Marteniuk et al. (1987) showed that an effect of object fragility was also present in the last phase of arm movements (deceleration). We can therefore suppose that the final movement phase is planned as well, and that the on-line control is not immune from effects of cognitive aspects of the target. If this were not true, lengthening of the deceleration phase as a result of greater object fragility (i.e., object familiarity) should be quickly corrected. Recently, Gentilucci (2002; 2003b) observed that the familiarity of target objects (in this case, fruits) affects grasp parameters (maximal finger aperture), which, according to Glover, should be under on-line control. Summing up, behavioural studies suggest that on-line control is partially affected by cognitive aspects of the target. We can explain the final corrections of errors in target location, attributable to perceptual/cognitive information, by proposing that the strength of egocentric cues increases with movement progression. To this purpose, we found that fixation of the vertex of the Müller-Lyer illusion, target of a pointing movement, reduced the localization error when compared with the condition in which the other vertex was fixated (Gentilucci et al. 1997a). In other words, when the flow of information in egocentric coordinates exceeds other information, movement control is only egocentrically driven.

According to Glover, the clear-cut distinction between motor planning and on-line control finds an anatomical counterpart in two sensorimotor pathways located in the ventral and dorsal parietal-premotor cortices, respectively. An argument in favour of the hypothesis that the dorsal parietal-premotor pathway is exclusively involved in the control of movement execution is provided by motor deficits observed in patients with optical ataxia due to lesions of the posterior dorsal parietal cortex. Recently, Roy et al. (in press) studied the reaching-grasping kinematics of a patient with a unilateral lesion restricted to the posterior part of the dorsal parietal cortex. Although this patient showed an apparent recovery from optic ataxia, the early kinematic aspects of the patient's reaching-grasping movements were not normally modulated by either intrinsic or extrinsic visual properties of objects. These results constitute evidence that the posterior region of the dorsal parietal cortex, besides playing a role in the on-line control of movement execution, may also be involved in aspects of planning such as implementing and coordination of the various phases of arm movements (Gentilucci et al. 2000b; Roy et al., in press).

The ventral parietal-premotor circuit can also be involved in aspects related to perception and semantics other than those specifically related to planning an action. Indeed, neuroimaging studies have shown that the naming of tools or tool actions (Grabowski et al. 1998; Grafton et al. 1997; Martin et al. 1995), as well as viewing pictures of tools (Chao & Martin 2000), activates the human lateral premotor cortex. These findings suggest that the representations of an object (i.e., the actions associated with the object) can be automatically activated or retrieved by simply naming or viewing the object, without executing (and probably preparing) an object-related action. These results have their counterpart in behavioural data (Gentilucci 2003c) showing that class of word can be a factor selectively influencing motor control. Indeed, automatic reading of verbs more strongly influenced arm kinematics than adjectives.

Finally, action preparation and observation can be used to understand the meaning of an action (Rizzolatti et al. 2001) and to communicate with other individuals (Gentilucci 2003a; Gentilucci et al. 2001). The fact that the semantic face of speech and the arm gestures are reciprocally related, is supported by a new observation (Chieffi et al., in preparation) showing a reciprocal influence between the direction of deictic gestures (pointing towards a remote position or one's own body) and deictic terms (*QUA*, here, or *LA*', there) simultaneously pronounced. Indeed, the results showed that arm kinematics and voice spectra were reciprocally interfered with when the arm gesture was incongruent with the meaning of the deictic term.

Summing up: In our opinion, the distinction and definition of programming and on-line control of actions proposed by Glover can be partially reformulated. First, definition of on-line movement control should take into account that cognitive aspects of the object can at least partially penetrate into the feedback control of a movement. Second, definition of movement planning should take into account that some aspects of cognition (in particular semantics and speech) can be coded by action preparation.

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Plans for action

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Abstract: It is our contention that the concept of *planning* in Glover's model is too broadly defined, encompassing both action/goal selection and the programming of the constituent movements required to acquire the goal. We argue that this monolithic view of planning is untenable on neuropsychological, neurophysiological, and behavioural grounds. The evidence demands instead that a distinction be made between action planning and the specification of the initial kinematic parameters, with the former depending on processing in the ventral stream and the latter on processing in the dorsal stream.

