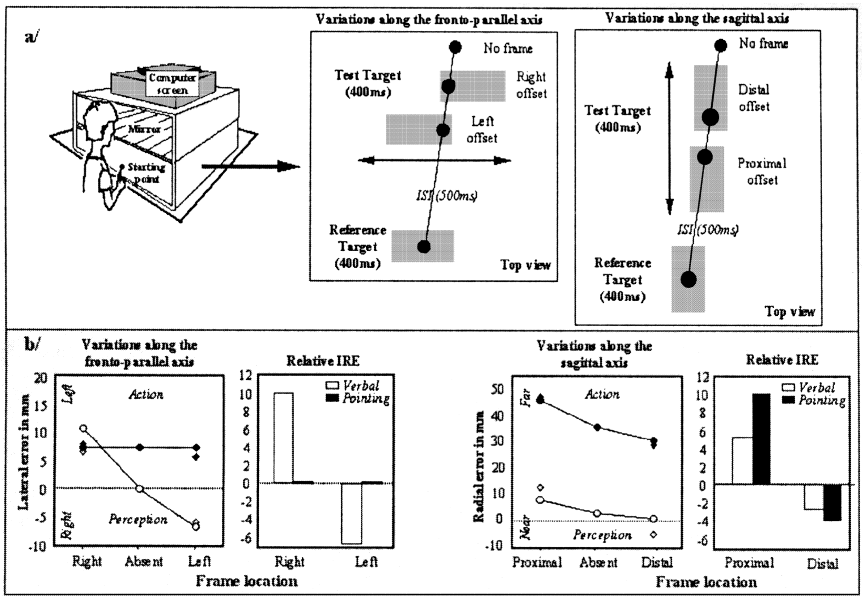


Figure 2 (Coello & Rossetti). (**a**) Apparatus and sequence of stimuli presented to the patient I.G. The Reference Target was presented simultaneously with a centred frame for 400 msec at two possible locations. Following a blank period of 500 msec, a Test Target was presented at a position similar to that of the Reference Target, at ±8mm, or at ±16mm along the fronto-parallel axis, or along the sagittal axis. It was accompanied with an off-centre frame or was presented alone. The task was to determine whether the Test Target was at the same position or not, compared to the Reference Target position, or to point towards the Test Target (for a detailed presentation of the method, see Coello et al. 2003). (**b**) Induced Roelofs effect along the fronto-parallel axis (left) and sagittal axis (right) for the patient I.G. Considering the fronto-parallel dimension, the induced Roelofs effect influenced the verbal response (open circle) but not the pointing response (filled circle) though the patients showed a constant bias to the left. Considering the sagittal dimension, the induced Roelofs effect influenced both the verbal response (open circle) and the pointing response (filled circle), the latter showing a constant overshoot of the target. Control performances (adapted from Coello et al. 2003) are indicated by the diamond, but normalised with respect to the no frame condition in order to allow a direct relative comparison of effect size in IG and controls.

suggested that the ventral stream is responsible for extracting distance information from monocular retinal cues, such as shading, texture, and perspective, while the dorsal stream has access to binocular information from disparities and vergence. This makes our results compatible with the Milner and Goodale model. Thus, the lack of dissociation between perception and action along the sagittal axis with the IRE could be interpreted as a greater participation of the ventral stream in distance processing, independent of the type of response or the viewing condition. However, according to Glover's model, the ventral system is involved in any aspect of motor planning. In this model, simple movements, such as reaching and grasping, tend to rely on the IPL for movement planning. Visual information can be projected to the IPL via the temporal lobe (which carries out information about spatial and nonspatial characteristics of a target and the surrounding context) and the "third" visual stream (sect. 1.2.2; but see review: Rossetti et al. 2000; Rossetti & Pisella 2002).

