cations with respect to the issues of awareness, and the types of representations and where they are stored.

Glover states that the functional properties of objects are stored in the IPL. The affordances of objects, though, are retrieved from a scene directly, and are perceived independently of object-specific knowledge and of the subject's will (Bickhard 1993; Norman 2002). Petitot (1995) discusses the early vision processes that retrieve bottom-up from a scene its aspectual properties, such as "transfer." The affordances of objects, therefore, cannot be among the contents of the IPL-r.

Let me move to Glover's postulation of two types of object representations. There is substantial evidence for an object-centered component to visual attention, in which attentional limitations are characterized in terms of the number of defined discrete objects which can be processed simultaneously (Pylyshyn & Storm 1988; Scholl 2001; Scholl & Leslie 1999). This attentional mechanism is designed to provide a representation of objects as discrete spatio-temporal entities. The representation encodes primarily spatio-temporal information. It functions as an indexing mechanism that focuses on and individuates objects. Object-centered attention may override featural information other than spatio-temporal information. Thus, there is evidence that there exists a level of visual processing in which objects in a scene are parsed and tracked as distinct entities without being recognized as particular objects. Object individuation precedes object identification.

It is at this point that Glover's dual representation comes into the scene. The SPL-r provides the content of the representation needed for object individuation, whereas the IPL-r is related to object identification and recognition. Recall also that the information stored in the SPL (i.e., spatio-temporal information, and information about size and viewer-centered shape) is retrieved bottom-up from the scene (see also Norman 2002; Raftopoulos 2001).

The descriptive theories of reference hold that a symbol is associated with a concept in the mind, which constitutes its meaning. This concept determines what the symbol refers to, since it allows one to pick out the objects that are "described" by it. By explaining references by descriptive means, these theories of reference appeal to descriptions of other words; they explain reference by appealing to the reference of other words. To escape from the infinite regress, there must be some words whose reference is founded directly in the world. If the fixing of reference of perceptual demonstratives could be achieved by means of a direct causal link with the environment without the mediation of descriptions, then the first move toward grounding representations in the world would be achieved, since the direct causal link would ground perceptual representational content in the world.

The content of the SPL-r that is retrieved bottom-up from a visual scene without any conceptual involvement provides the direct causal link that fixes the reference of perceptual demonstratives. A plausible neural mechanism that implements this is expounded in Ballard's theory of deictic codes. The shortest time at which actions and movements can be observed is the 1/3 sec time-scale. This is the embodiment level. Computations at this level govern the deployment of the body's sensors and effectors.

Suppose that one looks at a scene and, through eye focusing, selects a part of it for further processing. The resulting brain representation is about (i.e., refers to) that part of the scene. When an internal representation refers to an object through such a deictic representation, this is a "deictic reference." Thus, when fixating a location, the neurons that are linked to the fovea refer to information computed from that location. The object present at that location is the referent of the deictic reference. The act of fixation assigns to this object a pointer that allows object individuation and tracking; this is due to the fact that the fixation of the gaze creates a reference to a point in space and time and the properties of the referent can enter computations as a unit. It should be noted that the term "object," as used here, does not denote the objects of our experience. Rather, being the content of the SPL-r, the referent has only the content that is stored there. In this sense, the "objects" referred to above are really segmented perceptual three-dimensional viewer-centered surfaces.

Strong modularity and circular reasoning pervade the planning–control model

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Abstract: We believe the dichotomy of processes introduced in the target article is highly speculative, because the dichotomy is shaped by the questionable assumption of modularity and the complementary assumption of locality. As a result, the author falls into a line of circular reasoning that biases his analysis of the experimental and neuropsychological data, and weakens the proposed model.

The planning–control model proposed by Glover in the target article explores the existence of two distinct but interacting psychological processes for controlling reaching-grasping movements directed toward environmental objects. We believe the evidence provided is simply not compelling enough to warrant the assumption of two distinct processes (planning and control) under the control of distinct neurocognitive modules (located in the IPL and SPL, respectively). The functional and structural dichotomy between control and planning processes defended by Glover, is only one among different interpretations that could be drawn considering the evidence provided. We believe that the planning–control model reflects certain epistemological and ontological biases related to the concept of modularity, and that Glover offers a circular line of reasoning according to which experimental and neuropsychological evidence serves as proof for the processes that are supposed to explain the evidence.

