in addition to being dependent on a characterization of perception as information processing, such delays (and the need for delay compensation mechanisms) are also dependent upon a characterization of perception and action as processes that (primarily) occur with reference to the immediate (i.e., instantaneous) present.

From the perspective of ecological psychology, perception-action primarily occurs with reference to the (impending) future (Wagman & Malek, in press). In order to successfully achieve a behavioral goal (e.g., reaching for a cup of coffee or hitting a thrown ball), perceiver-actors must be able to perceive whether that (future) behavior is possible, and (if so) they must be able to perceive how to control their (future) movements such that this possibility is realized (Shaw & Turvey 1999). Thus, perception-action is inherently a prospective act (Turvey 1992). If perception-action is inherently prospective, there is no need for the nervous system to bring the perceiver-actor "up to speed" because perception-action places awareness "ahead of the world."

The prospectivity of perception-action is considered by some to be one of the fundamental hallmarks of a psychological being (E. Gibson 1994). From the perspective of ecological psychology, the stimulation variables that support such prospectivity are not the static and isolated variables of standard physics (so-called "lower-order" stimulation variables) but, rather, are the dynamic and relational variables of an ecological physics (so-called "higher order" stimulation variables) (Turvey & Shaw 1999). For example, a handheld object's resistance to rotational acceleration in different directions not only informs a perceiver about whether that object can be used to achieve a particular goal (e.g., striking another object) but also about how that object should be used to do so (Wagman & Carello 2001; 2003). If perception-action is characterized as a prospective act, then there is no need for delay compensation mechanisms in perception-action because higher-order relational variables are sufficient to specify impending states of affairs without the need for mediating processes.

Delays that are inherent in the sending and receiving of information create an explanatory gap in a scientific understanding of perception and action. However, rather than fill that gap with specialized delay compensation mechanisms, I propose that perception and action be (re)characterized in a way in which such delays are an impossibility and the explanatory gap dissolves. The ecological approach to perception-action provides such a (re)characterization.

Visuomotor extrapolation

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Abstract: Accurate perception of moving objects would be useful; accurate visually guided action is crucial. Visual motion across the scene influences perceived object location and the trajectory of reaching movements to objects. In this commentary, I propose that the visual system assigns the position of any object based on the predominant motion present in the scene, and that this is used to guide reaching movements to compensate for delays in visuomotor processing.

Nijhawan's article provides evidence for compensation mechanisms in visual perception and visually guided action. Most of this evidence is drawn from the flash-lag effect, where a single object moves across the retina. There are several other illusions, some of which are briefly mentioned in the target article, which might also support Nijhawan's position (De Valois & De Valois 1991; Hess 1904; Matin et al. 1976; Nishida & Johnston 1999; Ramachandran & Anstis 1990; Regan & Beverley 1984; Snowden 1998; Whitaker et al. 1999; Whitney & Cavanagh 2000). For a review of these illusions, see Whitney (2002). The strongest support for compensation in the perceptual system (e.g., extrapolation) comes from the displacement of stationary edges by motion. For example, visual motion viewed through a static aperture causes the aperture to appear shifted in the direction of the motion (De Valois & De Valois 1991; Ramachandran & Anstis 1990; Regan & Beverley 1984); the motion aftereffect is accompanied by a concurrent shift in the apparent position of a static test stimulus (Nishida & Johnston 1999; Snowden 1998; Whitaker et al. 1999); and, static flashed objects appear shifted in the direction of nearby motion (Whitney & Cavanagh 2000). Whereas the flash-lag effect may be due to differential latencies for moving and flashed objects (Ogmen et al. 2004; Purushothaman et al. 1998; Whitney & Murakami 1998), these other mislocalizations of static edges by visual motion cannot be caused by temporal mechanisms such as differential latencies (Whitney 2002).

Although these mislocalizations of static edges by visual motion provide the strongest support for perceptual extrapolation (i.e., compensation for neural delays in the perceptual system), some of these illusions greatly complicate things: Several papers have shown that flashed objects appear shifted forward, in a direction consistent with any nearby visual motion, even when that motion is several degrees away from the flash. This has been called the "flash-drag" effect or the "flash-shift" effect (Durant & Johnston 2004; Eagleman & Sejnowski 2007; Watanabe et al. 2002; 2003; Whitney 2006; Whitney & Cavanagh 2000; 2003). Because the flash is not moving, and it is distantly separated from the moving object, it does not immediately make sense why the flash should appear shifted (or extrapolated) in the direction of nearby motion. This result is somewhat difficult to reconcile with the notion of compensation for moving object positions, but it is not entirely incompatible. In fact, this flash-drag effect suggests that the sort of compensation that Nijhawan describes for a single moving object extends to all objects, and may be a far more pervasive and important mechanism than simply allowing us to perceptually extrapolate a baseball or other moving object's position.

In Nijhawan's article, the primary case that is considered is one in which a single moving object needs to be perceived or grasped. This is a relatively rare situation compared to what normally happens: usually, there is image motion across the entire retina, not just a single moving object. Normally the world is physically stationary, and it is we (our eyes, heads, or bodies) that move around; and it is our movement which generates retinal image motion. For example, when we reach to any object, we usually make an eye or head movement during or just before the reach. In this case, there is retinal motion of the scene and the target object. On account of delays in visual processing, delays in coordinate transformations, and other factors such as imperfect efference copy signals (Bridgeman 1995) – along with the fact that targets of reaching movements are coded in eye-centered coordinates (Buneo et al. 2002; Crawford et al. 2004; Henriques et al. 1998) – our visuomotor system faces a somewhat similar challenge to the one outlined by Nijhawan, but on a much grander scale. Because of these visuomotor delays, we should miss-direct nearly every reaching movement we make to virtually any object. Every time we reach toward our coffee cup, we should either hit the cup, knocking it over, or fall short of the cup – all because of sluggish visual and motor processing.

How does the visuomotor system avoid these errors? In a recent series of studies, we found that the visuomotor system samples motion across the visual field and then shifts the trajectory of the hand in the direction of that motion when reaching to any object in the scene (Whitney & Goodale 2005; Whitney et al.

2003; 2007). This effect was recently called *the manual following response* (Gomi et al. 2006; Saijo et al. 2005) and reveals an adaptive mechanism: The visuomotor system uses retinal motion to gauge movements of the eye and body (probably because it is as fast or faster than using vestibular or proprioceptive cues), and then adjusts the trajectory of the reach based on this information to improve the accuracy of goal-directed action. In support of this, when subjects were passively rotated, the presence of background retinal image motion improved the accuracy of reaching movements compared to cases in which only static information, or nothing, was visible (Whitney et al. 2003). The manual following response is conceptually similar to the "flash-drag effect" described above, and it suggests that the visual and visuomotor systems use retinal image motion (the kind generated every time we move our eyes) to update/extrapolate/shift the representations of object position (causing objects to appear shifted in position) – and this allows us to guide our hand more accurately than would otherwise be possible.

This visuomotor extrapolation model has the advantage that it accounts for several psychophysical findings that are discrepant with the perceptual extrapolation model; and it also has the advantage that it explains accurate visuomotor behavior under the most common circumstances – where the world is stationary and we are moving.

Compensation for time delays is better achieved in time than in space

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Abstract: Mechanisms of visual prediction based on spatial extrapolation work only for targets moving at constant speed, but do not easily accommodate accelerating or decelerating motion. We argue that mechanisms based on temporal extrapolation deal with both uniform and non-uniform motion. We provide behavioural examples from interception of falling objects and suggest possible neurophysiological substrates of time extrapolation.

Nijhawan makes a clear case for the need to compensate for delays arising from processing and transmission times. The evidence for compensation in perceptual decision and visual awareness appears somewhat controversial (Eagleman & Sejnowski 2000; Krekelberg & Lappe 2001), but the evidence for compensation for motor reactions to a rapidly changing sensory stimulus is uncontroversial. Typical visuomotor delays in ballistic interception of fast targets (such as in catching or hitting in ball games) are about 200 msec – at least an order of magnitude longer than the temporal accuracy required for interception (about ± 10 msec). Unless the nervous system has built-in mechanisms to compensate for such delays, the interception program would be based on obsolete visual information about target motion, and, as a consequence, the target would be badly missed.

Nijhawan proposes a mechanism for neural compensation of delays that is based on a spatial extrapolation linearly related to the time delay. According to his hypothesis, visual prediction would be concerned primarily with horizontal processes, which transmit neural information between two neighbouring retinotopic sites. The speed of neural transmission and the distance between neighbouring neurons along the horizontal direction would jointly determine the amount of spatial and temporal extrapolation. Another mechanism could consist in a shift of the receptive field in response to moving stimuli. Sundberg et al. (2006) found that neurons in monkey area V4 exhibit such a shift in response to a particular type of moving stimuli. The direction of the receptive field shift was opposite to the direction of target motion, as if the cell had been recruited by a wave of activity preceding the target. Ferrera and Barborica (2006) argued that a moving target would leave a trail of refractory neurons in its wake so that spiking activity would be shifted toward the leading edge.

Interestingly, mechanisms of visual prediction based on spatial extrapolation, such as those mentioned above, work only for targets moving at constant speed (uniform motion), because the spatial shifts co-vary with the time samples in a fixed manner. Most targets, however, accelerate or decelerate to a variable extent. Let us consider a very common situation – that of motion affected by Earth's gravity, such as free-fall, ballistic, pendulum, or wave motion. Although all objects are accelerated downward by gravity at the same rate, the corresponding acceleration of the retinal image is not at all constant, being inversely related to the apparent viewing distance of the object. The question then is how the central nervous system (CNS) compensates for delays in the case of accelerating or decelerating motion. Here we show that temporal extrapolation rather than spatial extrapolation can more easily do the job.

Figure 1A depicts space–time plots similar to those of Figures 3 and 4 of Nijhawan, but for an object moving at constant acceleration (when the spatial variable decreases from right to left) or deceleration (when the spatial variable increases from left to right). The dashed curve depicts the physical trajectory, and the dotted curve depicts the corresponding trajectory "seen" by a neuron with a fixed visual delay. Clearly, the spatial shifts required to compensate for the visual delay (solid line segments connecting the two curves) are not constant anymore, as they were in the spatial extrapolation scheme proposed by Nijhawan.

In theory, a first-order model might be used to approximate a second-order motion. One such model is provided by the tau function, tau $= x(t)/v(t)$, where $x(t)$ is the spatial position of the target and $v(t)$ is the corresponding velocity (Lee 1976). However, it can be shown that, in case of free-fall motion from relatively short drop heights, such an approximation would imply significant temporal errors in interception ($>$50 msec), corresponding to the difference between the time-to-contact predicted by tau and the actual time-to-contact of the ball accelerated by gravity (Zago & Lacquaniti 2005). In fact, we know that unless taken by surprise, people can easily intercept targets descending along the vertical accelerated by gravity (Lacquaniti & Maioli 1989; Zago et al. 2004); they generally intercept

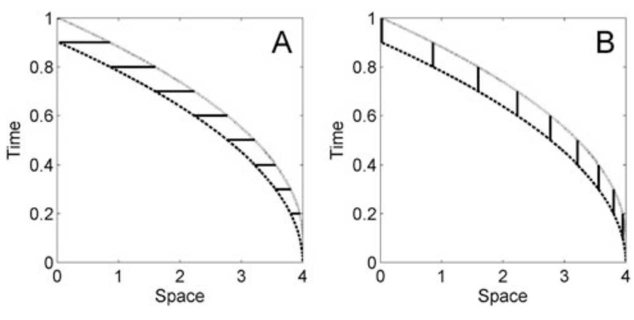

Figure 1 (Zago & Lacquaniti). Figure depicts space-time plots similar to those of Figures 3 and 4 in the target article, but for an object moving at constant acceleration (when the spatial variable decreases from right to left) or deceleration (when the spatial variable increases from left to right). The dashed curve depicts the physical trajectory and the dotted curve depicts the corresponding trajectory "seen" by a neuron with a fixed visual delay.

a mechanism would have the necessary speed to produce the interception of accelerating objects, as has been demonstrated by Lacquaniti and colleagues. A time-extrapolation could supplement the task of prediction, and work cooperatively with space-extrapolation to yield a more robust system than each type of extrapolation alone would.