One way to contrast these two models would be to evaluate the performance of a patient with an impaired dorsal stream when confronted with the IRE. According to the ventral-dorsal dichotomy, an impaired dorsal stream would lead the patient to be unable to perform accurate motor acts considering the strong implication of the dorsal stream in motor control. Previous observations have shown, however, that this is not the case (Rossetti et al. 2003). Another possibility would be that the participation of the ventral stream is strengthened in the organisation and control of the motor acts in order to compensate for the impaired dorsal stream (Milner & Dijkerman 2001; Rossetti & Pisella 2002). One would therefore expect an effect of the IRE in both the fronto-parallel and the sagittal axes. By contrast, according to the planning-control dichotomy, the ventral stream participates in movement planning in all aspects and therefore, no discrepancy between the patient and the control participants is expected. We recently tested patient I.G., a 31-year-old woman who had suffered bilateral parieto-occipital infarction one and a half years ago, resulting in a severe bilateral ataxia (see Pisella et al. [2000] for a detailed description). As shown in Figure 2, when submitted to the IRE, I.G. showed a pattern of results very similar to that of the control subjects, which stands in support for Glover's model.

In conclusion, many of the recent data concerning visual illusions are hardly compatible with the simple perception–action model, assuming in particular that only the perception system is subjected to context influence. The planning–control dichotomy offers an alternative that better accounts for the apparent controversy in experimental data related to visual illusions. However, to provide a general framework, it seems imperative to solve the paradox in the model, which originates from the fact that the role of the control system is thought to reduce spatial errors denying context information, while it nonetheless has been demonstrated that visual context broadly contributes to the accurate coding of target location.

The planning–control model and spatio-motor deficits following brain damage

H. Branch Coslett[a] and Laurel J. Buxbaum[b]

[a]*Department of Neurology, University of Pennsylvania, Philadelphia, PA 19104;* [b]*Moss Rehabilitation Research Institute, Thomas Jefferson University, Philadelphia, PA 19141.* **hbc@mail.med.upenn.edu**
lbuxbaum@einstein.edu

Abstract: Glover's planning–control model accommodates a substantial number of findings from subjects who have motor deficits as a consequence of brain lesions. A number of consistently observed and robust findings are not, however, explained by Glover's theory; additionally, the claim that the IPL supports planning whereas the SPL supports control is not consistently supported in the literature.

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Although we agree that the distinction between planning and control of action provides a useful framework for analyzing motor performance, the claim that motor planning is mediated by the inferior parietal lobe (IPL) and control by the superior parietal lobe (SPL) appears to be too strong. Whereas the planning–control hypothesis offers an adequate account of the basic features of ideomotor apraxia and optic ataxia, there are several important aspects of these clinical syndromes that are not accommodated by the planning–control model as articulated by Glover.

1. Planning and praxis. The planning–control model bears a number of similarities to a model of apraxia we recently proposed (Buxbaum 2001). We suggested that skilled action retrieval and production is a constructive process, requiring that stored representations of object-related actions mediated by the left IPL be tempered on-line by the dorsal stream in response to current environmental contingencies. We argued that the most common type of ideomotor apraxia is attributable to damage to what we called the "representational" IPL system and relative preservation of the "dynamic" dorsal system. The planning–control model goes beyond this proposal to explicitly align the representational system with planning stages of action, and we believe that this nuance has the potential to offer additional insights about the behavior of apraxic patients.

One observation consistent with the planning–control model is that IPL-lesioned apraxics are deficient in their ability to generate or recognize hand postures associated with using familiar objects in a skilled manner, but intact in their ability to generate and recognize postures for grasping the same objects. In fact, in the former situation, they often "default" to a generic grasping posture. This suggests that their deficits in the IPL-mediated skilled knowledge system force reliance on dorsally mediated on-line motor control (Buxbaum et al. 2002). Even more directly relevant to the planning/control distinction is the observation that apraxics are deficient in motor imagery (Sirigu et al. 1996). Apraxics are impaired in planning grasp of objects based on their orientation in space, as judged by their deficient motor imagery of the grasp posture they would use if they were to grasp the object. In contrast, their actual grasping of the same objects is intact. Presumably, once movement is launched, reliance upon intact feedback loops from proprioception and sensation enables correction of error arising in the earlier planning component (Buxbaum et al., submitted).

