

modestly cluttered environments, it is clear that observers can use both of these sources of information for heading judgments, although they spend more time looking at members of an invariant pair, when available, than at those of a cue pair. Are completely different neural mechanisms used in the two cases? – innate for the convergence invariant and algorithmic for accelerating divergence cue? I think not. Following E. J. Gibson (1969), I suggest these information sources are experienced by the young traveler – one found very trustworthy (convergence), the other less so (accelerating divergence) – and differentiated through that experience. Why hardwire either from birth?

In summary, cues are not just “ventral,” and invariants not just “dorsal.” Moreover, invariants are probably too rare to govern all of action, and some are likely to be learned.

Ecological and constructivist approaches and the influence of illusions

Denise D. J. de Grave, Jeroen B. J. Smeets and Eli Brenner

Department of Neuroscience, Erasmus University Rotterdam, 3000 DR

Rotterdam, The Netherlands. degrave@fys.fgg.eur.nl

<http://www.eur.nl/fgg/fys/people/grave.htm> smeets@fys.fgg.eur.nl

<http://www.eur.nl/fgg/fys/people/smeets.htm>

brenner@fys.fgg.eur.nl

<http://www.eur.nl/fgg/fys/people/brenner.htm>

Abstract: Norman tries to link the ecological and constructivist approaches to the dorsal and ventral pathways of the visual system. Such a link implies that the distinction is not only one of approach, but that different issues are studied. Norman identifies these issues as perception and action. The influence of contextual illusions is critical for Norman's arguments. We point out that fast (dorsal) actions can be fooled by contextual illusions while (ventral) perceptual judgements can be insensitive to them. We conclude that both approaches can, in principle, be used to study visual information processing in both pathways.

The visual system has two main pathways for processing visual information: the ventral and the dorsal. Color, texture, and shape are primarily analyzed in the ventral pathway, while motion and egocentric position are analyzed in the dorsal pathway (Mishkin et al.

1983). More important for Norman's distinction, the ventral pathway is believed to consider contextual information, while the dorsal pathway is believed not to do so. This difference in processing contextual information is what distinguishes ecologists' invariants from constructivists' cues and constancies. Thus, the influence of illusions, which often arise from misinterpreting the context, can be considered critical for this debate. Many studies have compared information processing in the dorsal and ventral pathways by comparing the influence of illusions in perceptual and motor tasks. In perceptual tasks, assumed to be processed by the ventral system, illusions obviously show an influence on the measured variables (otherwise, they would not be illusions). In motor tasks, assumed to be processed by the dorsal system, often no influence is found.

However, although they have received less attention, many experiments show that motor tasks can be influenced by illusions. When hitting a moving target with one's hand, a moving background can lead to changes in the hand's speed (Smeets & Brenner 1995a) and in the hand's direction (Smeets & Brenner 1995b). Bridgeman et al. (1997) studied pointing movements towards a target within a frame. For half their subjects, an offset of the frame from the subject's objective median plane caused a bias in the pointing movements in the opposite direction. Brenner and Smeets (1996) demonstrated that the force exerted to lift an object is influenced by the Ponzo illusion. Jackson and Shaw (2000) found the same for grip force. Yamagishi et al. (2001) showed that pointing movements towards a small window with a moving grating displayed behind it were biased in the direction of the grating's motion. These experiments show that when performing motor tasks, as used by the ecologists to study invariants, subjects can be fooled by illusions.

Individual illusions also do not influence performance in all perceptual tasks. Smeets and Brenner (1995a) showed that background motion influences the perceived motion of a target, but not the perceived position. Similarly, the Müller-Lyer illusion influences perceived size but not the perceived positions of the endpoints (Gillam & Chambers 1985). Vishton et al. (1999) showed that the horizontal-vertical illusion is reduced considerably if the perceptual judgement is an absolute judgement of a single element of the display instead of a relative judgement of two elements. Similar results were obtained for the Ebbinghaus illusion