Cunningham suggests that in addition to spatial compensation for delays, there should also be temporal compensation; and in addition to compensation for delays for continuous events, there should also be compensation for discrete events. There are perhaps two ways of describing temporal compensation. One is similar to whatz **Zago & Lacquaniti** might call time-extrapolation. This may be called *absolute temporal compensation*, as it affects delays between a physical event and its registration. The other is *relative temporal compensation*, where the nervous system actively coordinates sensory signals to compensate for temporal asynchronies between modalities (see commentary by **Cutting**).

Relative temporal compensation is what **Cunningham** and colleagues have shown in their interesting experiments. Let us consider absolute temporal compensation further. First, there is a form of absolute temporal compensation, as demonstrated by experiments on finger tapping to auditory tones. Within limits, human subjects can predict repetitive discrete tones and put their finger taps just in advance of the tones (Mates et al. 1994). This is a good example of where the sensorimotor system must have information about the actual time of an external event. But can absolute temporal compensation occur for perception (as opposed to behavior such as finger taps)? Can the visual system generate the percepts of repetitive flashes, for example, simultaneously with the actual flashes? The answer would appear to be no, and this is where spatial and temporal compensations differ. The claim of spatial compensation is that it can put the percept of the moving object closer to (or even ahead of) the actual position of the moving object. In contrast, temporal compensation cannot, it seems, put the perceptual event close to the time of the actual event.

I fully endorse the amendment suggested by **Cunningham** that: "The goal of visual prediction is to use priors acquired from both previous experience and the currently unfolding visual stimulus to create a perceived state of the world that matches, as far as possible, the actual state of the world."

R6.7. Mental extrapolation and (not "or") visual extrapolation

Kerzel & Müsseler suggest that sensorimotor prediction and mental extrapolation, as opposed to visual extrapolation, can overcome perceptual latencies. There is no doubt that sensorimotor prediction is an important, and highly flexible, contributor to successful behavioral acts. The role of mental extrapolation in the context of flash-lag effect is, however, not as clear as these commentators propose. Kerzel & Müsseler claim that the missing predictive-overshoot in the flash-terminated condition opposes the visual extrapolation account, and they invoke mental extrapolation in explaining the forward-shift of fading moving objects (Maus & Nijhawan 2006). However, it is not clear how mental extrapolation escapes this very criticism. Why does mental extrapolation not lead to an overshoot in the flash-terminated condition?

Mental extrapolation falls in the general category of phenomena such as mental imagery and mental rotation. Researchers have investigated the neural basis of mental imagery. One of the key findings is that mental imagery tasks engage the primary visual cortex (Kosslyn & Sussman 1994). In addition, Kosslyn and colleagues have found a number of similarities between mental imagery and visual perception, such as the topographic nature of both representations (Kosslyn et al. 1995). Thus, the existence of mental extrapolation would predict the existence of visual extrapolation. **Kerzel & Müsseler**'s proposal that mental extrapolation exists but visual extrapolation does not is unparsimonious.

I claim that the task of mental extrapolation is not to solve the problem of neural conduction delays, but rather, it is to determine when a moving object, occluded by another object, will reappear (Wexler & Klam 2001). In the case of continuous sensory input from a moving object, the task of mental extrapolation is to determine the object's future position. The task of visual extrapolation is to use sensory input to determine the object's current position (after compensating for visual conduction delays). In past studies, Kerzel and colleagues have used either probe stimuli presented after a retention interval, or pointing movements, and so in effect asked for the remembered final position of the moving target. In flash-lag experiments, or in the task used by Maus and Nijhawan (2006), participants make an online perceptual judgment comparing the position of the moving target to a flash or to a static probe. Although obviously the observer's response is given after the visual offset, the judgment is based on simultaneously visible stimuli. It is likely that the two experimental methods differentially engage mental and perceptual extrapolation. In this context, it is interesting to note that the forward-shift effect of the fading moving object observed by Maus and Nijhawan (2006) is 175 msec, which is a much larger shift than the typical flash-lag effect of 80 msec. It is possible that this is a cumulative effect of both visual and mental extrapolation.

Reference

Letters "a" and "r" appearing before authors' initials refer to target article and response, respectively.

Ahissar, E. & Ahissar, M. (1994) Plasticity in auditory cortical circuitry. *Current Opinion in Neurobiology* 4:580–87. [DWC]

Aho, A. C., Donner, K., Helenius, S., Larsen, L. O. & Reuter, T. (1993) Visual performance of the toad (*Bufo bufo*) at low light levels: Retinal ganglion cell responses and prey-catching accuracy. *Journal of Comparative Physiology A* 172(6):671–82. [aRN]

Alais, D. & Burr, D. (2003) The "flash-lag" effect occurs in audition and cross-modally. *Current Biology* 13(1):59–63. [MVCB, JB, aRN]

Anderson, B. L. & Barth, H. C. (1999) Motion-based mechanisms of illusory contour synthesis. *Neuron* 24:433–41. [JB]

Andersen, R. A. & Buneo, C. A. (2002) Intentional maps in posterior parietal cortex. *Annual Review of Neuroscience* 25:189–220. [aRN]

Andersen, R. A., Snyder, L. H., Li, C. S. & Stricanne, B. (1993) Coordinate transformations in the representation of spatial information. *Current Opinion in Neurobiology* 3(2):171–76. [aRN]

Anderson, C. H. & Van Essen, D. C. (1987) Shifter circuits: A computational strategy for dynamic aspects of visual processing. *Proceedings of the National Academy of Science USA* 84(17):6297–301. [aRN]

Anderson, C. H., Van Essen, D. C. & Gallant, J. L. (1990) Blur into focus. *Nature* 343(6257):419–20. [aRN]

Anstis, S. (2007) The flash-lag effect during illusory chopstick rotation. *Perception* 36:1043–48. [JB]

Anstis, S. M., Smith, D. R. & Mather, G. (2000) Luminance processing in apparent motion, Vernier offset and stereoscopic depth. *Vision Research* 40(6):657–75. [aRN]

Arbib, M. A. (1972) *The metaphorical brain: An introduction to cybernetics as artificial intelligence and brain theory*. Wiley Interscience. [aRN]

Attneave, F. (1954) Informational aspects of visual processing. *Psychological Review* 61:183–93. [HO]

Bachmann, T. & Poder, E. (2001) Change in feature space is not necessary for the flash-lag effect. *Vision Research* 41(9):1103–106. [BRS]

Bahill A. T. & LaRitz T. (1984) Why can't batters keep their eyes on the ball? *American Scientist* 72:249–53. [GP]

Bahill, A. T. & McDonald, J. D. (1983) Smooth pursuit eye movements in response to predictable target motions. *Vision Research* 23:1573–83. [GP]

Bair, W., Cavanaugh, J., Smith, M. & Movshon, J. (2002) The timing of response onset and offset in macaque visual neurons. *Journal of Neuroscience* 22(8):3189–205. [BKr]

Baldo, M. V. & Caticha, N. (2005) Computational neurobiology of the flash-lag effect. *Vision Research* 45(20):2620–30. [aRN, MVCB]

Baldo, M. V. C., Kihara, A. H., Namba, J. & Klein, S. A. (2002) Evidence for an attentional component of perceptual misalignment between moving and flashing stimuli *Perception* 31:17–30. [MVCB]

Baldo, M. V. C. & Klein, S. A. (1995) Extrapolation or attention shift? *Nature* 378(6557):565–66. [MVCB, rRN]

(in press) Paying attention to the flash-lag effect. In: *Space and time in perception and action*, ed. R. Nijhawan & B. Khurana. Cambridge University Press. [MVCB]

Baldo, M. V. C. & Namba, J. (2002) The attentional modulation of the flash-lag effect. *Brazilian Journal of Medical and Biological Research* 35:969–72. [MVCB, BRS]

Balkenius, C. & Johansson, B. (2007) Anticipatory models in gaze control: A developmental model. *Cognitive Processing* 8:167–74. [CB]

Barlow, H. B. (1953) Summation and inhibition in the frog's retina. *Journal of Physiology* 119:69–88. [arRN]

(1961a) Possible principles underlying the transformations of sensory messages. In: *Sensory communication*, ed. W. A. Rosenblith. Wiley. [aRN, HO]

(1961b) Three points about lateral inhibition. In: *Sensory communication*, ed. W. A. Rosenblith, pp. 782–86. MIT Press. [HO]

(1961c) The coding of sensory messages. In: *Current problems in animal behaviour*, ed. W. H. Thorpe & O. L. Zangwill, pp. 331–60. Cambridge University Press. [HO]

(1979) Reconstructing the visual image in space and time. *Nature* 279(5710):189–90. [aRN]

(1981) The Ferrier Lecture, 1980. Critical limiting factors in the design of the eye and visual cortex. *Proceedings of the Royal Society of London B: Biological Sciences* 212(1186):1–34. [aRN]

Barlow, H. B. & Pettigrew, J. D. (1971) Lack of specificity of neurones in the visual cortex of young kittens. *Journal of Physiology* 218(1):98P–100P. [rRN]

Barnes, G. R. & Asselman, P. T. (1991) The mechanism of prediction in human smooth pursuit eye-movements. *Journal of Physiology* 439:439–61. [JBJS]

Barnes, G. R., Barnes, D. M. & Chakraborti, S. R. (2000) Ocular pursuit responses to repeated, single-cycle sinusoids reveal behavior compatible with predictive pursuit. *Journal of Neurophysiology* 84:2340–55. [GP]

Batista, A. P., Buneo, C. A., Snyder, L. H. & Andersen, R. A. (1999) Reach plans in eye-centered coordinates. *Science* 285(5425):257–60. [aRN]

Bedell, H. E. & Lott, L. A. (1996) Suppression of motion-produced smear during smooth pursuit eye movements. *Current Biology* 6:1032–34. [HO]

Bedford, F. L. (1993) Perceptual learning. *Psychology of Learning and Motivation* 30:1–60. [DWC]

Beilock, S. L., Bertenthal, B. I., McCoy, A. M. & Carr, T. H. (2004) Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. *Psychonomic Bulletin and Review* 11:373–79. [JEC]

Benguigui, N., Broderick, M. P., Baurès, R. & Amorim, M. A. (in press) Motion prediction and the velocity effect in children. *British Journal of Developmental Psychology*. [NB]

Benguigui, N., Ripoll, H. & Broderick, M. P. (2003) Time-to-contact estimation of accelerated stimuli is based on first-order information. *Journal of Experimental Psychology: Human Perception and Performance* 29(6):1083–101. [NB]

Bennett, K. M. B. & Castiello, U. (1995) Reorganization of prehension components following perturbation of object size. *Psychology and Aging* 10:204–14. [NB]

Berry, M. J., Brivanlou, I. H., Jordan, T. A. & Meister, M. (1999) Anticipation of moving stimuli by the retina. *Nature* 398(6725):334–38. [MVCB, arRN, GP, WvdG]

