (1990) The perception of 3-dimensional affine structure from minimal apparent motion sequences. *Perception & Psychophysics*, 48, 419-430.

Domini, F. & Caudek, C. (2003) 3-D structure perceived from dynamic information: A new theory. *Trends in Cognitive Sciences*, 7, 444-449.

Koenderink, J.J., van Doorn, A.J., Kappers, A.M.L., & Todd, J.T. (2001) Ambiguity and the 'mental eye' in pictorial relief. *Perception*, 30, 431-448.

## Part III. Visual Control of Action

### Oct. 9 Affordances

*Reading for discussion of "Shape 3: Topological structure":*

Phillips, F., Todd, J.T., Koenderink, J.J., & Kappers, A.M.L. (2003) Perceptual representation of visible surfaces. *Perception & Psychophysics*, 65, 747-762.

Fleming, R.W., Torralba, A., & Adelson, E.H. (2004) Specular reflections and the perception of shape. *Journal of Vision*, 4, 798-820.

*Going further:*

- Lappin, J.S., Norman, J.F., & Phillips, F. (2011) Fechner, information, and shape perception. *Attention, Perception & Psychophysics*, 73, 2353-2378.
- Koenderink, J. J., & van Doorn, A. J. (1995) Relief: Pictorial and otherwise. *Image and Vision Computing*, 13, 321-334.
- Perotti, V.J., Todd, J.T., Lappin, J.S., & Phillips, F. (1998) The perception of surface curvature from optical motion. *Perception & Psychophysics*, 60, 377-388.
- Todd, J.T., Thaler, L., Dijkstra, T.M.H., Koenderink, J.J., & Kappers, A.M.L. (2007) The effects of viewing angle, camera angle, and sign of curvature on the perception of three-dimensional shape from texture. *Journal of Vision*, 7, 1-16.

### Oct. 11 Embodied perception

#### Reports:

- Proffitt, D. R., Stefanucci, J., Banton, T., & Epstein, W. (2003). The role of effort in distance perception. *Psychological Science*, 14, 106-113.
- Witt, J. K., Linkenauger, S. A., Bakdash, J. Z., & Proffitt, D. R. (2008). Putting to a bigger hole: Golf performance relates to perceived size. *Psychonomic Bulletin and Review*, 15, 581-585.

#### Reading for discussion of "Affordances":

- Gibson, Ch. 8.
- Warren, W. (1984) Perceiving affordances: Visual guidance of stair climbing. *Journal of Experimental Psychology: Human Perception and Performance*, 10, 683-703.

#### Going further:

- Warren, W. H., & Whang, S. (1987). Visual guidance of walking through apertures: Body scaled information for affordances. *Journal of Experimental Psychology: Human Perception and Performance*, 13, 371-383.
- Mark, L. S. (1987). Eyeheight-scaled information about affordances: A study of sitting and stair climbing. *Journal of Experimental Psychology: Human Perception and Performance*, 13, 360-370.
- Stoffregen, T.A., Yang, C.-M., Giveans, M.R., Flanagan, M., & Bardy, B.G. (2009) Movement in the perception of an affordance for wheelchair locomotion. *Ecological Psychology*, 21, 1-36.
- Turvey, M.T. (1992) Affordances and prospective control: An outline of the ontology. *Ecological Psychology*, 4, 173-187.
- Chemero, A. (2003) An outline of a theory of affordances. *Ecological Psychology*, 15, 181-195.

### Oct. 16 Time-to-contact: The *tau* variable

#### Report:

- Lee, D. & Reddish, P. (1981) Plummeting gannets: A paradigm of ecological optics. *Nature*, 293, 293-294.

#### Reading for discussion of "Embodied perception":

- Proffitt, D. (2006) Embodied perception and the economy of action. *Perspectives on Psychological Science*, 1, 110-122.
- Firestone, C. (2011) Against 'visual paternalism'. *Society for Philosophy and Psychology*, 1-10.
- Witt, J. K., & Riley, M. (2012). Getting in touch with your inner Gibson: Reconciling action-specific and ecological approaches. Submitted for publication, 1-15.