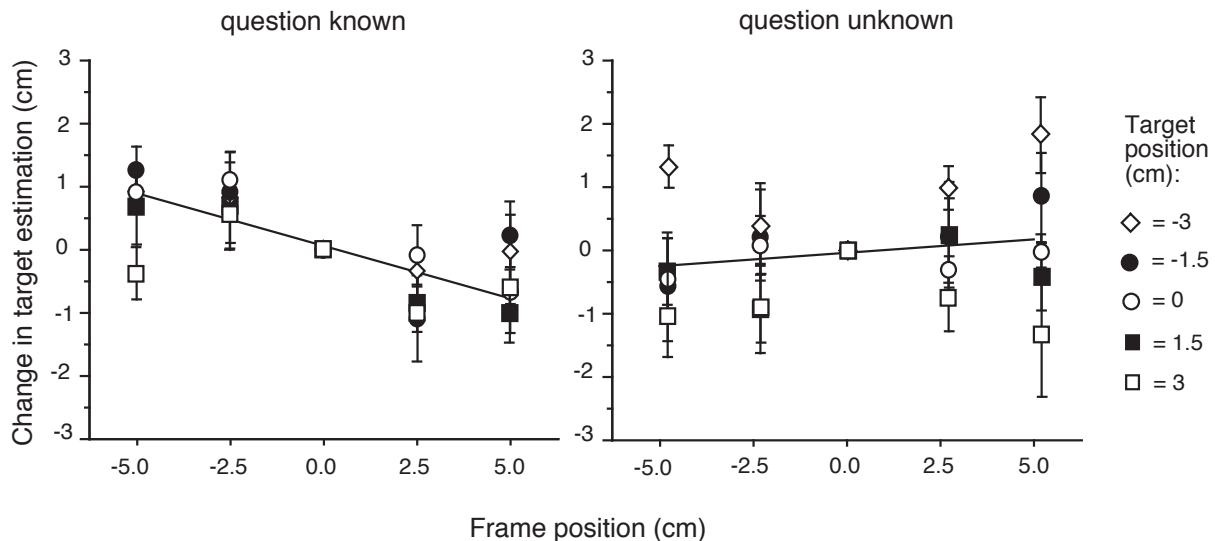


Figure 1 (de Grave et al.). Target estimation when the question was or was not known in advance. The values show the difference between the estimated position with the frame straight ahead and the estimated target position when the frame was shifted 2.5 or 5 cm to the left (negative) or right (positive). Error bars represent standard errors between subjects.

(Pavani et al. 1999) and the Müller-Lyer illusion (Franz et al. 2001). These experiments show that when performing perceptual tasks, as used by constructivists to study cues, the effect of the illusion can be absent.

Hence, whether an illusion affects a task does not depend on whether the task is an ecologist's motor task or a constructivist's perceptual task, but largely on the question asked or variable studied. However, the influence of illusions is not even fixed within a single experimental paradigm for a single question. We showed this recently using a constructivist's paradigm based on the induced Roelofs effect (de Grave et al. 2002). Subjects were presented a target within a frame in complete darkness. Target and frame could both be shifted to the left or right of the objective straight ahead. Subjects gave verbal estimates about the position of either the target or the frame. In one condition, subjects knew prior to stimulus presentation that they would be questioned about the position of the target. In another condition, they had no prior knowledge whether the question would be to respond to the position of the target or to the position of the frame. In the "question known" condition the perceived position of the target followed the misjudgement of the eccentricity of the frame (the induced Roelofs effect). But in the "question unknown" condition, the illusory effect was not present (Fig. 1).

We argue that the illusory influences on both perception and action depend on the aspect of the task that is studied and on the circumstances under which this is done. Since contextual illusions are generally linked to the ventral stream, the ecological and the constructivist approach cannot correspond with the dorsal and the ventral pathway, respectively.

Evolutionary and intellectual antecedents of primate visual processing streams

Colin G. Ellard

Department of Psychology, University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada. cellard@watarts.uwaterloo.ca
<http://watarts.uwaterloo.ca/~cellard/>

Abstract: The main function of vision in many animals is to control movement. In rodents, some visuomotor acts require the construction of models of the external world while others rely on Gibsonian invariants. Such findings support Norman's dual processing approach but it is not clear that the two types of processing rely on homologs of visual processing streams described in primates.