Berzhanskaya, J., Grossberg, S. & Mingolla, E. (2004) Motion-to-form cortical projections and distortion of the position maps. Paper presented at the Vision Sciences Society Conference, Sarasota, FL, May 1–5, 2004, p. 149. [JB]

(2007) Laminar cortical dynamics of visual form and motion interactions during coherent object motion perception. *Spatial Vision* 20(4):337–95. [JB]

Bialek, W., Rieke, F., de Ruyter van Steveninck, R. R. & Warland, D. (1991) Reading a neural code. *Science* 252(5014):1854–57. [aRN]

Blair, H. T. & Sharp, P. E. (1995) Anticipatory head direction signals in anterior thalamus: evidence for a thalamocortical circuit that integrates angular head motion to compute head direction. *Journal of Neuroscience* 15(9):6260–70. [rRN]

Blake, R., Tadin, D., Sobel, K. V., Raissian, T. A. & Chong, S. C. (2006) Strength of early visual adaptation depends on visual awareness. *Proceedings of the National Academy of Sciences USA* 103(12):4783–88. [ZL]

Blakemore, C. & Cooper, G. F. (1970) Development of the brain depends on the visual environment. *Nature* 228(5270):477–78. [rRN]

Blakemore, S. J., Wolpert, D. M. & Frith, C. D. (2002) Abnormalities in the awareness of action. *Trends in Cognitive Sciences* 6(6):237–42. [aRN]

Bolz, J., Rosner, G. & Wässle, H. (1982) Response latency of brisk-sustained x and brisk-sustained y cells in the cat retina. *Journal of Physiology (London)* 328:171–90. [DWC]

Bootsma, R. J. & Oudejans, R. R. (1993) Visual information about time-to-collision between two objects. *Journal of Experimental Psychology: Human Perception and Performance* 19(5):1041–52. [aRN]

Bootsma, R. J. & van Wieringen, P. C. W. (1990) Timing an attacking forehand drive in table tennis. *Journal of Experimental Psychology: Human Perception and Performance* 16:21–29. [NB, JEC]

Born, R. T. & Bradley, D. C. (2005) Structure and function of visual area MT. *Annual Review of Neuroscience* 28:157–89. [BKr]

Brenner, E. & Smeets, J. B. (2000) Motion extrapolation is not responsible for the flash-lag effect. *Vision Research* 40(13):1645–48. [arRN, JBJS]

(2007) Eye movements in a spatially and temporally demanding interception task. *Journal of Vision* 7(9):565. [JBJS]

Brenner, E., Smeets, J. B. J. & van den Berg, A. V. (2001) Smooth eye movements and spatial localization. *Vision Research* 41:2253–59. [aRN]

Bridgeman, B. (1995) A review of the role of efference copy in sensory and oculomotor control systems. *Annals of Biomedical Engineering* 23(4):409–22. [DW]

Bringuier, V., Chavane, F., Glaeser, L. & Fregnac, Y. (1999) Horizontal propagation of visual activity in the synaptic integration field of area 17 neurons. *Science* 283(5402):695–99. [aRN]

Britten, K. H. (2004) The middle temporal area: Motion processing and the link to perception. In: *Visual neurosciences*, ed. L.M. Chalupa & J. S. Werner. MIT Press. [GP]

Britten, K. H., Newsome, W. T., Shadlen, M. N., Celebrini, S. & Movshon, J. A. (1996) A relationship between behavioral choice and the visual responses of neurons in macaque MT. *Visual Neuroscience* 13:87–100. [GP]

Brooks, R. (1991) Intelligence without representation. *Artificial Intelligence* 47:139–59. [rRN]

Bruce, C. J., Friedman, H. R., Kraus, M. S. & Stanton, G. B. (2004) The primate frontal eye field. In: *Visual neurosciences*, ed. L. M. Chalupa & J. S. Werner. MIT Press. [GP]

Bullock, D. (2003) Motoneuron recruitment. In: *The handbook of brain theory and neural networks*, ed. M. A. Arbib. MIT Press. [aRN]

Buneo, C. A., Jarvis, M. R., Batista, A. P. & Andersen, R. A. (2002) Direct visuomotor transformations for reaching. *Nature* 416(6881):632–36. [DW]

Burr, D. C. (1980) Motion smear. *Nature* 284(5752):164–65. [aRN]

Burr, D. C. & Morgan, M. J. (1997) Motion deblurring in human vision. *Proceedings of the Royal Society of London B: Biological Sciences* 264(1380):431–36. [aRN]

Burr, D. C. & Ross, J. (1979) How does binocular delay give information about depth? *Vision Research* 19(5):523–32. [aRN]

Butts, D. A., Feller, M. B., Shatz, C. J. & Rokhsar, D. S. (1999) Retinal waves are governed by collective network properties. *Journal of Neuroscience* 19(9):3580–93. [rRN]

Butz, M. V., Sigaud, O., Pezzulo, G. & Baldassarre, G., eds. (2007) *Anticipatory behavior in adaptive learning systems: Advances in anticipatory processing.* Springer. [GT]

Cai, R. & Schlag, J. (2001) A new form of illusory conjunction between color and shape. *Journal of Vision* 1(3):127, 127a. [JB]

Cantor, C. R. L. & Schor, C. M. (2007) Stimulus dependence of the flash-lag effect. *Vision Research* 47:2841–54. [WvdG]

Carpenter, R. H. S. (1988) *Movements of the eyes*, 2nd edition. Pion Press. [GP]

Cavanagh, P. (1997) Predicting the present. *Nature* 386(6620):19, 21. [aRN]

Changizi, M. A. (2001) "Perceiving the present" as a framework for ecological explanations of the misperception of projected angle and angular size. *Perception* 30:195–208. [MAC]
(2003) *The brain from 25,000 feet: High level explorations of brain complexity, perception, induction and vagueness*. Kluwer Academic. [MAC]
Changizi, M. A., Hsieh, A., Nijhawan, R., Kanai, R. & Shimojo, S. (in press) Perceiving-the-present and a systematization of illusions. *Cognitive Science*. [MAC, aRN]
Changizi, M. A. & Widders, D. (2002) Latency correction explains the classical geometrical illusions. *Perception* 31:1241–62. [MAC]
Chappell, M., Hine, T. J., Acworth, C. & Hardwick, D. R. (2006) Attention "capture" by the flash-lag flash. *Vision Research* 46:3205–13. [MVCB]
Chawla, D., Friston, K. J. & Lumer, E. D. (2001) Zero-lag synchronous dynamics in triplets of interconnected cortical areas. *Neural Networks* 14(6–7):727–35. [rRN]
Chen, S., Bedell, H. E. & Öğmen, H. (1995) A target in real motion appears blurred in the absence of other proximal moving targets. *Vision Research* 35:2315–28. [HO]
Chung, S. T. L., Patel, S. S., Bedell, H. E. & Yilmaz, O. (2007) Spatial and temporal properties of the illusory motion-induced position shift for drifting stimuli. *Vision Research* 47:231–43. [GP]
Ciszak, M., Marino, F., Toral, R. & Balle, S. (2004) Dynamical mechanism of anticipating synchronization in excitable systems. *Physical Review Letters* 93:114102. [NS]
Coenen, A. M. & Eijkman, E. G. (1972) Cat optic tract and geniculate unit responses corresponding to human visual masking effects. *Experimental Brain Research* 15(5):441–51. [JPM]
Collewijn, H. & Tamminga, E. P. (1984) Human smooth and saccadic eye movements during voluntary pursuit of different target motions on different backgrounds. *Journal of Physiology* 351:217–50. [JBJS]
Coppola, D. & Purves, D. (1996) The extraordinarily rapid disappearance of entopic images. *Proceedings of the National Academy of Sciences USA* 93(15):8001–8004. [rRN]
Coren, S. & Girgus, J. S. (1973) Visual spatial illusions: Many explanations. *Science* 179(72):503–504. [rRN]
Craver, C. F. & Darden, L. (2001) Discovering mechanisms in neurobiology: The Case of spatial memory. In: *Theory and method in neuroscience*, ed. P.K. Machamer, R. Grush & P. McLaughlin, pp. 112–37. University of Pittsburgh Press. [GT]
Crawford, J. D., Medendorp, W. P. & Marotta, J. J. (2004) Spatial transformations for eye-hand coordination. *Journal of Neurophysiology* 92(1):10–19. [DW]
Crick, F. & Koch, C. (1995) Are we aware of neural activity in primary visual cortex? *Nature* 375(6527):121–23. [ZL, aRN]
Cudeiro, J. & Sillito, A. M. (2006) Looking back: Corticothalamic feedback and early visual processing. *Trends in Neuroscience* 29(6):298–306. [aRN]
Cummins, R. (1983) *The nature of psychological explanation*. MIT Press/Bradford Books. [GT]
Cunningham, D. W., Billock, V. A. & Tsou, B. H. (2001a) Sensorimotor adaptation to violations of temporal contiguity. *Psychological Science* 12:532–35. [DWC, DME]
Cunningham, D. W., Chatziasros, A., von der Heyde, M. & Bülthof, H.H. (2001b) Driving in the future: Temporal visuomotor adaptation and generalization. *Journal of Vision* 1(2):88–98. [DWC]
Cynader, M. & Berman, N. (1972) Receptive-field organization of monkey superior colliculus. *Journal of Neurophysiology* 35(2):187–201. [aRN]
Davidson, D. (1970) Mental events. In: *The nature of mind*, ed. D. Rosenthal. Oxford University Press. [aRN]
De Valois, R. L. & Cottaris, N. P. (1998) Inputs to directionally selective simple cells in macaque striate cortex. *Proceedings of the National Academy of Sciences USA* 95(24):14488–93. [aRN]
De Valois, R. L. & De Valois, K. K. (1991) Vernier acuity with stationary moving Gabors. *Vision Research* 31(9):1619–26. [JB, arRN, GP, DW]
Dean, P., Redgrave, P. & Westby, G. W. (1989) Event or emergency? Two response systems in the mammalian superior colliculus. *Trends in Neuroscience* 12(4):137–47. [aRN]
Dennett, D. C. & Kinsbourne, M. (1992) Time and the observer: The where and when of consciousness in the brain. *Behavioral and Brain Sciences* 15:183–247. [aRN]
Desimone, R. (1998) Visual attention mediated by biased competition in extrastriate visual cortex. *Philosophical Transactions of the Royal Society of London B: Biological Sciences* 353(1373):1245–55. [aRN]
Desimone, R. & Duncan, J. (1995) Neural mechanisms of selective visual attention. *Annual Review of Neuroscience* 18:193–222. [aRN]
DeYoe, E. A. & Van Essen, D. C. (1988) Concurrent processing streams in monkey visual cortex. *Trends in Neuroscience* 11(5):219–26. [aRN]
DiCarlo, J. J. & Maunsell, J. H. (2005) Using neuronal latency to determine sensory-motor processing pathways in reaction time tasks. *Journal of Neurophysiology* 93(5):2974–86. [aRN]
Diedrichsen, J., Verstynen, T., Hon, A., Lehman, S. L. & Ivry, R. B. (2003) Anticipatory adjustments in the unloading task: Is an efference copy necessary for learning? *Experimental Brain Research* 148(2):272–76. [aRN]
Dowling, J. E. (1979) Information processing by local circuits: the vertebrate retina as a model system. In: *The neurosciences: Fourth study program*, ed. F. O. Schmitt & F. G. Worden. MIT Press. [aRN]
Dreher, B., Fukada, Y. & Rodieck, R. W. (1976) Identification, classification and anatomical segregation of cells with X-like and Y-like properties in the lateral geniculate nucleus of old-world primates. *Journal of Physiology* 258(2):433–52. [aRN]
Dubois, D. M. (2003) Mathematical foundations of discrete and functional systems with strong and weak anticipations. In: *Lecture notes in computer science*, *2684*, pp. 110–32. Springer. [NS]
DuBois, R. M. & Cohen, M. S. (2000) Spatiotopic organization in human superior colliculus observed with fMRI. *Neuroimage* 12(1):63–70. [aRN]
Duhamel, J.-R., Colby, C. L. & Goldberg, M. E. (1992) The updating of the representation of visual space in parietal cortex by intended eye movements. *Science* 255:90–92. [aRN, GP]
Durant, S. & Johnston, A. (2004) Temporal dependence of local motion induced shifts in perceived position. *Vision Research* 44(4):357–66. [DW]
Eagleman, D. M. (2001) Visual illusions and neurobiology. *Nature Reviews Neuroscience* 2(12):920–26. [DME]
Eagleman, D. M. & Sejnowski, T. J. (2000) Motion integration and postdiction in visual awareness. *Science* 287(5460):2036–38. [DME, arRN, JBJS, MZ]
(2007) Motion signals bias localization judgments: a unified explanation for the flash-lag, flash-drag, flash-jump, and Frohlich illusions. *Journal of Vision* 7(4):3, 1–12. [DME, PDH, rRN, DW]
Engel, A. K., Fries, P. & Singer, W. (2001) Dynamic predictions: Oscillations and synchrony in top-down processing. *Nature Reviews Neuroscience* 2(10):704–16. [aRN]
Enns, J. T. & Oriet, C. (2004) Perceptual asynchrony: Modularity of consciousness or object updating? [Abstract]. *Journal of Vision* 4(8):27, 27a. Available at: http://journalofvision.org/4/8/27/. [MVCB]
Erlhagen, W. (2003) Internal models for visual perception. *Biological Cybernetics* 88(5):409–17. [MVCB, arRN]
Eskandar, E. N. & Assad, J. A. (1999) Dissociation of visual, motor and predictive signals in parietal cortex during visual guidance. *Nature Neuroscience* 2(1):88–93.
Fajen, B. R. (2007) Rapid recalibration based on optic flow in visually guided action. *Experimental Brain Research* 183:61–74. [DWC]
Farrer, C., Frey, S. H., Van Horn, J. D., Tunik, E., Turk, D., Inati, S. & Grafton, S. T. (2008) The angular gyrus computes action awareness representations. *Cerebral Cortex* 18(2):254–61. [JEC]
Fawcett, J. W. & O'Leary, D. M. (1985) The role of electrical activity in the formation of topographical maps in the nervous system. *Trends in Neuroscience* 8:201–206. [rRN]
Fein, A. & Szuts, E. Z. (1982) *Photoreceptors: Their role in vision*. Cambridge University Press. [aRN]
Felleman, D. J. & Van Essen, D. C. (1991) Distributed hierarchical processing in the primate cerebral cortex. *Cerebral Cortex* 1(1):1–47. [aRN]
Ferrera, V. P. & Barborica, A. (2006) A flashing line can warp your mind. *Neuron* 49(3):327–29. [MZ]
Franz, V. H., Gegenfurtner, K. R., Bulthoff, H. H. & Fahle, M. (2000) Grasping visual illusions: no evidence for a dissociation between perception and action. *Psychological Science* 11(1):20–25. [aRN]
Freyd, J. J. (1987) Dynamic mental representations. *Psychological Review* 94(4):427–38. [DK, aRN]
Fröhlich, F. W. (1923) Über die Messung der Empfindungszeit. [On the measurement of sensation time]. *Zeitschrift für Sinnesphysiologie* 54:58–78. [DK]
Fu, Y. X., Shen, Y. & Dan, Y. (2001) Motion-induced perceptual extrapolation of blurred visual targets. *Journal of Neuroscience* 21(20):RC172. [aRN]
Fu, Y. X., Shen, Y., Gao, H. & Dan, Y. (2004) Asymmetry in visual cortical circuits underlying motion-induced perceptual mislocalization, *Journal of Neuroscience* 24:2165–71. [JB, BRS]
Fujisaki, W., Shimojo, S., Kashino, M. & Nishida, S. (2004) Recalibration of audiovisual simultaneity. *Nature Neuroscience* 7:773–78. [DWC]
Fukushima, K., Yamanobe, T., Shinmei, Y. & Fukushima, J. (2002) Predictive responses of periarcuate pursuit neurons to visual target motion. *Experimental Brain Research* 145(1):104–20. [rRN, GP]
Gawne, T. J., Kjaer, T. W. & Richmond, B. J. (1996) Latency: Another potential code for feature binding in striate cortex. *Journal of Neurophysiology* 76(2):1356–60. [DME]
Gegenfurtner, K. (1999) Neurobiology. The eyes have it! *Nature* 398(6725):291–92. [aRN]
Georgopoulos, A. P. (1986) On reaching. *Annual Review of Neuroscience* 9:147–70. [aRN]
Ghez, C. & Krakauer, J. (2000) The organization of movement. In: *Principles of neural science*, ed. E. R. Kandel, J. H. Schwartz & T. M. Jessell. McGraw Hill.