Introduction. For the most part, Scott Glover's proposed "planning–control" model (PCM) bears a strong family resemblance to our "perception–action" model (PAM: Goodale & Milner 1992; Milner & Goodale 1995), and indeed it makes many similar predictions. But there are differences, and it is important to isolate precisely what they are, as well as to give a fair and correct account of the PAM. Take for example, this seemingly innocuous sentence taken from Glover's "Conclusions" section:

> The studies reviewed here are less consistent . . . with a perception–action model in which actions are thought to be both planned and controlled using a single visual representation in the SPL. (target article, sect. 5, para. 1)

Is this statement correct? Well, although it might be convenient for Glover if it were, the stubborn fact is that we never proposed that actions are "planned and controlled by a single visual representation in the SPL." It may suit the confrontational style of *BBS* to set up a straw man of this kind, but a closer look at what we have argued will show that the PAM makes no such simple-minded proposal. But first let us examine Glover's last clause in this sentence more closely since it does carry the germ of the real disagreement between us.

We can set to one side two relatively minor errors that are implicit in the sentence. The first error is to locate the human dorsal stream entirely within the SPL (superior parietal lobule). There is now ample fMRI evidence that the dorsal stream, particularly those regions involved in voluntary saccades and object-directed grasping, is centered on the human IPS (intraparietal sulcus), on the border between IPL and SPL (Binkofski et al. 1998; Connolly et al. 2002; Culham 2004; Culham & Kanwisher 2001; Culham et al. 2003). Only the region associated with visually guided reaching (as opposed to looking or grasping) appears to be located entirely within the SPL (Connolly et al. 2003). These neuroimaging results broadly back up the lesion localization evidence of Perenin and Vighetto (1988, Table 1), who found that a group of eight patients with optic ataxia all had brain damage that included the IPS, whereas only five of them had SPL damage. Indeed, the overlapping region in their patients was largely centered on the IPS. The

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second error in the sentence is the implication that we envisage that there are "visual representations" existing within the dorsal stream to control action. In fact, we have always been careful to emphasize our belief that visual information has *direct* control over action in the dorsal stream, without any intervening "representations." As Frith et al. (1999) have argued, not all neural activity is correlated with mental representations – at least in the sense of enduring representations of objects in the world. In our view, the neural activity in the dorsal stream does not reflect the representation of objects or events but rather the direct transformation of visual information into the required coordinates for action.

Much more central to our disagreement with Glover is that his summary sentence imputes to PAM the view that the dorsal stream plays a "master" role in the planning as well as the control of actions. This we find a surprising suggestion. In the first chapter of Milner and Goodale (1995) we wrote:

> As we shall see, despite the complexity of their interconnections, primate cortical visual areas can be divided into two functional groupings: one with rather direct links to motor control systems, and the other with connections to systems associated with memory, *planning,* and other more "cognitive" processes. (p. 19, emphasis added)

We have never associated planning with the dorsal stream, in any of our publications, before or since. Indeed, like Glover, we have argued for some time that the perceptual system, vested in the ventral stream and elaborated in the right IPL, provides a perceptual representation of the surrounding visual world that is used in the planning of actions.

So how has this apparent misinterpretation come about? The answer comes in section 1.1.2, paragraph 1 of the target article:

> At a high level, planning is responsible for such things as selecting an appropriate target, or choosing to grasp an object in a certain manner. Beyond these selection processes, however, planning also determines the initial kinematic parametrization of the movements, including their timing and velocity.

In other words, for Glover, "planning" is given a very broad meaning quite different from most usages of the term in the literature, in that it includes what he calls the "initial kinematic parametrization of the movements." According to Glover, planning includes processes that extend from goal selection right through to the initial programming of the constituent elements of the goal-directed action. To put it starkly, then, for Glover, the movements constituting the act of reaching out and grasping even a simple block are initially calibrated by a rich visual representational system (in the IPL) that is subject to the full panoply of contextual and cognitive influences. This, as far as we can see, is the crux of the disagreement between the PAM and the PCM.

According to our view, action planning and selection need to be separated, both conceptually and empirically, from the specification of initial movement parameters; and we have proposed that these two sets of processes each use a different visual information stream. We believe that action planning depends on visual processing in the ventral stream and right IPL, but that the initial movement parameters of the selected action are determined by processing in the dorsal stream (i.e., IPS/SPL). Our chief disagreement thus comes down to one crucial question:

> Is the initial kinematic specification of an action performed using "bottom-up" visual information within the dorsal stream, as we propose, or is it a part and parcel of the "planning" process, along with target selection and hand posture selection, and thus driven by the ventral stream, as Glover proposes?

