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

https://doi.org/10.1017/S0140525X04290021 Published online by Cambridge University Press

it is brought to bear in the motor control of the action. A prototypical example of a scale error, and one of the original observations that sparked our interest in this topic, is a toddler attempting to sit on a miniature (dollhouse-size) chair. Other examples we have informally observed include young children trying to lie down in a doll's bed and attempting to get into a small toy car.

A scale error is defined as an attempt to perform an action that is totally impossible because of extreme differences in size – in this case, between a child's own body and a target object. When committing scale errors, children appear to be completely serious, with no indication of pretense or joking.

In our initial study designed to document the phenomenon of scale errors, children between 18 and 30 months of age were induced to play with three large toys in a laboratory playroom. They climbed up and slid down an indoor slide, sat in a child-sized chair, and got into and propelled a car around the room. Then, while the child was out of the room, each of the three large items was replaced by a miniature replica.

When they returned to the room, almost half of the children committed scale errors that were captured on camera. Some of them tried to climb up the stairs of the little slide, typically causing it to tip over. Others sat on top of the slide and attempted to go down it, often falling off in the process. Some of the children sat firmly down on the tiny chair, whereas others perched gingerly on top. Most remarkable of all, some children earnestly tried to get into the miniature car. After opening the car door, they attempted – sometimes quite persistently – to shove their foot in the small opening. The best way to appreciate the nature of these scale errors is to see them in action (which can be done by going to the following website: http://faculty.virginia.edu/childstudycenter/projects.html).

A particularly intriguing aspect of scale errors is that although the child's general plan is impossible because of the size of the target object, some of the movements that the child makes toward the object are accurately scaled. When trying to sit in a tiny chair, children typically check visually to see where the chair is, sometime even bending over and looking between their legs to locate it precisely. They then squat over it, lowering themselves to the point of contact. When trying to get into the miniature car, children first use fine motor control to open the car door. In addition, they sometimes hold on to the top of the car while trying to force their foot through the door, especially if their initial effort to get in has caused the car to skitter away.

It is this remarkable combination of wildly inaccurate and highly accurate behavior for which we find Glover's planning–control model to be particularly helpful. Interpreting scale errors in terms of his theory places their origin in the planning system. When a very young child encounters a miniature replica of a highly familiar type of object, visual processing of the replica activates the child's semantic representation of the larger object, or the class of objects, it stands for. Included in the activated memory representation of the full-sized object is the motor program or routine for interacting with it. Normally, visual processing of the size of the replica inhibits execution of the activated motor routine, and the child either does not attempt to act on the replica at all or carries out a very different action, such as pretense (for example, setting a doll in the miniature chair or pushing the car around on the floor making "vroom" sounds). Occasionally, however, for some reason an action plan is formed that does not take the available size information into account. Once the plan is initiated, the control system draws on the visual representation of size and adapts the child's movements to the actual size of the object. Thus, in the commission of a scale error, a child formulates an impossible plan but then employs finely controlled motor actions in the futile pursuit of it.

The application of Glover's theory to the scale error phenomenon extends it in three ways. First, in contrast to most of the research on which the model was originally formulated, here it is applied to full-body movements performed in large-scale space on real objects. Second, the planning–control dissociation is shown in the behavior of individuals, rather than by comparisons across participants. The same child fails to use size information in the process of formulating a fundamentally faulty plan, but does incorporate perceived size in the attempted execution of the plan. Third, applying Glover's planning–control model to the scale errors of very young children extends it to the developmental domain. Some developmental researchers have profitably applied the dual visual systems theory of Milner and Goodale (1995) to research on visually directed reaching in infants (e.g., Bertenthal 1996; Newman et al. 2001; Vishton 2003; Von Hofsten et al. 1998), and further valuable insights are likely to result from the consideration of early behavior in the light of the planning–control model.

ACKNOWLEDGMENTS

I am grateful to Dennis Profitt, Peter Vishton, and Patrick Cavanaugh for many helpful suggestions and comments about this work.

Visual context can influence on-line control

Digby Elliott[a] and Daniel V. Meegan[b]

[a]*Department of Kinesiology, McMaster University, Hamilton, Ontario, L8S 4K1, Canada;* [b]*Department of Psychology, University of Guelph, Guelph, Ontario, N1G 2W1, Canada.* **elliott@mcmaster.ca**
dmeegan@psy.uoguelph.ca

Abstract: Several lines of evidence indicate that the on-line control of rapid target-aiming movements can be influenced by the visual context in which the movements are performed. Although this may result in movement error when an illusory context is introduced, there are many situations in which the control system must know about context in order to get the limb to the target rapidly and safely.

Beginning with the seminal work of Woodworth (1899), there is a long history of theorizing about the separate contribution of movement planning and on-line control processes to the regulation of goal-directed movement (see Elliott et al. [2001] for a recent review). However, Glover's planning and control formulation does have several features that make it a unique dual-process model of motor control. The most important of these features is the postulate that separate visual representations subserve movement preparation and on-line control. Although it is clear that different types of visual information are important for response selection, movement parameterization, and the rapid on-line modulation of movement, we are not convinced that the dichotomy described by Glover captures the flexible nature of on-line control. In this commentary, we review evidence from several aiming studies that indicates control processes can be sensitive to the visual context in which the aiming movement is performed.

In two of our recent experiments (cf. Meegan et al., in press), participants were required to aim a stylus from one vertex of Müller-Lyer figures to the other. In the first experiment, vision of both the limb and the figure was eliminated upon movement initiation, and in the second experiment participants were able to see their limb but not the figure during the movement. Regardless of whether there was a delay between elimination of the target figure and movement initiation, participants' aiming accuracy was biased by the Müller-Lyer configurations. Measures of displacement taken at peak velocity, at peak deceleration, and at the end of the movement indicated that the absolute magnitude of illusion-induced biases actually increased as the movement progressed. This was in spite of a dramatic trial-to-trial spatial variability decrease between peak deceleration and the end of the movement, indicating that participants were engaged in on-line control. These results are incompatible with both Glover's planning–control model, and Goodale and Milner's (1992) ventral-dorsal model.

In this same theoretical context, Proteau and Masson (1997) reported work that creates difficulty for the notion that the control system is uninfluenced by the visual environment surrounding the target. Their research involved participants making aiming move-

https://doi.org/10.1017/S0140525X04290021 Published online by Cambridge University Press