Gibson, E. J. (1994) Has psychology a future? *Psychological Science* 5:69–76. [JBW]

Gibson, J. J. (1961) Ecological optics. *Vision Research* 1:253–62. [aRN]

(1979) *The ecological approach to visual perception.* Houghton Mifflin. [JBW]

Glennan, S. (2005) Modeling mechanisms. *Studies in History and Philosophy of Biological and Biomedical Sciences* 36:443–64. [GT]

Goel, A., Jiang, B., Xu, L. W., Song, L., Kirkwood, A. & Lee, H. K. (2006) Cross-modal regulation of synaptic AMPA receptors in primary sensory cortices by visual experience. *Nature Neuroscience* 9(8):1001–1003. [aRN]

Gomi, H., Abekawa, N. & Nishida, S. (2006) Spatiotemporal tuning of rapid interactions between visual-motion analysis and reaching movement. *Journal of Neuroscience* 26(20):5301–308. [DW]

Goodale, M. A. & Milner, A. D. (1992) Separate visual pathways for perception and action. *Trends in Neurosciences* 15(1):20–25. [aRN]

Goodale, M. A., Pelisson, D. & Prablanc, C. (1986) Large adjustments in visually guided reaching do not depend on vision of the hand or perception of target displacement. *Nature* 320(6064):748–50. [BKh, aRN]

Gottlieb, J. P., Bruce, C. J. & MacAvoy, M. G. (1993) Smooth eye movements elicited by microstimulation in the primate frontal eye field. *Journal of Neurophysiology* 69:786–99. [GP]

Gottlieb, J. P., MacAvoy, M. G. & Bruce, C. J. (1994) Neural responses related to smooth pursuit eye movements and their correspondence with electrically elicited slow eye movements in the primate frontal eye field. *Journal of Neurophysiology* 72:1634–53. [GP]

Gottsdanker, R. M. (1952) The accuracy of prediction motion. *Journal of Experimental Psychology* 43:26–36. [GP]

Grant, K. W., van Wassenhove, V. & Poeppel, D. (2004) Detection of auditory (cross-spectral) and auditory-visual (cross-modality) asynchrony. *Speech Communication* 44:43–53. [JEC]

Gregory, R. (1979) *Eye and brain*, Weidenfeld and Nicholson. [rRN]

Grossberg, S. & Mingolla, E. (1985) Neural dynamics of form perception: Boundary completion, illusory figures, and neon color spreading. *Psychological Review* 92(2):173–211. [JB]

Grush, R. (2004) The emulator theory of representation: Motor control, imagery and perception. *Behavioral and Brain Sciences* 27:377–442. [CB]

Grzywacz, N. M. & Amthor, F. R. (1993) Facilitation in ON-OFF directionally selective ganglion cells of the rabbit retina. *Journal of Neurophysiology* 69(6):2188–99. [arRN]

Grzywacz, N. M., Watamaniuk, S. N. J. & McKee, S. P. (1995) Temporal coherence theory for the detection and measurement of visual motion. *Vision Research* 35:3183–203. [HO]

Harris, C. S. (1963) Adaptation to displaced vision: Visual, motor, or proprioceptive change? *Science* 140:812–13. [aRN]

(1980) Insight or out of sight? Two examples of perceptual plasticity in the human adult. In: *Visual coding and adaptability*, ed. C. S. Harris. Erlbaum. [aRN]

Hawkins, J. & Blakeslee, S. (2004) *On intelligence*. Owl Press. [DME]

Haykin, S. (1996) *Adaptive filter theory*. Prentice Hall. [DJM]

Hazelhoff, F. & Wiersma, H. (1924) Die Wahrnehmungszeit I. *Zeitschrift für Psychologie* 96:171–88. [WvdG, aRN]

(1925) Die Wahrnehmungszeit II. *Zeitschrift für Psychologie* 97:174–90. [WvdG]

He, S., Cavanagh, P. & Intriligator, J. (1996) Attentional resolution and the locus of visual awareness. *Nature* 383(6598):334–37. [ZL, aRN]

Held, R. & Freedman, S. J. (1963) Plasticity in human sensorimotor control. *Science* 142:455–62. [aRN]

Henriques, D. Y., Klier, E. M., Smith, M. A., Lowy, D. & Crawford, J. D. (1998) Gaze-centered remapping of remembered visual space in an open-loop pointing task. *Journal of Neuroscience* 18(4):1583–94. [DW]

Henry, G. H., Goodwin, A. W. & Bishop, P. O. (1978) Spatial summation of responses in receptive fields of single cells in cat striate cortex. *Experimental Brain Research* 32(2):245–66. [BRS]

Hess, C. V. (1904) Untersuchungen über den Erregungsvorgang in Sehorgan bei Kurz- und bei länger dauernder Reizung. *Pflügers Archiv für die gesammte Physiologie des Menschen und Thiere* 101:226–62. [DW]

Hess, E. H. (1956) Space perception in the chick. *Scientific American* 195:71–80. [aRN]

Holy, T. E. (2007) A public confession: The retina trumpets its failed predictions. *Neuron* 55(6):831–32. [rRN]

Houtkamp, R., Spekreijse, H. & Roelfsema, P. R. (2003) A gradual spread of attention during mental curve tracing. *Perception and Psychophysics* 65:1136–44. [MVCB]

Hubbard, T. L. (2005) Representational momentum and related displacement in spatial memory: A review of the findings. *Psychonomic Bulletin & Review* 12(5):822–51. [DK]

Hubel, D. H. & Livingstone, M. S. (1987) Segregation of form, color, and stereopsis in primate area 18. *Journal of Neuroscience* 7:3378–415. [HO]

Hubel, D. H. & Wiesel, T. N. (1959) Receptive fields of single neurons in the cat's striate cortex. *Journal of Physiology* 148:574–91. [rRN]

(1961) Integrative action in the cat's lateral geniculate body. *Journal of Physiology* 155:385–98. [PDH]

(1962) Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. *Journal of Physiology* 160:106–54. [PDH, aRN]

Hupe, J. M., James, A. C., Payne, B. R., Lomber, S. G., Girard, P. & Bullier, J. (1998) Cortical feedback improves discrimination between figure and background by V1, V2 and V3 neurons. *Nature* 394(6695):784–87. [aRN]