#### Going further:

- Noe, A. (2006) *Action in Perception*, Ch. 1-3. MIT Press.

- Witt, J. K., Proffitt, D.R., & Epstein, W. (2005). Tool use affects perceived distance but only when you intend to use it. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 880-888.
- Durgin, F. H., Baird, J. A., Greenburg, M., Russell, R., Shaughnessy, K., & Waymouth, S. (2009). Who is being deceived? The experimental demands of wearing a backpack. *Psychonomic Bulletin and Review*, 16, 964-969.
- Woods, A.J., Philbeck, J.W., & Danoff, J.V. (2009) The various perceptions of distance: An alternative view of how effort affects distance judgments. *Journal of Experimental Psychology: Human Perception and Performance*, 35, 1104-1117.
- Witt, J. K., Proffitt, D. R., & Epstein, W. (2010). How and when does action scale perception? *Journal of Experimental Psychology: Human Perception and Performance*, 36, 1153-1160.

### Oct. 18 On mechanism and learning

ESSAY 2 DUE - upload PDF file to the course website by 11:59 pm

Report:

Wang, Y. & Frost, B.J. (1992) Time to collision is signaled by neurons in the nucleus rotundus of pigeons. *Nature*, 356, 236-238.

Reading for discussion of "Time-to-contact":

Lee, D. (1980) Visuo-motor coordination in space-time. Reprinted in G.J. Pepping & M.L. Grealy (Eds.) (2007), *Closing the gap: The scientific writings of David N. Lee*. Mahwah, NJ: Erlbaum, p. 259-277.

Tresillian, J.R. (1999) Visually timed action: Time-out for tau? *Trends in Cognitive Sciences*, 3, 301-310.

Warren, W.H. (2007) Action-scaled information - comment on Lee (1980). In G.J. Pepping & M.L. Grealy (Eds.), *Closing the gap: The scientific writings of David N. Lee*. Mahwah, NJ: Erlbaum, 253-268.

Going further:

Bootsma, R. J. & van Wieringen, P. (1990). Timing an attacking forehand drive in table tennis. *Journal of Experimental Psychology: Human Perception and Performance*, 16(1), 21-29.

Gray, R., & Regan, D. (1998). Accuracy of estimating time to collision using binocular and monocular information. *Vision Research*, 38, 499-512.

Rushton, S. K., & Wann, J. P. (1999). Weighted combination of size and disparity: A computational model for timing a ball catch. *Nature Neuroscience*, 2, 186-190.

Hecht, H. & Savelsbergh, G. J. P. (2004). *Theories of Time-to-Contact*. *Advances in Psychology* (Vol. 135). Amsterdam: Elsevier.

Lee, D. N. (1976). A theory of visual control of braking based on information about time-to-collision. *Perception*, 5(4), 437-459.

Yilmaz, E. H., & Warren, W. H. (1995). Visual control of braking: A test of the tau-dot hypothesis. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 996-1014.

Fajen, B.R. (2005) Calibration, information, and control strategies for braking to avoid a collision. *Journal of Experimental Psychology: Human Perception and Performance*, 31, 480-501.

### Oct. 23 Catching and the outfielder problem

Reading for discussion of "On mechanism and learning":

Gibson (1979) Ch. 14

Van de Grind, W. (1988) The possible structure and role of neuronal smart mechanisms in vision. *Cognitive Systems*, 2, 163-180.

Jacobs, D.M. & Michaels, C.F. (2002) On the apparent paradox of learning and realism. *Ecological Psychology*, 14, 127-139.

Going further:

Sun, H. & Frost, B.J. (1998) Computation of different optical variables of looming objects in pigeon nucleus rotundus neurons. *Nature Neuroscience*, 1, 296-303.

Norman, J. (2002). Two visual systems and two theories of perception: An attempt to reconcile the constructivist and ecological approaches. *Behavioral and Brain Sciences*, 25, 73-144.

Smith, M. R., Flach, J. M., Dittman, S. M., & Stanard, T. (2001). Monocular optical constraints on collision control. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 395-410.

Michaels, C.F., Arzamarski, R., Isenhower, R.W., & Jacobs, D.M. (2008) Direct learning in dynamic touch. *Journal of Experimental Psychology: Human Perception and Performance*, 34, 944-957.