Evidence from neurophysiology and neuroimaging. Our belief that movement parameter specification occurs within the dorsal stream rests on a consideration of a broad range of physiological, neuropsychological, and behavioural data. A large amount of single-neuron recording evidence reveals the existence of neurons within the monkey's posterior parietal cortex that have both visual receptive fields and time-locked responses to the eye and arm movements directed at targets located in different regions of the visual field. A saccade-related area has been found in the lateral bank of the IPS, in a region now known as lateral intraparietal area (LIP) (Andersen et al. 1992). More recent neurophysiological studies have also revealed a "parietal reach region" (PRR) located in the posterior and medial part of the intraparietal sulcus extending into neighbouring area V6A (Galletti et al. 1997b; Snyder et al. 1997). Damage to this region is reported to cause misreaching with initial heading errors that are misdirected to the medial side of the target as well as deficits in wrist orientation (Battaglini et al. 2002a; Faugier-Grimaud et al. 1978). More anterior to LIP lies an area (anterior parietal area [AIP]) where neurons respond to the geometric appearance of objects and have motor responses linked to grasping movements directed to these objects (Taira et al. 1990). Therefore, contrary to previous belief – echoed here by Glover – that "the dorsal stream in the macaque brain terminates in the inferior parietal lobule" (see target article, sect. 3, and Fig. 3 caption), current evidence now locates it in and around the IPS. Also, as we mentioned earlier, direct homologues of LIP, PRR, and AIP have now been identified using functional MRI in humans (Binkofski et al. 1998; Connolly et al. 2000; 2002; 2003; Culham 2004; Culham et al. 2003). It would therefore appear that the areas in and around the IPS make up the dorsal stream in both the human and the monkey posterior parietal cortex.

The evidence from fMRI in humans, like the neurophysiological studies in monkeys, suggests that the transformation of visual information into the appropriate motor coordinates for action takes place within the dorsal stream. Thus, in a recent event-related fMRI experiment, Connolly et al. (2002) showed that there is no activation in the human homologue of LIP as subjects prepare to make a saccade to a target that had not yet been presented. Activity increased in this region only when the target appeared. This suggests that LIP (unlike the frontal eye fields and other premotor areas) does not play a significant role in preparing for action – unless the location of the target has already been specified. In other words, the activity in LIP is related to the programming of eye movements to particular spatial locations but not to action planning in general. These findings are entirely consistent with results from similar studies in the monkey (Andersen et al. 1992; Snyder et al. 1997). In another event-related fMRI study, Culham et al. (2003) demonstrated that the lateral occipital complex (LOC), a ventral stream area implicated in object perception and recognition, shows no differential activation during visually guided grasping as compared to visually guided reaching – suggesting that the visually driven specification of the required movements for grasping is mediated entirely in AIP, which shows greater activation during grasping as compared to reaching. In short, the weight of physiological (and human neuroimaging) evidence indicates that the visually defined movement parameters are set within the dorsal stream in both monkeys and humans.

It is perhaps worth pointing out that not only is Glover's review of neuroimaging literature confined almost entirely to PET studies, but the evidence he presents on planning and control does not differentiate between the predictions and theoretical assumptions of the PCM and the PAM. None of the studies he discusses had sufficient temporal resolution to establish whether the activation that was observed corresponds only to the on-line control of movement, and not also to the programming ("planning," in the PCM sense) of a visually guided movement. We surmise that both would have contributed to the observed activations. Yet Glover goes on to argue that the "results were generally not consistent with the perception–action model . . . which predicts motor-related activity in the SPL but not in the IPL" (sect. 3.3, para. 4). But as we have already discussed, this argument is based on a misunderstanding of the location of the dorsal-stream areas within the parietal cortex, many of which are located within the IPS. This is compounded by the fact that the spatial resolution of PET is not nearly as good as that seen in fMRI, particularly in the high-field fMRI used today. As a consequence, motor control activations that were apparently localized to the IPL could sometimes have been located in

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the IPS. (The same arguments a fortiori apply to the TMS studies cited by Glover.)

Evidence from neuropsychology. Our PAM is also, we believe, supported strongly by neuropsychological evidence. This is principally derived from patient D.F., whose profound visual form agnosia we now know results from bilateral damage to the ventral-stream area LOC (James et al. 2003), and patients I.G. and A.T., who both have bilateral optic ataxia from bilateral damage to the dorsal stream (including IPS and SPL, though also more inferior parietal regions in A.T.'s case). Glover's PCM makes two strong predictions about these patients, which he states as follows:

1. "Deficits in optic ataxics should be concentrated in the later stages of movement" (sect. 4.4, para. 1).
2. "In the planning–control framework, damage to D.F.'s ventral stream should impair many aspects of how she plans movements, but should leave her control processes essentially intact" (sect. 4.6).