Critically, Glover seems to hold a strong modular approach that precedes the analysis of the evidence, which in turn is portrayed as supporting the modular properties of the processes included in the model. Both control and planning are believed to be independent processes because of their reliance on two different sets of information (i.e., two different visual representations) about the spatial and nonspatial characteristics of the object. The separation between the processes is justified by the assumed informational encapsulation of the two modules.

This strong modularity assumption pervades the design and interpretation of experiments conducted to test the planning–control model, in terms of a separation between different movement parameters associated with each process. Although Glover recognizes the methodological difficulties inherent in finding a task that targets only one of the processes, he insists upon defending the independence of the processes. The proposed independence leads him to introduce indeterminations in the assessment of the experimental evidence. Among them, parameter crossover – when one movement parameter (e.g., hand orientation) represents the effects of planning during some part of the movement, and control during some other part of the movement – is vaguely stated.

Particularly troubling to us is that no means is offered for determining at what time(s) a given parameter reflects either planning or control. Furthermore, the fact that 29 of the 52 entries listed in Glover's Table 2 are characterized as reflecting either "mostly" control or "mostly" planning is, we believe, diagnostic of the fact that so-called planning and control processes are not distinct. Moreover, parameter crossover seems to reflect the kind of interactivity that violates the *additive-factors logic* demanded by the modularity assumption (cf. Van Orden et al. 2001). The interaction between processes is systematically neglected in Glover's account, opening the door to the counterargument that planning and control may as well be two extremes in the on-line unfolding

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of a single, more complex process, rather than being two independent processes.

Glover's model also seems to depend on the *locality assumption* – the position that planning and control processes (in this case) are independently implemented in two distinct brain areas, the IPL and SPL, respectively. According to this assumption (and central to Glover's model), damage to one of those brain areas will produce a discrete impairment that can be identified with and circumscribed to the affected module without affecting critically the workings of the remaining components of the system (Farah 1994). The IPL and SPL, however, are believed to be part of the fronto-parietal network, which functions as an integrated system during the execution of movements (Wise et al. 1997). Glover's use of neuropsychological evidence to support the planning–control model relies on the locality assumption. Glover assumes that local damage to the brain produces only a selective behavioral impairment, which can be identified with the malfunction of a distinct cognitive process. It is one thing to assume the independence of the brain centers putatively responsible for planning and control, but it is another to assume that the planning and control processes are thus *necessarily* independent (Farah 1994). The functional distinctions drawn on the basis of anatomical evidence artificially reduces the complexity of movement control to a dichotomy in the planning–control model, even though the brain system responsible for the execution of reaching-grasping is believed to be distributed among a complex network of connections linking different brain centers (Ietswaart et al. 2001).

Glover presents a host of neuropsychological case studies to support his planning–control model. His strategy is one of establishing a double dissociation: Damage to the IPL disrupts planning, but not control, and damage to the SPL disrupts control, but not planning. That double dissociation is supposed to provide evidence that planning and control reflect the activity of independent neurocognitive modules, respectively located in the IPL and SPL. But the argument for the existence of independent neurocognitive modules for planning and control based on double dissociations entails a circular reasoning (see Shallice 1988) – double dissociations are assumed to occur only in the case of modular architectures, and therefore cannot be used to verify the existence of neurocognitive modules (Van Orden et al. 2001).