Jacobs, D. M. & Michaels, C. F. (2006) Lateral interception I: Operative optical variables, attunement, and calibration. *Journal of Experimental Psychology: Human Perception and Performance* 32(2):443–58. [NB]

Jagadeesh, B., Wheat, H. S., Kontsevich, L. L., Tyler, C. W. & Ferster, D. (1997) Direction selectivity of synaptic potentials in simple cells of the cat visual cortex. *Journal of Neurophysiology* 78(5):2772–89. [JB]

Jancke, D., Erlhagen, W., Dinse, H. R., Akhavan, A. C., Giese, M., Steinhage, A. & Schoner, G. (1999) Parametric population representation of retinal location: Neuronal interaction dynamics in cat primary visual cortex. *Journal of Neuroscience* 19(20):9016–28. [aRN]

Jeannerod, M., Kennedy, H. & Magnin, M. (1979) Corollary discharge: Its possible implications in visual and oculomotor interactions. *Neuropsychologia* 17(2):241–58. [aRN]

Jiang, Y., Zhou, K. & He, S. (2007) Human visual cortex responds to invisible chromatic flicker. *Nature Neuroscience* 10(5):657–62. [ZL]

Johansson, R. S. & Westling, G. (1988) Programmed and triggered actions to rapid load changes during precision grip. *Experimental Brain Research* 71(1):72–86. [aRN]

Kafalıgönül, H., Patel, S. S., Öğmen, H., Bedell, H. E. & Purushothaman, G. (in press) Perceptual asynchronies and the dual-channel differential latency hypothesis. In: *Space and time in perception and action*, ed. R. Nijhawan & B. Khurana. Cambridge University Press. [HO]

Kanai, R., Sheth, B. R. & Shimojo, S. (2004) Stopping the motion and sleuthing the flash-lag effect: spatial uncertainty is the key to perceptual mislocalization. *Vision Research* 44(22):2605–19. [MVCB, aRN, BRS]

Kandel, E. R. & Wurtz, R. H. (2000) Constructing the visual image. In: *Principles of neural science*, ed. E. R. Kandel, J. H. Schwartz & T. M. Jessell. McGraw Hill. [arRN]

Kaplan, E. & Shapley, R. M. (1982) X and Y cells in the lateral geniculate nucleus of macaque monkeys. *Journal of Physiology* 330:125–43. [aRN]

Kawato, M. (1999) Internal models for motor control and trajectory planning. *Current Opinion in Neurobiology* 9(6):718–27. [CB, aRN]

Kawato, M., Furukawa, K. & Suzuki, R. (1987) A hierarchical neural-network model for control and learning of voluntary movement. *Biological Cybernetics* 57(3):169–85. [aRN]

Keating, E. G. (1991) Frontal eye field lesions impair predictive and visually guided pursuit eye movements. *Experimental Brain Research* 86:311–23. [GP]

Kerzel, D. (2003) Mental extrapolation of target position is strongest with weak motion signals and motor responses. *Vision Research* 43(25):2623–35. [DK]

Kerzel, D. & Gegenfurtner, K. R. (2003) Neuronal processing delays are compensated in the sensorimotor branch of the visual system. *Current Biology* 13(22):1975–78. [DK, GP]

Keysers, C. & Perrett, D. I. (2002) Visual masking and RSVP reveal neural competition. *Trends in Cognitive Sciences* 6(3):120–25. [aRN]

Khurana, B., Carter, R. M., Watanabe, K. & Nijhawan, R. (2006) Flash-lag chimeras: The role of perceived alignment in the composite face effect. *Vision Research* 46(17):2757–72. [BKh, aRN]

Khurana, B. & Nijhawan, R. (1995) Extrapolation or attention shift? Reply to Baldo and Klein. *Nature* 378:565–66. [MVCB, DME, arRN]

Khurana, B., Watanabe, K. & Nijhawan, R. (2000) The role of attention in motion extrapolation: Are moving objects "corrected" or flashed objects attentionally delayed? *Perception* 29(6):675–92. [arRN]

Kirschfeld, K. (1983) Are photoreceptors optimal? *Trends in Neurosciences* 6:97–101. [aRN]

Kirschfeld, K. & Kammer, T. (1999) The Fröhlich effect: A consequence of the interaction of visual focal attention and metacontrast. *Vision Research* 39(22):3702–709. [aRN]

Koenderink, J. J. (1984a) The concept of local sign. In: *Limits in perception*, ed. A. J. van Doorn, W.A. van de Grind & J. J. Koenderink, pp. 495–547. VNU Science Press. [WvdG]

(1984b) Simultaneous order in nervous nets from a functional standpoint. *Biological Cybernetics* 50:35–41. [WvdG]

Koken, P. W. & Erkelens, C. J. (1992) Influences of hand movements on eye movements in tracking tasks in man. *Experimental Brain Research* 88:657–64. [JBJS]

Komatsu, H. & Wurtz, R. H. (1988) Relation of cortical areas MT and MST to pursuit eye movements. I. Localization and visual properties of neurons. *Journal of Neurophysiology* 60:580–603. [GP]

Kosslyn, S. M. & Sussman, A. (1994) Roles of imagery in perception: Or, there is no such thing as immaculate perception. In: *The cognitive neurosciences*, ed. M. S. Gazzaniga. MIT Press. [rRN]

Kosslyn, S. M., Thompson, W. L., Kim, I. J. & Alpert, N. M. (1995) Topographical representations of mental images in primary visual cortex. *Nature* 378(6556):496–98. [rRN]

Krauzlis, R. J. (2004) Recasting the Smooth Pursuit Eye Movement System. *Journal of Neurophysiology* 91(2):591–603. [JPM]

Krekelberg, B. & Albright, T. D. (2005) Motion mechanisms in macaque MT. *Journal of Neurophysiology* 93(5):2908–21. [BKr]

Krekelberg, B., Dannenberg, S., Hoffmann, K. P., Bremmer, F. & Ross, J. (2003) Neural correlates of implied motion. *Nature* 424(6949):674–77. [BKr]

Krekelberg, B. & Lappe, M. (1999) Temporal recruitment along the trajectory of moving objects and the perception of position. *Vision Research* 39:2669–79. [GP]

(2001) Neuronal latencies and the position of moving objects. *Trends in Neurosciences* 24:335–39. [ZL, arRN, BRS, MZ]

Krekelberg, B., van Wezel, R. J. & Albright, T. D. (2006) Adaptation in macaque MT reduces perceived speed and improves speed discrimination. *Journal of Neurophysiology* 95(1):255–70. [BKr]

Lacquaniti, F. & Maioli, C. (1989) The role of preparation in tuning anticipatory and reflex responses during catching. *Journal of Neuroscience* 9(1):134–48. [aRN, MZ]

Lamarre, Y., Busby, L. & Spidalieri, G. (1983) Fast ballistic arm movements triggered by visual, auditory, and somesthetic stimuli in the monkey. I. Activity of precentral cortical neurons. *Journal of Neurophysiology* 50(6):1343–58. [aRN]

Lamme, V. A. & Roelfsema, P. R. (2000) The distinct modes of vision offered by feedforward and recurrent processing. *Trends in Neuroscience* 23(11):571–z79. [ZL, aRN]

Land, M. F. & Furneaux, S. (1997) The knowledge base of the oculomotor system. *Philosophical Transactions of the Royal Society of London B* 352:1231–39. [GP]

Land, M. F. & McLeod, P. (2000) From eye movements to actions: how batsmen hit the ball. *Nature Neuroscience* 3(12):1340–45. [JEC, aRN, GP, JBJS]

Lankheet, M. J. M. & van de Grind, W. (in press) Simultaneity versus asynchrony of visual motion and luminance changes. In: *Space and time in perception and action*, ed. R. Nijhawan & B. Khurana, Ch. 18. Cambridge University Press. [WvdG]

Le Runigo, C., Benguigui, N. & Bardy, B. G. (2005) Perception-action coupling and expertise in interceptive action. *Human Movement Science* 24:429–45. [NB]

Lee, C., Rohrer, W. H. & Sparks, D. L. (1988) Population coding of saccadic eye movements by neurons in the superior colliculus. *Nature* 332(6162):357–60. [aRN]

Lee, D. N. (1976) A theory of visual control of braking based on information about time-to-collision. *Perception* 5(4):437–59. [aRN, MZ]

Lee, D. N. & Reddish, P. E. (1981) Plummeting gannets: A paradigm of ecological optics. *Nature* 293:293–94. [aRN]

Lee, D. N., Young, D. S., Reddish, P., Lough, S. & Clayton, T. (1983) Visual timing in hitting an accelerating ball. *Quarterly Journal of Experimental Psychology* 35:333–46. [NB]

Lee, J., Williford, T. & Maunsell, J. H. (2007) Spatial attention and the latency of neuronal responses in macaque area V4. *Journal of Neuroscience* 27(36):9632–37. [DME]

Leon, M. I. & Shadlen, M. N. (2003) Representation of time by neurons in the posterior parietal cortex of the macaque. *Neuron* 38(2):317–27. [MZ]

Levitt, J. B. & Lund, J. S. (1997) Contrast dependence of contextual effects in primate visual cortex. *Nature* 387(6628):73–76. [BRS]

Liberman, A. M. & Mattingly, I. G. (1985) The motor theory of speech perception revised. *Cognition* 21(1):1–36. [aRN]

Lin, Z. & He, S. (in press) Seeing the invisible: The scope and limits of unconscious processing in binocular rivalry. *Progress in Neurobiology* [ZL]

Lisberger, S. G. & Movshon, J. A. (1999) Visual motion analysis for pursuit eye movements in area MT of macaque monkeys. *Journal of Neuroscience* 19:2224–46. [GP, MZ]

Liu, J. & Newsome, W. T. (2005) Correlation between speed perception and neural activity in the middle temporal visual area. *Journal of Neuroscience* 25:711–22. [GP]

Livingstone, M. S. (1998) Mechanisms of direction selectivity in macaque V1. *Neuron* 20:509–26. [JB]

Lobjois, R., Benguigui, N. & Bertsch J. (2006) The effect of aging and tennis playing on coincidence-timing accuracy. *Journal of Aging and Physical Activity* 14(1):75–98. [NB, JEC]

MacAvoy, M. G., Gottlieb, J. P. & Bruce, C. J. (1991) Smooth pursuit eye movement representation in the primate frontal eye field. *Cerebral Cortex* 1:95–102. [GP]

Machamer, P., Darden, L. & Craver, C. F. (2000) Thinking about mechanisms. *Philosophy of Science* 67:1–25. [GT]

Macknik, S. L., Martinez-Conde, S. & Haglund, M. M. (2000) The role of spatiotemporal edges in visibility and visual masking. *Proceedings of the National Academy of Sciences USA* 97(13):7556–60. [aRN]

Maimon, G. & Assad, J. A. (2006) A cognitive signal for the proactive timing of action in macaque LIP. *Nature Neuroscience* 9(7):948–55. [MZ]

Marr, D. (1982) *Vision*. W. H. Freeman. [aRN]

Mateeff, S. & Hohnsbein, J. (1988) Perceptual latencies are shorter for motion towards the fovea than for motion away. *Vision Research* 28(6):711–19. [aRN]

Mates, J., Muller, U., Radil, T. & Poppel, E. (1994) Temporal integration in sensorimotor synchronization. *Journal of Cognitive Neuroscience* 6:332–40. [rRN]

Matin, L., Boff, K. & Pola, J. (1976) Vernier offset produced by rotary target motion. *Perception & Psychophysics* 20(2):138–42. [DW]