Optic ataxia. In a recent study, we directly addressed the question of whether optic ataxia affects only the later stages of movement (Milner et al. 2003). We examined reach trajectories in both of our patients right from the outset of each movement to see whether there was any problem in their initial heading direction. Strong and consistent heading errors were present in both patients right from the start of each of their reaches: In fact, the heading error predicted the final error very accurately. In other words, although these patients certainly do have serious problems with the on-line control of their reaching (as demonstrated by use of perturbation paradigms, Gréa et al. [2002]), they also have problems with the initial specification of their movements. It is important to bear in mind here that although A.T. has brain damage that extends well into the IPL, I.G. has only slight damage there (Pisella et al. 2000). Her heading errors therefore most likely arise, as far as we can tell, from her IPS/SPL damage.

Consistent with these results is the well-established finding, as Glover notes in his article (sect. 4.4.1), that optic ataxic patients are impaired in open-loop reaching. In this case, no on-line visual corrections are possible, because there is no visual feedback from the hand. So in Glover's terms, this task should be one of "pure planning." Why, then, are optic ataxic patients so inaccurate? The reason seems likely to be the same as in our closed-loop reaching task: The patients head off in the wrong direction from the outset, something that is never observed in normal subjects. It is also worth remembering that human optic ataxia looks strikingly similar to the misreaching and misgrasping seen in monkeys with dorsal-stream lesions. In fact, a direct comparison between monkeys with ventral- or dorsal-stream lesions (Glickstein et al. 1998) yields the same double dissociation between perception and action that we have observed in our patients. Glover seems to accept this, but nonetheless insists that "the 'what/how' distinction found in monkeys cannot be easily translated into an explanation of human brain organization" (sect. 3.1.1). It seems premature to dismiss so cavalierly the striking similarities in visual processing at all levels between humans and our primate cousins. The parsimonious and indeed most plausible default assumption to make is always one of biological continuity, and one should demand extremely persuasive evidence to reject it.

Visual form agnosia. In direct counterpoint to our optic ataxia results, we have found that D.F. has no difficulty at all in the initial specification of her movement parameters. In our first study of her visually guided movements (Milner et al. 1991), we videotaped her reaches to post a card into an oriented slot. As documented in that study, she began to turn her hand toward the target orientation *right from the very start of her movements.* D.F.'s reaching to point targets is also indistinguishable from normal, with no sign that early aspects of the movements are not normally programmed. This finding cannot be reconciled with Glover's view that the ventral/perceptual system plays a leading role in the early stages of movement planning (e.g., programming the initial movements of the hand in a reaching or grasping movement).

Yet, it is true that D.F. does have problems with certain high-level aspects of action, such as her inappropriate (but highly adept) grasping of tools. When, for example, she reaches out to pick up a screwdriver that has been placed on the table with the handle pointed away from her, she picks it up quite deftly but grasps it by its shaft rather than its handle – and only then rotates it in her hand so that she can hold it properly. In other words, because her damaged ventral stream is unable to process the screwdriver's shape, D.F. has no idea what it is ahead of time and is therefore unable to generate the functionally appropriate grasping movement shown by normal subjects when faced with the same task. Nevertheless, the intact visuomotor systems in her dorsal stream can still compute the required metrics to ensure that her grasping movement, however inappropriate, is well formed and efficient. To reiterate, we have never found any sign of faulty specification of her movement parameters, strengthening our belief that the selection of the appropriate functional hand posture needs to be distinguished from the metrical scaling of the constituent movements. We agree with Glover that D.F.'s "deficits in motor behavior can be likened to those suffered by many apraxics, whereas her spared abilities can be likened to those impaired in many optic ataxics" (sect. 4.6.2), but for different reasons. According to the PCM, patients with ideomotor apraxia would be predicted to have faulty specification of the initial movement parameters (as indeed should D.F.). Yet in fact most of these patients (like D.F.) do not have any measurable visuomotor abnormalities (Ietswaart et al. 2001) – and those who do (Haaland et al. 1999), appear to have damage extending to more superior parietal regions, including the IPS.

Before leaving this issue, it is important to emphasize that D.F. does not have ideomotor apraxia. Her problem is one of identifying the goal object on the basis of its shape, not one of selecting an action appropriate to its function. If she knows what the object is, she has no problem selecting a hand posture that matches its function.

Evidence from visual illusions. The study of visual illusions in healthy subjects does not bear directly on issues of visual processing streams. But PAM theory has allowed us to make certain counterintuitive predictions about illusions. Essentially the story goes like this: The perceptual (ventral stream) system uses an obligatory relative or contextual coding system for size, distance, and orientation, while the visuomotor (dorsal stream) system is designed to use "real world" metrics. We therefore predicted that some simple movements might be made without the influence of visual context or top-down visual knowledge. The remarkable fact is that the prediction has frequently worked: In several suitably engineered situations (particularly with so-called *pictorial* illusions, such as the Ebbinghaus and Ponzo), context really does have no – or minimal – effect on action parameters. There are exceptions, of course, but often these exceptions are highly instructive in themselves.