Fajen, B. R. (2008). Learning novel mappings from optic flow to the control of action. *Journal of Vision*, 8, 1-12.

## Oct. 25 Optic flow

Report:

Lee, D. N. & Aronson, E. (1974) Visual proprioceptive control of standing in human infants. *Perception & Psychophysics*, 15, 529-532.

Reading for discussion of "Catching":

Montagne, G., Laurent, M., Durey, A., & Bootsma, R. (1999) Movement reversals in ball catching. *Experimental Brain Research*, 129, 87-92.

Montagne, G., Laurent, M., & Durey, A. (1998) Visual guidance of goal-oriented locomotor displacements: The example of ball interception tasks. *Ecological Psychology*, 10, 25-37.

Going further:

Peper, L., Bootsma, R. J., Mestre, D. R., & Bakker, F. C. (1994). Catching balls: How to get the hand to the right place at the right time. *Journal of Experimental Psychology: Human Perception and Performance*, 20, 591-612.

Arzamarski, R., Harrison, S.J., Hajnal, A., & Michaels, C.F. (2007) Lateral ball interception: hand movements during linear ball trajectories. *Experimental Brain Research*, 177, 312-323.

McBeath, M. K., Shaffer, D. M., & Kaiser, M. K. (1995). How baseball outfielders determine where to run to catch fly balls. *Science*, 268, 569-573.

Fink, P.W., Foo, P.S., & Warren, W.H. (2009) Catching fly balls in virtual reality: A critical test of the outfielder problem. *Journal of Vision*, 9, 1-8.

Craig, C.M., Goulon, C., Berton, E., Rao, G., Fernandez, L., & Bootsma, R. (2009) Optic variables used to judge future ball arrival position in expert and novice soccer players. *Attention, Perception & Psychophysics*, 71, 515-522.

## Oct. 30 Visual control of posture and locomotion v1.0

Report:

Duchon, A.P. & Warren, W.H. (2002) A visual equalization strategy for locomotor control. *Psychological Science*, 13, 272-278.

Reading for discussion of "Optic flow":

Gibson (1979) Ch. 7

Warren, W.H. (2004) Optic flow. In L. Chalupa & J. Werner (Eds.) *The Visual Neurosciences, v. II*. Cambridge, MA: MIT Press, 1247-1259.

Srinivasan, M.V. (1998) Insects as Gibsonian animals. *Ecological Psychology, 10*, 251-270.

Going further:

Lee, D. & Lishman, J. (1975) Visual proprioceptive control of stance. *Journal of Human Movement Studies, 1*, 87-95.

Warren, W. H., & Hannon, D. J. (1988). Direction of self-motion is perceived from optical flow. *Nature, 336*(6195), 162-163.

Banks, M. S., Ehrlich, S. M., Backus, B. T., & Crowell, J. A. (1996). Estimating heading during real and simulated eye movements. *Vision Research, 36*, 431-443.

Li, L., & Warren, W. H. (2000). Perception of heading during rotation: Sufficiency of dense motion parallax and reference objects. *Vision Research, 40*, 3873-3894.

Li, L. & Cheng, C.K. (2011). Perceiving path from optic flow. *Journal of Vision, 11*(1):22, 1-15.

### Nov. 1 DEBATE 1: Direct vs. Indirect perception

Ullman, S. (1980) Against direct perception. *Behavioral and Brain Sciences, 3*, 373-415 [including as much of the peer commentary as you can stand].

Gibson, Ch. 14

Going further:

Fodor, J.A. & Pylyshyn, Z.W. (1981) How direct is visual perception? Some reflections on Gibson's "Ecological Approach." *Cognition, 9*, 139-196.

Turvey, M. T., Shaw, R. E., Reed, E. S., & Mace, W. M. (1981). Ecological laws of perceiving and acting: In reply to Fodor and Pylyshyn (1981). *Cognition, 9*, 237-304.