Maunsell, J. H., Ghose, G. M., Assad, J. A., McAdams, C. J., Boudreau, C. E. & Noerager, B. D. (1999) Visual response latencies of magnocellular and parvocellular LGN neurons in macaque monkeys. *Visual Neuroscience* 16(1):1–14. [DME]

Maunsell, J. H. & Gibson, J. R. (1992) Visual response latencies in striate cortex of the macaque monkey. *Journal of Neurophysiology* 68(4):1332–44. [aRN]

Maus, G. W. & Nijhawan, R. (2006) Forward displacements of fading objects in motion: The role of transient signals in perceiving position. *Vision Research* 46(26):4375–81. [PDH, DK, arRN, HO, GP]

(in press) Going going gone: Localizing abrupt offsets of moving objects. *Journal of Experimental Psychology: Human Perception and Performance*. [rRN]

Mayo, J. P. & Sommer, M. A. (submitted) Neuronal adaptation due to sequential visual stimulation in the frontal eye field. [JPM]

McGraw, P. V., Walsh, V. & Barrett, B. T. (2004) Motion-sensitive neurones in V5/MT modulate perceived spatial position. *Current Biology* 14(12):1090–1093. [JB]

McIntyre, J., Zago, M., Berthoz, A. & Lacquaniti, F. (2001) Does the brain model Newton's laws? *Nature Neuroscience* 4:693–94. [MZ]

McLeod, P. (1987) Visual reaction time and high-speed ball games. *Perception* 16 49–59. [NB]

Mehta, B. & Schaal, S. (2002) Forward models in visuomotor control. *Journal of Neurophysiology* 88(2):942–53. [aRN]

Meister, M., Wong, R. O., Baylor, D. A. & Shatz, C. J. (1991) Synchronous bursts of action potentials in ganglion cells of the developing mammalian retina. *Science* 252(5008):939–43. [rRN]

Merchant, H., Battaglia-Mayer, A. & Georgopoulos, A. P. (2004) Neural responses during interception of real and apparent circularly moving stimuli in motor cortex and area 7a. *Cerebral Cortex* 14:314–31. [MZ]

Merfeld, D. M., Zupan, L. & Peterka, R. J. (1999) Humans use internal models to estimate gravity and linear acceleration. *Nature* 398(6728):615–18. [aRN]

Metzger, W. (1932) Versuch einer gemeinsamen Theorie der Phänomene Fröhlichs und Hazelhoffs und Kritik ihrer Verfahren zur Messung der Empfindungszeit. *Psychologische Forschung* 16:176–200. [aRN, WvdG]

Meyer, D. E., Osman, A. M., Irwin, D. E. & Yantis, S. (1988) Modern mental chronometry. *Biological Psychology* 26(1–3):3–67. [aRN]

Miall R. C. & Jackson J. K. (2006) Adaptation to visual feedback delays in manual tracking: evidence against the Smith Predictor model of human visually guided action. *Experimental Brain Research* 172:77–84. [DWC]

Milner, A. D. & Goodale, M. A. (1995) *The visual brain in action*. Oxford University Press. [aRN]

Mishkin, M. & Ungerleider, L. G. (1983) Object vision and spatial vision: Two cortical pathways. *Trends in Neuroscience* 6:414–35. [aRN]

Morgan, M. J. & Thompson, P. (1975) Apparent motion and the Pulfrich effect. *Perception* 4(1):3–18. [aRN]

Mountcastle, V. B., Motter, B. C., Steinmetz, M. A. & Duffy, C. J. (1984) Looking and seeing: the visual functions of the parietal lobe. In: *Dynamic aspects of neocortical function*, ed. G. M. Edelman, W. E. Gall & W. M. Cowan, pp. 159–93. Wiley. [rRN]

Mrotek, L. A. & Soechting, J. F. (2007) Target interception: Hand-eye coordination and strategies. *Journal of Neuroscience* 27(27):7297–309. [JBJS]

Murakami, I. (2001) A flash-lag effect in random motion *Vision Research* 41:3101–19. [HO]

Müsseler, J. & Kerzel, D. (2004) The trial context determines adjusted localization of stimuli: Reconciling the Fröhlich and onset repulsion effects. *Vision Research* 44(19):2201–206. [DK]

Müsseler, J. & Prinz, W. (1996) Action planning during the presentation of stimulus sequences: effects of compatible and incompatible stimuli. *Psychological Research* 59(1):48–63. [aRN]

Müsseler, J., Stork, S. & Kerzel, D. (in press) Localising the onset of moving stimuli by pointing or relative judgment: Variations in the size of the Fröhlich effect. *Vision Research*. [DK]

Nakamura, K. & Colby, C. L. (2002) Updating of the visual representation in monkey striate and extrastriate cortex during saccades. *Proceedings of the National Academy of Sciences of the USA* 99:4026–31. [GP]

Nakamura, K., Matsumoto, K., Mikami, A. & Kubota, K. (1994) Visual response properties of single neurons in the temporal pole of behaving monkeys. *Journal of Neurophysiology* 71(3):1206–21. [aRN]

Nakayama, K. (1985) Biological image motion processing: a review. *Vision Research* 25(5):625–60. [rRN]

Namba, J. & Baldo, M. V. C. (2004) The modulation of the flash-lag effect by voluntary attention. *Perception* 34:621–31. [MVCB, BRS]

Navarra, J., Soto-Faraco, S. & Spence, C. (2007) Adaptation to audiotactile asynchrony. *Neuroscience Letters* 413:72–76. [DWC]

Neisser, U. (1976) *Cognition and reality: Principles and implications of cognitive psychology*. W.H. Freeman. [rRN]

Neuenschwander, S., Castelo-Branco, M., Baron, J. & Singer, W. (2002) Feed-forward synchronization: propagation of temporal patterns along the retinothalamocortical pathway. *Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences* 357(1428):1869–76. [rRN]

Newsome, W. T. & Paré, E. B. (1988) A selective impairment of motion perception following lesions of the middle temporal visual area (MT). *Journal of Neuroscience* 8:2201–11. [GP]

Newsome, W. T., Wurtz, R. H. & Komatsu, H. (1988) Relation of cortical areas MT and MST to pursuit eye movements. II. Differentiation of retinal from extraretinal inputs. *Journal of Neurophysiology* 60:604–20. [GP]

Nichols, M. J. & Newsome, W. T. (2002) Middle temporal visual area microstimulation influences veridical judgments of motion direction. *Journal of Neuroscience* 22:9530–40. [GP]

Nijhawan, R. (1992) Misalignment of contours through the interaction of the apparent and real motion systems. *Investigative Ophthalmology and Visual Science* 33(Suppl. 4):1415. [DME, aRN]

(1994) Motion extrapolation in catching. *Nature* 370(6487):256–57. [JB, MVCB, DME, BKh, arRN, HO, GP]

(1997) Visual decomposition of colour through motion extrapolation. *Nature* 386(6620):66–69. [MVCB, arRN]

(2001) The flash-lag phenomenon: object-motion and eye-movements. *Perception* 30:263–82. [arRN, GP]

(2002) Neural delays, visual motion and the flash-lag effect. *Trends in Cognitive Sciences* 6:387–93. [arRN]

Nijhawan, R. & Khurana, B. (2002) Motion, space and mental imagery. *Behavioral and Brain Sciences* 25:203–204. [rRN]

Nijhawan, R. & Kirschfeld, K. (2003) Analogous mechanisms compensate for neural delays in the sensory and the motor pathways: Evidence from motor flash-lag. *Current Biology* 13(9):749–53. [aRN]

Nishida, S. & Johnston, A. (1999) Influence of motion signals on the perceived position of spatial pattern. *Nature* 397(6720):610–12. [DW]

Noguchi, Y. & Kakigi, R. (2008) Knowledge-based correction of flash-lag illusion. *Journal of Cognitive Neuroscience* 20:1–13. [BKh]

Nunes, G. (2003) Comment on "Eyesight and the solar Wein peak," by James M, Overduin. *American Journal of Physics* 71:519. [rRN]

Öğmen, H., Patel, S. S., Bedell, H. E. & Camuz, K. (2004) Differential latencies and the dynamics of the position computation process for moving targets, assessed with the flash-lag effect. *Vision Research* 44:2109–28. [HO, GP, DW]

O'Regan, J. K. & Noe, A. (2001) A sensorimotor account of vision and visual consciousness. *Behavioral and Brain Sciences* 24(5):939–73. [JBJS]

Palmer, S. E. (1999) *Vision science: Photons to phenomenology.* MIT Press. [PDH]

Parkinson, J. & Khurana, B. (2007) Temporal order of strokes primes letter recognition. *Quarterly Journal of Experimental Psychology* 60:1265–74. [aRN]

Patel, S. S., Öğmen, H., Bedell H. E. & Sampath V. (2000) Flash-lag effect: Differential latency, not postdiction. *Science* 290:1051. [HO, GP, BRS]

Petersen, S. E., Baker, J. F. & Allman, J. M. (1985) Direction-specific adaptation in area MT of the owl monkey. *Brain Research* 346(1):146–50. [BKr]

Poritsky, R. (1969) Two- and three-dimensional ultrastructure of boutons and glial cells on the motoneuronal surface in the cat spinal cord. *Journal of Comparative Neurology* 135(4):423–52. [aRN]

Port, N. L., Kruse, W., Lee, D. & Georgopoulos, A. P. (2001) Motor cortical activity during interception of moving targets. *Journal of Cognitive Neuroscience* 13(3):306–18. [aRN]

Price, N. S., Ibbotson, M. R., Ono, S. & Mustari, M. J. (2005) Rapid processing of retinal slip during saccades in macaque area MT. *Journal of Neurophysiology* 94(1):235–46. [BKr]

Price, N. S., Ono, S., Mustari, M. J. & Ibbotson, M. R. (2005) Comparing acceleration and speed tuning in macaque MT: Physiology and modeling. *Journal of Neurophysiology* 94:3451–64. [MZ]

Purushothaman, G. & Bradley, D. C. (2005) Neural population code for fine perceptual decisions in area MT. *Nature Neuroscience* 8:99–106. [GP]

Purushothaman, G., Patel, S. S., Bedell, H. E. & Öğmen, H. (1998) Moving ahead through differential visual latency. *Nature* 396(6710):424. [arRN, HO, GP, BRS, DW]

Raiguel, S. E., Lagae, L., Gulyas, B. & Orban, G. A. (1989) Response latencies of visual cells in macaque areas V1, V2 and V5. *Brain Research* 493(1):155–59. [aRN]

Ramachandran, V. S. & Anstis, S. M. (1990) Illusory displacement of equiluminous kinetic edges. *Perception* 19(5):611–16. [JB, arRN, GP, DW]

Ramachandran, V. S., Rao, V. M. & Vidyasagar, T. R. (1974) Sharpness constancy during movement perception. *Perception* 3(1):97–98. [aRN]

Ratliff, F. (1965) *Mach bands: Quantitative studies on neural networks in the retina*. Holden-Day. [rRN]

Ratliff, F. & Hartline, H. K. (1959) The responses of limulus optic nerve fibers to patterns of illumination on the receptor mosaic. *Journal of General Physiology* 42(6):1241–55. [aRN]

Reed, E. S. (1996) *Encountering the world: Toward an ecological psychology.* Oxford University Press. [JBW]

Regan, D. (1992) Visual judgements and misjudgements in cricket, and the art of flight. *Perception* 21(1):91–115. [aRN]

Regan, D. & Beverley, K. I. (1984) Figure-ground segregation by motion contrast and by luminance contrast. *Journal of the Optical Society of America A* 1:433–42. [DW]