Another observation consistent with the proposed model is that object manipulation knowledge (arguably a form of semantic knowledge) appears to be mediated by the IPL. Knowledge of the manner in which an object is manipulated (but not knowledge of an object's function) is disrupted in apraxics with IPL damage (Buxbaum & Saffran 2002). In parallel, several recent fMRI studies have shown that questions about how objects are manipulated activate regions of the IPL and intraparietal sulcus (Boronat et al., submitted; Kellenbach et al. 2003). These data are suggestive of a relationship between action planning and semantic information similar to that proposed by Glover.

On the other hand, there are at least two observations from apraxia suggesting that the model requires refinement. One observation is that apraxics have difficulty learning new gestures (Gonzalez Rothi & Heilman 1984). The model doesn't account for the links between motor planning, new learning, and retention of previously learned motor skills. One possible explanation for this relationship is that all three require the ability to generate and maintain internal (forward and inverse) models of action. The second observation is that there is a large and frequently cited disparity between transitive (object-related) and intransitive (non-object-related) gesture. Critically, left IPL-lesioned apraxics often perform normally on tasks requiring retrieval of intransitive gestures from memory. This suggests that the left IPL is specialized not just for action planning, but for skilled object-oriented action planning as well. This proposal is consistent with the putative importance of this structure in mapping between ventral stream representations of objects, on the one hand, and dorsal action systems, on the other (Buxbaum 2001).

2. The planning–control model and reaching. The hypothesis that the IPL is specialized for planning skilled object-oriented action (and not just action in general) would explain the apparent preservation of planning of non-object-related movements (e.g., reach) in several patients we recently reported. One such patient (J.D.; cf. Schwoebel et al. 2001) had a predominantly left IPL lesion in the context of generalized atrophy. She exhibited a striking deficit in "motor control," in that she was unable to reach to a target after passive movement of her arm. For example, when J.D. reached toward a visually presented target after closing her eyes, terminal error was relatively small. If, on the other hand, her arm was passively moved to a new position after visualizing the target and closing her eyes, reaching was grossly inaccurate. In a different experiment, J.D. visualized a target, touched her nose, closed her eyes, and reached. Performance did not differ substantially from the condition in which she did not move her arm prior to reaching. In contrast, if J.D.'s hand was passively moved to her nose after visualizing the target and closing her eyes, reaching accuracy deteriorated markedly. We suggest that J.D. is unable to use proprioceptive feedback to guide reaching behavior, and despite her IPL lesion, relies on a "forward," or predictive, model for motor control. These and other data from patients with predominantly IPL lesions (e.g, Schwoebel & Coslett 2002) suggest that the claim that planning and control are mediated by the IPL and SPL respectively is too strong.

Finally, the account of optic ataxia offered by the planning–control account fails to address the often robust effects of factors such as the hemispace in which the action is performed. The fact that optic ataxia may be manifested by the contralesional hand in only one hemispace or exhibited in the contralesional hemispace by either hand suggests that both the "control" and the "planning" components of the model – and the boundaries between them and related perceptual and motor representations – need substantial elaboration (see Buxbaum & Coslett 1997, 1998; DeRenzi 1982).

In summary, we believe that Glover's assertion regarding the anatomic underpinnings of motor planning and control is overly simplistic, and we note a number of respects in which the account is underspecified. Nevertheless, as the hypothesis accommodates a substantial amount of evidence from diverse sources and generates specific, testable predictions, the planning–control model as articulated by Glover represents a welcome contribution to the rapidly evolving field of motor cognition.

Scale errors by very young children: A dissociation between action planning and control

Judy S. DeLoache

Department of Psychology, University of Virginia, Charlottesville, VA 22904.
jdeloache@virginia.edu

Abstract: Very young children occasionally commit *scale errors,* which involve a dramatic dissociation between planning and control: A child's visual representation of the size of a miniature object is not used in planning an action on it, but is used in the control of the action. Glover's planning–control model offers a very useful framework for analyzing this newly documented phenomenon.

The target article by Glover focuses exclusively on research with adults, but the planning–control model also has useful applications in the developmental domain. In particular, it is very helpful for thinking about a new developmental phenomenon – *scale errors* – that my colleagues and I have recently described (DeLoache et al. 2003).

Scale errors involve a dramatic dissociation between planning and control that occurs occasionally in the behavior of very young children: A child's visual representation of the size of an object is basically ignored in the process of planning an action on it, though

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