## Part IV. Coordination Dynamics

### Nov. 6 Action -- What's the problem?

Reading for discussion of "Locomotion v.1":

Gibson (1979) Ch. 13

Rushton, et al. (1998) Guidance of locomotion on foot uses perceived target location rather than optic flow. *Current Biology, 8*, 1191-1194.

Warren, et al. (2001) Optic flow is used to control human walking. *Nature Neuroscience, 4*, 213-216.

Going further:

Rushton, S. K. (2004). Egocentric direction and locomotion. In L. Vaina, S. A. Beardsley & S. K. Rushton (Eds.), *Optic flow and beyond* (pp. 339-362). Dordrecht: Kluwer.

Bruggeman, H., Zosh, W., & Warren, W. H. (2007). Optic flow drives human visuo-locomotor adaptation. *Current Biology, 17*, 2035-2040.

Patla, A. E. (1998). How is human gait controlled by vision? *Ecological Psychology, 10*, 287-302.

Warren, W.H., Young, D.S., & Lee, D.N. (1986) Visual control of step length during running over irregular terrain. *Journal of Experimental Psychology: Human Perception and Performance, 12*, 259-266.

Pepping, G.J. & Grealy, M.L. (Eds.) (2007) *Closing the gap: The scientific writings of David N. Lee*. Mahwah, NJ: Erlbaum.



Fajen, B. R. (2005). Perceiving possibilities for action: On the necessity of calibration and perceptual learning for the visual guidance of action. *Perception*, 34 (6), 741-755.

### **Nov. 8 Motor programs and computational motor control**

**ESSAY 3 DUE** – upload PDF file to the course website by 11:59 pm

*Reading for discussion of “Action: what’s the problem?”:*

Turvey, M., Fitch, H., & Tuller, B. (1982) The Bernstein perspective:

- I. The problems of degrees of freedom and context-conditioned variability.
- II. The concept of muscle linkage or coordinative structure. In S. Kelso (Ed.), *Human motor behavior: An introduction*, p. 239-270.

*Going further:*

Turvey, M. T. (1990). Coordination. *American Psychologist*, 45(8), 938-953.

Latash, M. L. (1996). The Bernstein Problem: How does the central nervous system make its choices? In M. L. Latash & M. T. Turvey (Eds.) *Dexterity and its Development* (pp. 277-303).

Latash M.L. (2008) *Synergy*. Oxford University Press: New York (Parts 3 & 4).

### **Nov. 13 Self-organization, dynamical systems, and synergies**

*Reading for discussion of “Motor programs”:*

Schmidt, R.A. (1991) Movement production and motor programs. Ch. 4 of *Motor learning and performance*, p. 77-100.

Wolpert, D.M. (1997) Computational approaches to motor control. *Trends in Cognitive Sciences*, 1, 209-216.

Kelso, S. (1984) Contrasting perspectives on order and regulation in movement. In J. Long & A. Baddley (Eds.), *Attention and performance IX*. p. 437-457.

*Going further:*

Jordan, M. I., & Wolpert, D. M. (1999). Computational motor control. In M. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 601-620). Cambridge, MA: MIT Press.

Kawato, M. (1999). Internal models for motor control and trajectory planning. *Current Opinion in Neurobiology*, 9, 718–727.

Körding KP & Wolpert DM (2006). Bayesian decision theory in sensorimotor control. *Trends in Cognitive Sciences*, 10(7), 319-326.

Todorov, E., & Jordan, M. I. (2002). Optimal feedback control as a theory of motor coordination. *Nature Neuroscience*, 5, 1226-1235.

Schall, S., Mohajjerian, P., & Ijspeert, A. (2007) Dynamic systems vs. optimal control – a unifying view. In P. Cisek, T. Drew, & J.F. Kalaska (Eds.) *Progress in brain research*, v. 165. Elsevier, p. 425-445.

### **Nov. 15 Oscillators, resonance, and absolute coordination**

*Report:*

Holt, K., Hamill, J., & Andres, R.O. (1990) The force-driven harmonic oscillator as a model for human locomotion. *Human Movement Science*, 9, 55-68.

*Reading for discussion of “Self-organization”:*

Camazine, et al. (2001) *Self-organization in biological systems*. Ch. 1, 2, 3, 5.