Reichardt, W. (1961) Autocorrelation, A principle for the evaluation of sensory information by the central nervous system. In: *Sensory communication*, ed. W. A. Rosenblith, pp. 303–17. Wiley. [JB]

Rizzolatti, G., Fadiga, L., Fogassi, L. & Gallese, V. (1997) The space around us. *Science* 277(5323):190–91. [aRN]

Robinson, D. L. & Kertzman, C. (1995) Covert orienting of attention in macaques: III. Contributions of the superior colliculus. *Journal of Neurophysiology* 74(2):713–21. [JPM]

Roelfsema, P. R., Lamme, V. A. F. & Spekreijse, H. (2000) The implementation of visual routines. *Vision Research* 40:1385–1411. [MVCB]

Rojas-Anya, H., Thirkettle, M. & Nijhawan, R. (2005) Flash-lag anisotropy for movement in three domains. *Perception* 34:219–20. [aRN]

Roufs, J. A. J. (1963) Perception lag as a function of stimulus luminance. *Vision Research* 3:81–91. [aRN]

Saijo, N., Murakami, I., Nishida, S. & Gomi, H. (2005) Large-field visual motion directly induces an involuntary rapid manual following response. *Journal of Neuroscience* 25(20):4941–51. [DW]

Salzman, C. D., Britten, K. H. & Newsome, W. T. (1990) Cortical microstimulation influences perceptual judgments of motion direction. *Nature* 346:174–77. [GP]

Salzman, C. D., Murasugi, C. M., Britten, K. H. & Newsome, W. T. (1992) Microstimulation in visual area MT: Effects on direction discrimination performance. *Journal of Neuroscience* 12:2331–55. [GP]

Sarich, D., Chappell, M. & Burgess, C. (2007) Dividing attention in the flash-lag illusion. *Vision Research* 47:544–47. [MVCB]

Sarlegna, F. R., Gauthier, G. M., Bourdin, C., Vercher, J. L. & Blouin, J. (2006) Internally driven control of reaching movements: A study on a proprioceptively deafferented subject. *Brain Research Bulletin* 69(4):404–15. [rRN]

Sarnat, H. B. & Netsky, M. G. (1981) *Evolution of the nervous system*. Oxford Uinversity Press. [aRN]

Schall, J. D. (2004) Selection of targets for saccadic eye movements. In: *Visual neurosciences*, ed. L. M. Chalupa & J. S. Werner. MIT Press. [GP]

Schiller, P. H. (1984) The superior colliculus and visual function. In: *Handbook of physiology: The nervous system. Neurophysiology*, ed. I. Darien-Smith. American Physiological Society. [aRN]

Schiller, P. H. & Malpeli, J. G. (1978) Functional specificity of lateral geniculate nucleus laminae of the rhesus monkey. *Journal of Neurophysiology* 41(3):788–97. [aRN]

Schlack, A. & Albright, T. (2007) Remembering visual motion: Neural correlates of associative plasticity and motion recall in cortical area MT. *Neuron* 53(6):881–90. [BKr]

Schlack, A., Krekelberg, B. & Albright, T. D. (2007) Recent history of stimulus speeds affects the speed tuning of neurons in area MT. *Journal of Neuroscience* 27(41):11009–18. [MZ]

Schlag, J. & Schlag-Rey, M. (2002) Through the eye slowly: delays and localization errors in the visual system. *Nature Reviews Neuroscience* 3:191–200. [aRN]

Schmolesky, M. T., Wang, Y., Hanes, D. P., Thompson, K. G., Leutgeb, S., Schall, J. D. & Leventhal, A. G. (1998) Signal timing across the macaque visual system. *Journal of Neurophysiology* 79(6):3272–78. [aRN]

Schoppmann, A. & Hoffmann, K. P. (1976) Continuous mapping of direction selectivity in the cat's visual cortex. *Neuroscience Letters* 2:177–81. [BKr]

Schwartz, G., Harris, R., Shrom, D. & Berry, M. J. (2007a) Detection and prediction of periodic patterns by the retina. *Nature Neuroscience* 10(5):552–54. [JPM]

Schwartz, G., Taylor, S., Fisher, C., Harris, R. & Berry, M. J., 2nd. (2007b) Synchronized firing among retinal ganglion cells signals motion reversal. *Neuron* 55(6):958–69. [WvdG, rRN]

Senot, P., Zago, M., Lacquaniti, F. & McIntyre, J. (2005) Anticipating the effects of gravity when intercepting moving objects: Differentiating up and down based on nonvisual cues. *Journal of Neurophysiology* 94(6):4471–80. [MZ]

Serre, T., Kouh, M., Cadieu, C., Knoblich, U., Kreiman, G. & Poggio, T. (2005) A theory of object recognition: Computations and circuits in the feedforward path of the ventral stream in primate visual cortex. CBCL Paper No. 259/AI Memo No. 2005-036, Massachusetts Institute of Technology, MA: Cambridge. Available at: http://cbcl.mit.edu/projects/cbcl/publications/ai-publications/2005/AIM-2005-036.pdf. [GT]

Sestokas, A. K. & Lehmkuhle, S. (1986) Visual response latency of x- and y- cells in the dorsal lateral geniculate nucleus of the cat. *Vision Research* 26:1041–54. [DWC]

Shapley, R. M. & Victor, J. D. (1978) The effect of contrast on the transfer properties of cat retinal ganglion cells. *Journal of Physiology* 285:275–98. [aRN]

Shaw, R. E. & Turvey, M. T. (1999) Ecological foundations of cognition: II. Degrees of freedom and conserved quantities in animal-environment systems. *Journal of Consciousness Studies* 6:111–23. [JBW]

Shaw, R. E. & Wagman, J. B. (2001) Explanatory burdens and natural law: Invoking a field description of perception-action. *Behavioral and Brain Sciences* 24:905–906. [JBW]

Sheridan, T. B. & Ferrel, W. R. (1963) Remote manipulative control with transmission delay. *Perceptual and Motor Skills* 20:1070–72. [DWC]

Sheth, B. R., Nijhawan, R. & Shimojo, S. (2000) Changing objects lead briefly flashed ones. *Nature Neuroscience* 3(5):489–95. [JB, MVCB, aRN, BRS]

Shi, Z. & Nijhawan, R. (under review) Behavioral significance of motion direction causes anisotropic flash-lag, flash-mislocalization and movement-mislocalization effects. *Journal of Vision*. [rRN]

Sillito, A. M., Jones, H. E., Gerstein, G. L. & West, D. C. (1994) Feature-linked synchronization of thalamic relay cell firing induced by feedback from the visual cortex. *Nature* 369(6480):479–82. [arRN]

Smeets, J. B. J. & Bekkering, H. (2000) Prediction of saccadic amplitude during smooth pursuit eye movements. *Human Movement Science* 19(3):275–95. [JBJS]

Smith, K. U., Wargo, L., Jones, R. & Smith, W. M. (1963) Delayed and space displaced sensory feedback and learning. *Perceptual and Motor Skills* 16:781–96. [DWC]

Smith, W. M., McCrary, J. R. & Smith, K. U. (1962) Delayed visual feedback and behavior. *Science* 132:1013–14. [DWC]

Snowden, R. J. (1998) Shifts in perceived position following adaptation to visual motion. *Current Biology* 8(24):1343–45. [DW]

Snyder, L. (1999) This way up: Illusions and internal models in the vestibular system. *Nature Neuroscience* 2(5):396–98. [arRN]

Somers, D. C., Todorov, E. V., Siapas, A. G., Toth, L. J., Kim, D. S. & Sur, M. (1998) A local circuit approach to understanding integration of long-range inputs in primary visual cortex. *Cerebral Cortex* 8(3):204–17. [BRS]

Sommer, M. A. & Wurtz, R. H. (2002) A pathway in primate brain for internal monitoring of movements. *Science* 296(5572):1480–82. [JPM]

(2006) Influence of the thalamus on spatial visual processing in frontal cortex. *Nature* 444(7117):374–77. [JPM]

Sparks, D. L. & Jay, M. F. (1986) The functional organization of the primate superior colliculus: a motor perspective. *Progress in Brain Research* 64:235–41. [aRN]

Sparks, D. L., Lee, C. & Rohrer, W. H. (1990) Population coding of the direction, amplitude, and velocity of saccadic eye movements by neurons in the superior colliculus. *Cold Spring Harbor Symposium on Quantitative Biology* 55:805–11. [aRN]

Sperry, R. W. (1950) Neural basis of the spontaneous optokinetic response produced by visual inversion. *Journal of Comparative and Physiological Psychology* 43:482–89. [aRN]

(1952) Neurology and the mind-brain problem. *American Scientist* 40:291–312. [aRN]

Stemmler, M., Usher, M. & Niebur, E. (1995) Lateral interactions in primary visual cortex: A model bridging physiology and psychophysics. *Science* 269(5232):1877–80. [BRS]

Stepp, N. & Turvey, M. T. (2007) Strong anticipation, weak anticipation, and ecological psychology. Presented at the 14th International Conference on Perception & Action, Yokohama, Japan, July 2007. [NS]

Sterzer, P. & Kleinschmidt, A. (2007) A neural basis for inference in perceptual ambiguity. *Proceedings of the National Academy of Sciences USA* 104(1):323–28.

Stetson, C., Cui, X., Montague, P. R. & Eagleman D. M. (2006) Motor-sensory recalibration leads to an illusory reversal of action and sensation. *Neuron* 51:651–59. [DWC, DME]

Stoerig, P. & Cowey, A. (1997) Blindsight in man and monkey. *Brain* 120 (Part 3):535–59. [aRN]

Stratton, G. M. (1896) Some preliminary experiments on vision without inversion of the retinal image. *Psychological Review* 3:611–17. [aRN]

Stuart, A., Kalinowski, J., Rastatter, M. P. & Lynch, K. (2002) Effect of delayed auditory feedback on normal speakers at two speech rates. *Journal of the Acoustical Society of America* 111:2237–41. [JEC]

Stürmer, B., Aschersleben, G. & Prinz, W. (2000) Correspondence effects with manual gestures and postures: A study of imitation. *Journal of Experimental Psychology: Human Perception and Performance* 26(6):1746–59. [aRN]

Suddendorf, T. & Corballis, M. C. (2007) Mental time travel across the disciplines: The future looks bright. *Behavioral and Brain Sciences* 30(3):335–45. [DME]

Sugita, Y. & Suzuki, Y. (2003) Audiovisual perception: Implicit estimation of sound-arrival time. *Nature* 421(6926):911. [rRN]

Sun, H. & Frost, B. J. (1998) Computation of different optical variables of looming objects in pigeon nucleus rotundus neurons. *Nature Neuroscience* 1(4):296–303. [aRN]

Sundberg, K. A., Fallah, M. & Reynolds, J. H. (2006) A motion-dependent distortion of retinotopy in area V4. *Neuron* 49(3):447–57. [JB, aRN, MZ]

Taira, M., Mine, S., Georgopoulos, A. P., Murata, A. & Sakata, H. (1990) Parietal cortex neurons of the monkey related to the visual guidance of hand movement. *Experimental Brain Research* 83(1):29–36. [aRN]

Tanaka, K. & Fukushima, K. (1998) Neuronal responses related to smooth pursuit eye movements in the periarcuate cortical area of monkeys. *Journal of Neurophysiology* 80:28–47. [GP]

Taube, J. S., Muller, R. U. & Ranck, J. B., Jr. (1990) Head-direction cells recorded from the postsubiculum in freely moving rats. I. Description and quantitative analysis. *Journal of Neuroscience* 10(2): 420–35. [rRN]