Norman attempts to draw the sweep of phylogeny into his view of perception and action by mentioning some seminal findings from old experiments involving nonprimates. It is accurate to characterize Schneider's hamsters and Ingle's frogs as the *intellectual* predecessors to Milner and Goodale's DF, as both of these sets of studies were strong influences on the "two cortical visual systems" idea. One of my interests has been in asking whether there is an *evolutionary* relationship as well as an intellectual one between the organization of cortical visual streams in primates and the simpler visual systems of other animals. Is there anything like a ventral stream in a rat and, if so, what is it for? This is a question that has troubled me for some time, as most descriptions of the primate ventral stream are steeped in discussions of awareness and viewpoint-independent object recognition. In contrast, my own experiments, like those of many others, have suggested that the main function of vision in rodents is to control action directly, rather than to produce abstract representations of the external world (Ellard 1998; Goodale & Carey 1990). When I read Norman's paper, though, it organized some inchoate thoughts that had been sloshing around in my mind about some of my own experiments involving the visual control of running and jumping in the Mongolian gerbil (Ellard & Shankar 2001).

Gerbils can be trained to jump long distances with great accu-

racy (Ellard et al. 1984), and one of the most potent sources of information that gerbils use to estimate such distances is retinal image size (RIS) (Goodale et al. 1990). In order to use RIS, gerbils need to learn a calibration between the size of the proximal image and its distance. Not only do gerbils appear to learn such calibrations very quickly, but they can learn to keep a kind of catalog of such things for multiple objects and they can rapidly and effectively update the catalog in light of feedback (see Ellard & Goodale 1991; Ellard & Shankar 2001 for reviews). These findings suggest that gerbils in these tasks are constructing a model of the external world on the basis of the outcomes of visuomotor interactions with that world. Not only is the model liable to modifications depending on the success with which it is applied, but it is applied in slightly different ways depending on prevailing conditions. For example, when RIS is rendered less reliable by making object size more variable, it may still be used to compute distance but it will make a smaller contribution than when object size is stable. Gerbils are constructing a modest model of the external world.

Gerbils can be trained to run towards a visual target and to brake effectively so as to avoid hitting the target. As was first suggested in Goodale's lab (Sun et al. 1992) and confirmed in later experiments in my lab (Shankar & Ellard 2000), they are probably using a Gibsonian invariant called time-to-collision (TTC) to time braking in this task. TTC relies on the ratio between the proximal size of a target and its instantaneous rate of change as it is approached (Lee 1976), and so can be used even when the distal properties of the target are unknown. Unlike the case for jumping, the information that is used to compute braking time in the running task is not prone to the influence of experience. For example, presenting misleading TTC information (by changing target size as the animal runs towards it) does not influence the performance of gerbils on subsequent trials (Ellard & Blais, in preparation). These experiments are compatible with the ecological view of perception.

I think it is possible to imagine how both ways of using visual information (constructing models of the world and using Gibsonian invariants) can contribute to an animal's ability to navigate through space. Animals may move from place to place largely under open loop control, relying on path integration and a set of invariants like TTC. Between such movements they may update their locations by taking "fixes" that rely in part on stored information about allocentric space.

It would be nice if I could conclude my commentary by saying that there was also an anatomical correspondence between the dorsal and ventral streams in gerbil cortex and the running and jumping abilities that I have described, but, alas, I cannot. Large lesions of temporal cortex have no effect at all on RIS in gerbils, and lesions of parietal cortex can be shown to produce effects that mirror object recognition deficits (Ellard & Sharma 1996). We know little about the neural substrates involved in computation of TTC in the gerbil, but it appears as though a small "dorsal" cortical area may play an integral role (Shankar & Ellard 2000). This may only mean that our knowledge of rodent cortex is not advanced enough to make the proper comparisons, but my hunch is that the differences are simply too great to make much of a case for a parallel between rodent and primate visual cortical streams.

What impact does this have on Norman's hypothesis? For one thing, if there is no real homolog to the ventral stream in rodents it means that the evolutionary antecedents for different modes of perception preceded the anatomical parcellation. On the other hand, if gerbils are constructing allocentric models of the world using a procrustean version of the ventral stream that has yet to be identified, it might help to point us in the right direction to find it. It might also help us to understand ventral stream function in a way that can be characterized without reference to consciousness and rumination. I would find it satisfying if the evolutionary roots of both streams were to be related to the kinds of problems for which vision first arose – moving one's body through space.