Kelso, J.A.S. (1995) *Dynamic patterns: The self-organization of brain and behavior*, Ch.1

Warren, W. (2006) The dynamics of perception and action. *Psychological Review*, 113, p. 358-366 only.

*Going further:*

Haken, H. (2006) *Information and self-organization* (3<sup>rd</sup> Edition), Ch. 1. Berlin: Springer.

- Turvey, M. T., & Carello, C. (1996). Dynamics of Bernstein's level of synergies. In M. Latash. & M. T. Turvey (Eds.), *Dexterity and its development* (pp. 339-376). Hillsdale, NJ: Erlbaum.
- D'Avella, A., & Bizzi, E. (1998). Low dimensionality of supraspinally induced force fields. *Proceedings of the National Academy of Sciences*, 95, 7711-7714.
- Scholz J. P., Schöner G. (1999). The uncontrolled manifold concept: identifying control variables for a functional task. *Experimental Brain Research*, 126, 289-306.
- Turvey, M. T. (2007). Action and perception at the level of synergies. *Human Movement Science*, 26, 657-697.

## Nov. 20 Phase transitions

### Report:

- Yamanishi, J., Kawato, M., & Suzuki, R. (1980). Two coupled oscillators as a model for coordinated finger tapping by both hands. *Biological Cybernetics*, 37, 219-225.

### Reading for discussion of "Absolute coordination":

- Strogatz, S.H. & Stewart, I. (1993) Coupled oscillators and biological synchronization. *Scientific American*, 269(12), 102-109.
- Goodman, L., Riley, M., Mitra, S., & Turvey, M. T. (2000). Advantages of rhythmic movements at resonance: Minimal active degrees of freedom, minimal noise, and maximal predictability. *Journal of Motor Behavior*, 32, 3-8.
- Schmidt, R.C. & Turvey, M.T. (1989) Absolute coordination: An ecological perspective. In S.A. Wallace (Ed.) *Perspectives on the coordination of movement*.

### Going further:

- Glass, A. (2001) Synchronization and rhythmic processes in physiology. *Nature*, 410, 277-284.
- Kay, B., Kelso, J. A. S., Saltzman, E., & Schöner, G. (1987). Space-time behavior of single and bi-manual rhythmical movements: Data and limit cycle model. *Journal of Experimental Psychology: Human Perception and Performance*, 13, 178-192.
- Amazeen, P. G., Amazeen, E. L., & Turvey, M. T. (1998). Dynamics of human intersegmental coordination: Theory and research. In D. A. Rosenbaum & C. E. Collyer (Eds.), *Timing of behavior: Neural, computational, and psychological perspectives*. (pp. 237-259). Cambridge, MA: MIT Press.
- Riley, M.A., Richardson, M.J., Shockley, K., & Ramenzoni, V.C. (2011) Interpersonal synergies. *Frontiers in Psychology*, 2, Article 38, 1-7.

## Nov. 22 THANKSGIVING BREAK

## Nov. 27 Relative coordination, mode locking, and variability

ESSAY 4 DUE - upload PDF file to course website by 11:59 pm

### Report:

- Miles, L.K., Griffiths, J.L., Richardson, M. J., & Macrae, C.H. (2010). Too late to coordinate: Contextual influences on behavioral synchrony. *European Journal of Social Psychology*, 40, 52-60.

### Reading for discussion of "Phase transitions":

- Kelso, J.A.S. (1995) Ch. 2.
- Mechsner, F., Kerzel, D., Knoblich, G., & Prinz, W. (2001) Perceptual basis of bimanual coordination. *Nature*, 414, 69-73.
- Hoyt, D. F., & Taylor, C. R. (1981). Gait and the energetics of locomotion in horses. *Nature*, 292, 239-240.