In addition, Glover explicitly states that the neuropsychological evidence he provides is inconsistent and in some cases may fit the alternative model (perception–action) as well as the planning–control model. Nevertheless, that evidence is included because of its parallels with the results of PET studies. The taxonomy of cases used is strongly reminiscent of the classical model proposed by Liepmann (1900), even though Liepmann's model and the line of reasoning introduced by it are recognized as an oversimplification (Cubelli et al. 2000). This is not an innocent fact, given the similarities between Glover's and Liepmann's models. (Liepmann's model stresses the importance of the division between two separate stages in the production of movement: the formulation of a motor plan – planning, in this case – and the implementation of the planned spatio-temporal sequence of movements – control, in this case.) The argument for the existence of representations or memories of movement is a critical point of discussion in the neuropsychological literature; it is conceived by some authors as a bottleneck in the study of apraxia (Iestwaart et al. 2001).

We feel that Glover's model is constrained by the assumptions of neurocognitive modularity and locality, while the experimental evidence is either inconsistent with these assumptions (e.g., parameter crossover), or inconclusive with respect to them (e.g., the neuropsychological case studies). These assumptions have been criticized by several authors (e.g., Farah 1994; Uttal, 1998; 2000; Van Orden et al. 2001; Weldon 1999) and seem, in this case, to lead us down the wrong path in our efforts to understand movement control.

Is efficient control of visually guided movement directly mediated by current feedback?

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Abstract: The main issue addressed here concerns the central notion of a forward internal model, through which efficient control and planning are linked together and to the related online predictive error processing. The existence of such a model has strong implications in action production and may question Glover's model.

Glover's approach to hand-reaching follows a view current since Woodworth (1899), Fitts (1957), Keele and Posner (1968), and Meyer et al. (1988), according to which the movement results from two basic components: one planned action determining the gross organization of the response and a final part including a fine control of the hand movements based on the simultaneous vision of the hand and target (in Glover's model, supposed to involve, respectively, the IPL and SPL). The extent to which visually guided movements are planned in advance or controlled on-line during the execution, is still a matter of debate. Whereas many studies have searched for the origin of planning errors (see Desmurget et al. [1998] for a review), another series of experiments have tried to identify whether the so-called planning phase was really planned and not under the control of either central or peripheral feedback. These studies have been carried out in normal subjects (Bridgeman et al. 1979; Desmurget et al. 1999; 2001; Goodale et al. 1986; Pélisson et al. 1986; Prablanc & Martin 1992), but also in deafferented patients (i.e., those who have lost the sense of position) (Bard et al. 1999). Basically, their overall finding is that a third component does exist, namely, an unconscious control applied during the first phase of the movement. In all these experiments, a target perturbation inducing a planning error was randomly introduced during the so-called saccadic suppression, making these perturbations unconsciously perceived. The specificity of the corresponding corrections was both their smoothness and their early stage as compared with the corrections observed under conscious double step experiments. In these latter experiments, despite sometimes a nonspecific early short reaction time, the path deviation indicating the corrections occurred with a normal reaction time, and with a clear double peak velocity profile (Georgopoulos et al 1981, Soechting & Lacquaniti 1983). One important point to notice is that the smooth online corrections were mostly observed for unconsciously detected errors. In Glover's planning–control model, online adjustments to perturbations of the spatial characteristics of the target should occur relatively quickly, irrespective of the nature of the perturbation.

However, this unconscious error detection may not be the only prerequisite for producing fast and smooth corrections. The delays introduced by conduction processing times at the different relays along the visuomotor stream have led some authors to postulate the existence of a "look-ahead" or Smith predictor (Hoff & Arbib 1992, Miall et al. 1993). More recently, Desmurget and Grafton (2000) have emitted the hypothesis that the correct execution of a hand movement is based mainly upon a forward internal model. This "internal model" is a predicted output of the upper limb endpoint derived from the real command signals fed to the motor apparatus, together with the updated passive visual and proprioceptive information of the end-point effector (the hand). In another paper, Prablanc et al. (2003) have also suggested that the fast error correction was not directly derived from the available retinal error signal between hand and target, but resulted from a comparison between a central representation of both the target and hand, mixing both sensory signals (visual and proprioceptive) and an efferent copy of the upper limb motor commands. According to Desmurget and Grafton (2000), if the normal vision of the hand and target is available during the motor response, the

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