Tessier-Lavigne, M. (2000) Visual processing by the retina. In: *Principles of neural science*, ed. E. R. Kandel, J. H. Schwartz & T. M. Jessell. McGraw Hill. [aRN]

Thiel, A., Greschner, M., Eurich, C. W., Ammermuller, J. & Kretzberg, J. (2007) Contribution of individual retinal ganglion cell responses to velocity and acceleration encoding. *Journal of Neurophysiology* 98(4):2285–96. [MZ]

Thier, P. & Ilg, U. J. (2005) The neural basis of smooth-pursuit eye movements. *Current Opinion in Neurobiology* 15(6):645–52. [aRN, JBJS]

Tootell, R. B., Silverman, M. S., Switkes, E. & De Valois, R. L. (1982) Deoxyglucose analysis of retinotopic organization in primate striate cortex. *Science* 218(4575):902–904. [aRN]

Treisman, A. (1996) The binding problem. *Current Opinions in Neurobiology* 6(2):171–78. [ZL]

Tresilian, J. R. (1993) Four questions of time to contact: A critical examination of research on interceptive timing. *Perception* 22(6):653–80. [NB, JEC, arRN]

(1999) Visually timed action: time-out for "tau"? *Trends in Cognitive Sciences* 3(8):301–10. [aRN]

Tresilian, J. R., Plooy, A. & Carroll, T. J. (2004) Constraints on the spatiotemporal accuracy of interceptive action: Effects of target size on hitting a moving target. *Experimental Brain Research* 155:509–26. [NB]

Treue, S. (2003) Climbing the cortical ladder from sensation to perception. *Trends in Cognitive Sciences* 7(11):469–71. [aRN]

Turvey, M. T. (1992) Affordances and prospective control: An outline of the ontology. *Ecological Psychology* 4:173–87. [JBW]

(2004) Impredicativity, dynamics, and the perception-action divide. In: *Coordination dynamics: Issues and trends. Vol. 1. Applied complex systems*, ed. V. K. Jirsa & J. A. S. Kelso, pp. 1–20. Springer Verlag. [JBW]

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. [JBW]

van de Grind, W. (2002) Physical, neural, and mental timing. *Consciousness and Cognition* 11(2):241–64; discussion 308–13. [aRN, WvdG]

van de Grind, W. A. (2006) Representing times of the past, present and future in the brain. In: *Timing the future. A case for time-based prospective memory*, ed. J. Glicksohn & M. S. Myslobodski. World Scientific Publishing Company. [WvdG]

van den Berg, A. V. (1988) Human smooth pursuit during transient perturbations of predictable and unpredictable target movement. *Experimental Brain Research* 72:95–108. [JBJS]

van Santen, J. P. & Sperling, G. (1985) Elaborated Reichardt detectors. *Journal of the Optical Society of America* 2:300–21. [JB]

Vatakis, A., Navarra, J., Soto-Faraco, S. & Spence, C. (2007) Temporal recalibration during asynchronous audiovisual speech perception. *Experimental Brain Research* 181:173–81. [DWC, DJM]

von Holst, E. & Mittelstaedt, H. (1950) Das Reafferenzprinzip. *Naturwissenschaften* 37:464–76. [aRN]

Voss, H. U. (2000) Anticipating chaotic synchronization. *Physical Review E* 61:5115–19. [NS]

Vroomen, J., Keetels, M., de Gelder, B. & Bertelson, P. (2004) Recalibration of temporal order perception by exposure to audio–visual asynchrony. *Cognitive Brain Research* 22:32–35. [DWC]

Wagman, J. B. & Carello, C. (2001) Affordances and inertial constraints on tool use. *Ecological Psychology* 13:173–95. [JBW]

(2003) Haptically creating affordances: The user-tool interface. *Journal of Experimental Psychology: Applied* 9:175–86. [JBW]

Wagman, J. B. & Malek, E. A. (in press) Perception of affordances for walking under a barrier from distal and proximal points of observation. *Ecological Psychology*. [JBW]

Wagner, H. (1982) Flow-field variables trigger landing in flies. *Nature* 297:147–48. [aRN]

Wald, G. (1968) The molecular basis of visual excitation. *Nature* 219(5156):800–807. [aRN]

Walls, G. L. (1942) *The vertebrate eye and its adaptive radiation*. Cranbrook Press. [aRN]

Wang, Y. & Frost, B. J. (1992) Time to collision is signalled by neurons in the nucleus rotundus of pigeons. *Nature* 356(6366):236–38. [aRN]

Warren, R. M. & Warren, R. P. (1968) *Helmholtz on perception: Its physiology and development*. Wiley. [aRN]

Warren, W. H. (1988) Actions mode and laws of control for the visual guidance of action. In: *Complex movement behavior: The motor-action controversy*, ed. O. G. Meijer & K. Roth, pp. 339–80. North-Holland. [NB]

Watanabe, K., Nijhawan, R. & Shimojo, S. (2002) Shifts in perceived position of flashed stimuli by illusory object motion. *Vision Research* 42(24):2645–50. [DW]

Watanabe, K., Sato, T. R. & Shimojo, S. (2003) Perceived shifts of flashed stimuli by visible and invisible object motion. *Perception* 32(5):545–59. [DW]

Watts, R. G. & Bahill, A. T. (1990) *Keep your eye on the ball: The science and folklore of baseball.* W. H. Freeman. [JEC]

Weiskrantz, L. (1996) Blindsight revisited. *Current Opinion in Neurobiology* 6(2):215–20. [aRN]

Weiss, Y. & Adelson, E. H. (2000) Adventures with gelatinous ellipses – constraints on models of human motion analysis. *Perception* 29:543–66. [JB]

Welch, R. B. (1978) *Perceptual modification: Adapting to altered sensory environments*. Academic Press. [DWC]

Westheimer, G. & McKee, S. P. (1977) Perception of temporal order in adjacent visual stimuli. *Vision Research* 17(8):887–92. [aRN]

Wexler, M. & Klam, F. (2001) Movement prediction and movement production. *Journal of Experimental Psychology: Human Perception and Performance* 27(1):48–64. [rRN]

Whitaker, D., McGraw, P. V. & Pearson, S. (1999) Non-veridical size perception of expanding and contracting objects. *Vision Research* 39(18):2999–3009. [DW]

Whitaker, D., Perarson, S., McGraw, P. V. & Banford, M. (1998) Keeping a step ahead of moving objects. *Investigative Ophthalmology and Visual Science* 39(Suppl):S1078. [aRN]

Whiting, H. T. A., Gill, E. B. & Stephenson, J. M. (1970). Critical time intervals for taking in flight information in a ball-catching task. *Ergonomics* 13:265–72. [NB]

Whitney, D. (2002) The influence of visual motion on perceived position. *Trends in Cognitive Sciences* 6(5):211–16. [DME, rRN, DW]

Whitney, D. & Cavanagh, P. (2000) Motion distorts visual space: shifting the perceived position of remote stationary objects. *Nature Neuroscience* 3:954–59. [JB, rRN, DW]

(2003) Motion adaptation shifts apparent position without the motion aftereffect. *Perception & Psychophysics* 65(7):1011–18. [DW]

Whitney, D., Ellison, A., Rice, N. J., Arnold, D., Goodale, M., Walsh, V. & Milner, D. (2007) Visually guided reaching depends on motion area MT+. *Cerebral Cortex* 17(11):2644–49. [DW]

Whitney, D., Goltz, H. C., Thomas, C. G., Gati, J. S., Menon, R. S. & Goodale, M. A. (2003) Flexible retinotopy: Motion-dependent position coding in the visual cortex. *Science* 302(5646):878–81. [JB]

Whitney, D. & Goodale, M. A. (2005) Visual motion due to eye movements helps guide the hand. *Experimental Brain Research* 162(3):394–400. [DW]

Whitney, D. & Murakami, I. (1998) Latency difference, not spatial extrapolation. *Nature Neuroscience* 1(8):656–57. [DME, arRN, JBJS, DW]

Whitney, D., Westwood, D. A. & Goodale, M. A. (2003) The influence of visual motion on fast reaching movements to a stationary object. *Nature* 423(6942):869–73. [DW]

Wickelgren, L. W. (1969) The ocular response of human newborns to intermittent visual movement. *Journal of Experimental Child Psychology* 8(3):469–82. [rRN]

Wiesel, T. N. & Hubel, D. H. (1963) Single-cell responses in striate cortex of kittens deprived of vision in one eye. *Journal of Neurophysiology* 26:1003–17. [rRN]

Williams, H. & Nottebohm, F. (1985) Auditory responses in avian vocal motor neurons: a motor theory for song perception in birds. *Science* 229(4710):279–82. [aRN]

Williams, J. M. & Lit, A. (1983) Luminance-dependent visual latency for the Hess effect, the Pulfrich effect, and simple reaction time. *Vision Research* 23(2):171–79. [aRN, HO]

Williams, Z. M., Elfar, J. C., Eskandar, E. N., Toth, L. J. & Assad, J. A. (2003) Parietal activity and the perceived direction of ambiguous apparent motion. *Nature Neuroscience* 6(6):616–23. [aRN]

Wilson, J. A. & Anstis, S. M. (1969) Visual delay as a function of luminance. *American Journal of Psychology* 82:350–58. [HO]

Wilson, M. & Knoblich, G. (2005) The case for motor involvement in perceiving conspecifics. *Psychological Bulletin* 131(3):460–73. [arRN]

Witten, I. B., Bergan, J. F. & Knudsen, E. I. (2006) Dynamic shifts in the owl's auditory space map predict moving sound location. *Nature Neuroscience* 9(11):1439–45. [aRN]

Wolpert, D. M. & Flanagan, J. R. (2001) Motor prediction. *Current Biology* 11(18):R729–32. [aRN]

Wolpert, D. M., Ghahramani, Z. & Jordan, M. I. (1995) An internal model for sensorimotor integration. *Science* 269(5232):1880–82. [aRN, GT]

Wolpert, D. M., Miall, R. C. & Kawato, M. (1998) Internal models in the cerebellum. *Trends in Cognitive Sciences* 2:338–47. [aRN]

Woodworth, R. S. (1899) The accuracy of voluntary movement. *Psychological Review* 3(2), Whole No. 13. [aRN]

Woodworth, R. S. & Schlosberg, H. (1954) *Experimental psychology*. Methuen. [aRN]

Wurtz, R. H., Richmond, B. J. & Judge, S. J. (1980) Vision during saccadic eye movements. III. Visual interactions in monkey superior colliculus. *Journal of Neurophysiology* 43(4):1168–81. [JPM]

Young, A. W., Hellawell, D. & Hay, D. C. (1987) Configural information in face perception. *Perception* 16:747–59. [BKh]

Zago, M., Bosco, G., Maffei, V., Iosa, M., Ivanenko, Y. P. & Lacquaniti, F. (2004) Internal models of target motion: Expected dynamics overrides measured kinematics in timing manual interceptions. *Journal of Neurophysiology* 91:1620–34. [MZ]

(2005) Fast adaptation of the internal model of gravity for manual interceptions: Evidence for event-dependent learning. *Journal of Neurophysiology* 93:1055–68. [MZ]

Zago, M. & Lacquaniti, F. (2005) Cognitive, perceptual and action-oriented representations of falling objects. *Neuropsychologia* 43:178–88. [MZ]

Zanker, J. M., Quenzer, T. & Fahle, M. (2001) Perceptual deformation induced by visual motion. *Naturwissenschaften* 88(3):129–32. [aRN]