*Going further:*

- Haken, H., Kelso, J. A. S., & Bunz, H. (1985). A theoretical model of phase transitions in human hand movements. *Biological Cybernetics*, 51, 347-356.
- Bingham, G. P., Zaal, F. T. J. M., Shull, J. A., & Collins, D. R. (2001). The effect of frequency on the visual perception of relative phase and phase variability of two oscillating objects. *Experimental Brain Research*, 136, 543-552.
- Diedrich, F.J. & Warren, W.H. (1998) Dynamics of human gait transitions. In Rosenbaum, D.A. & Collyer, C.E., (Eds.) *Timing of behavior: Neural, psychological, and computational perspectives*.
- Bardy, B., Oullier, O., Bootsma, R. J., & Stoffregen, T. A. (2002). Dynamics of human postural transitions. *Journal of Experimental Psychology: Human Perception and Performance*, 28, 499-514.
- Schmidt, R. C., Carello, C., & Turvey, M. T. (1990). Phase transitions and critical fluctuations in the visual coordination of rhythmic movements between people. *Journal of Experimental Psychology: Human Perception and Performance*, 16, 227-247.
- 

**Part V. Behavioral Dynamics****Nov. 29 Dynamics of perception and action***Reading for discussion of "Relative coordination":*

- Kelso, J.A.S. (1995) Ch.4.
- Kay, B.A. & Warren, W.H. (1998). A dynamical model of the coupling between posture and gait. Theory and research. In D. A. Rosenbaum & C. E. Collyer (Eds.), *Timing of behavior: Neural, computational, and psychological perspectives*. Cambridge, MA: MIT Press, 293-322.

*Going further:*

- Beek, P. J., & Turvey, M. T. (1992). Temporal patterning in cascade juggling. *Journal of Experimental Psychology: Human Perception and Performance*, 18, 934-947.
- Peper, C. E., Beek, P. J., & van Wieringen, P. C. W. (1995). Multifrequency coordination in bimanual tapping: Asymmetrical coupling and signs of supercriticality. *Journal of Experimental Psychology: Human Perception and Performance*, 21, 1117-1138.
- Jagacinski, R.J., Peper, C, & Beek, P. (2000). Dynamic, stochastic, and topological aspects of polyrhythmic performance. *Journal of Motor Behavior*, 32, 323-336.
- Daffertshofer, A., Huys, R., & Beek, P.J. (2004) Dynamical coupling between locomotion and respiration. *Biological Cybernetics*, 90, 157-164.
- Balasubramaniam, R. & Turvey, M.T. (2004) Coordination modes in the multisegmental dynamics of hula hooping. *Biological Cybernetics*, 90, 176-190.
- Riley, M., & Turvey, M. T. (2002). Variability and determinism in motor behavior. *Journal of Motor Behavior*, 34, 99-125.

**Dec. 4 Visual control of posture and locomotion v2.0****PAPER TOPIC DUE - bring to class***Report:*

- Collins, S., Ruina, A., Tedrake, R., & Wisse, M. (2005) Efficient bipedal robots based on passive-dynamic walkers. *Science*, 307, 1082-1085.

*Reading for discussion of "Dynamics of perception and action":*

- Warren, W. (2006), The dynamics of perception and action, cont. p. 366-385.

Richardson, M.J., Shockley, K., Fajen, B.R., Riley, M.A., & Turvey, M.T. (2008) Ecological psychology: Six principles for an embodied-embedded approach to behavior. In P. Calvo & A. Gomila (Eds.) *Handbook of Cognitive Science: An Embodied Approach* (p. 161-187). Academic Press.

*Going further:*

- Goldfield, G., Kay, B., & Warren, W.H. (1993) Infant bouncing: The assembly and tuning of action systems. *Child Development*, 64, 1128-1142.
- Sternad, D., Duarte, M., Katsumata, H., & Schaal, S. (2001). Bouncing a ball: Tuning into dynamic stability. *Journal of Experimental Psychology: Human Perception and Performance*, 27, 1163-1184.
- Siegler, I., Bardy, B., & Warren, W.H. (2010) Passive vs. active control of rhythmic ball bouncing: The role of visual information. *Journal of Experimental Psychology: Human Perception and Performance*, 36, 729-750.
- Loomis, J. M. & Beall, A. C. (2004). Model-based control of perception/action. In L. Vaina, S. Beardsley, and S. Rushton (Eds.). *Optic Flow and Beyond* (pp. 421-441). Boston: Kluwer Academic Publishers.
- Brooks, R.A. (1991) Intelligence without representation. In Haugeland (Ed) *Mind Design II*, Ch. 15.
- Beer, R.D. (2008). Beyond control: The dynamics of brain-body-environment interaction in motor systems. In D. Sternad (Ed.), *Progress in Motor Control V: A Multidisciplinary Perspective*. Springer.

## Dec. 6 Pedestrian dynamics

*Report:*

Moussaïd, M., Helbing, D., Theraulaz, G. (2011) How simple rules determine pedestrian behavior and crowd disasters. *Proceedings of the National Academy of Sciences*, 108(17), 6884-6888.

*Reading for discussion of "Locomotion v.2":*

- Schöner, G. (1998) Action-perception patterns emerge from coupling and adaptation. *Ecological Psychology*, 10, 323-346.
- Matthis, J. & Fajen, B.F. (2012) Humans exploit the biomechanics of bipedal gait during visually guided walking over rough terrain. Vision Sciences Society conference.
- Bonneaud, S. & Warren, W.H. (2012) A behavioral dynamics approach to modeling realistic pedestrian behavior. Pedestrian and Evacuation Dynamics conference.

*Going further:*

- Kuo, A.D. (2007) The six determinants of gait and the inverted pendulum analogy: A dynamic walking perspective. *Human Movement Science*, 26, 617-656.
- Dickinson, M., Farley, C., Full, R. J., et al. (2000). How animals move: An integrative view. *Science*, 288, 100-106.
- Holmes, P., Full, R.J., Koditschek, D. & Guckenheimer, J. (2006) The dynamics of legged locomotion: Models, analyses, challenges. *SIAM Review*, 48, 207-304.
- Srinivasan, M. & Ruina, A. (2006) Computer optimization of a minimal biped model discovers walking and running. *Nature*, 439, 72-75.
- Riley, M.A., Balasubramaniam, R. & Turvey, M. T. (1999). Recurrence quantification analysis of postural fluctuations. *Gait & Posture*, 9, 65-78.

*Going further in "Pedestrian dynamics":*

- Warren, W.H. & Fajen, B.R. (2008) Behavioral dynamics of visually-guided locomotion. In A. Fuchs & V. Jirsa (Eds.), *Coordination: Neural, behavioral, and social dynamics*. Heidelberg: Springer.

- Wilkie, R. M., & Wann, J. P. (2003). Controlling steering and judging heading: Retinal flow, visual direction, and extra-retinal information. *Journal of Experimental Psychology: Human Perception and Performance*, 29, 363-378.
- Reynolds, C. W. (1987). Flocks, herds, and schools: a distributed behavioral model. *Computer Graphics*, 21, 25-34.
- Camazine, Ch. 11.
- Helbing, D., Molnar, P. (1995) Social force model for pedestrian dynamics. *Physical Review E* 51, 4282-4286.
- Helbing, D., Keltsch, J., & Molnar, P. (1997) Modeling the evolution of human trail systems. *Nature*, 388, 47-50.

**Dec. 11 DEBATE: Dynamics vs. Representation**

- van Gelder, T. (1996) Dynamics and cognition. In Haugeland (Ed) *Mind Design II*, Ch. 16.
- Clark, A. (2001) *Mindware*, Ch. 6 & 7.
- Going further:
- Markman, A. & Dietrich, E. (2000) Extending the classical view of representation. *Trends in Cognitive Sciences*, 4, 470-475.
- Chemero, A. (2001) Dynamical explanation and mental representations. *Trends in Cognitive Sciences*, 5, 141-2.
- Keijzer, F. (1998). Doing without representations which specify what to do. *Philosophical Psychology*, 11, 269-302.
- Van Gelder, T. (1998) The dynamical hypothesis in cognitive science. *Behavioral and Brain Sciences*, 21, 615-665.
- Chemero, A. (2009) The dynamical stance. Ch. 4 of *Radical embodied cognitive science*. Cambridge: MIT Press.
- Stepp, N. & Turvey, M.T. (2010) On strong anticipation. *Cognitive Systems Research*, 11, 148-164.

**Dec. 18 Tue. TERM PAPER DUE** - upload PDF file to course website by 11:59 pm