The simultaneous tilt illusion (STI), extensively used by Glover, is a good case in point. This illusion affects perception and action in much the same way, and indeed the perceptual and action effects are highly correlated (Dyde & Milner 2002). This result can be easily explained if we assume that the STI is mediated by an early (e.g., area V1) mechanism, and would thus affect both visual streams. Of course, the effect of the illusion on action is most evident in tasks in which observers receive no visual feedback during their reaches. When feedback is available, unsurprisingly, subjects do correct their actions, so that the illusion has a reduced magnitude at the movement endpoint (e.g., Glover & Dixon 2001c). These results, obtained in several studies by Glover and colleagues, would seem merely to reflect the fact that on-line feedback causes on-line corrections, but Glover argues that his results are "much less consistent with the perception–action model" (sect. 2.8, para. 2). In our view, it is obvious that on-line corrections will negate illusory effects, by allowing the subject to compare quite directly the orientation of the hand with the orientation of the goal during the closing phases of the movement. After all, that's what (in part) the on-line correction system is there for.

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Our perception–action model, of course, has the major virtue that it provides a theoretical rationale for those perception-action dissociations that can be demonstrated using pictorial illusions. It is true that the PAM and the PCM both agree that such illusions can affect the planning of actions – the question is, *why* do illusions affect such planning? Glover gives no reason, simply assuming that the "planning representations" are contextually dependent. It is unclear, furthermore, what he means by "planning representations." Are these just action plans or are they something else? We provide a more specific answer: Illusions affect the action planning because planning (a cognitive activity) requires *perceptual* representations, and it is these representations that are subject to illusory effects. This is a prediction, not an assumption. For example, if we plan to pick up the smaller of two objects in an Ebbinghaus display (in which the objects are in fact the same size), our choice can clearly be influenced by the illusion. Nevertheless, the programming of the actual movements to the selected object can escape such illusions, because the visuomotor system is not influenced by the top-down contextual information that drives perception. Parenthetically, if our theoretical position is correct, then losing crucial perceptual processing hardware should thereby also destroy the effects of pictorial illusions on action planning. Therefore, we would make a prediction directly opposite to one made by Glover, who argues that "the patient D.F. ought to . . . *show similar patterns of effects of visual illusions as healthy participants*" (sect. 4.8, last para., emphasis added).

Another strong prediction of the PCM is that *all* perceptual illusions should affect the initial phase of movements made toward the illusory target – after all, all movements require planning of some sort. Danckert et al. (2002), however, have provided rather unambiguous evidence showing that the Ebbinghaus illusion does *not* influence the finger-thumb aperture even at the very start of the reach – a result that is difficult to square with the PCM (although it is quite consistent with the PAM). In fact, even under certain conditions in which perception intrudes and the Ebbinghaus illusion affects grasping (Franz 2003), the size of that effect does not appear to change during the entire movement – a finding that is again inconsistent with Glover's view. Finally, the PCM predicts that there should never be a residual illusion at the end of the reach, because the action control system will always kick in during the final phase – even when visual feedback is not available. Yet this prediction is contradicted by Glover's own data: Glover and Dixon (2001c) found that a sizeable orientation illusion remained in their STI reach data when visual feedback was occluded (although they downplay this result). In contrast, when Dyde and Milner (2002) used an orientation illusion where the inducing background was changed from a contiguous grating (the STI) to a distant frame (the rod and frame illusion or RFI), they found no illusory effect on action at all, even though again no visual feedback was available. The PAM can explain this result by invoking the usual account of the RFI as a contextual illusion par excellence (Howard 1982), one that is presumably mediated by the scene-based frames of reference characteristic of the ventral stream. In contrast, the PCM can offer no explanation as to why there should be any dissociation between the STI and the RFI – both should affect hand orientation at the outset, and then the effects should disappear towards the end of the movement. The former prediction doesn't hold for the RFI (there is no illusion), and the latter prediction doesn't hold for the STI (it is still present at the end of the movement).

Summary. Our main criticism of Glover's PCM is that the concept of "planning" is used in a vague and overly broad fashion. It encompasses not only cognitive control (the selection of the goal object and, if necessary, an appropriate functional posture) but also the detailed programming of the constituent movements required to acquire the selected object. We believe that this monolithic view of planning is untenable on neuropsychological, neurophysiological, and behavioural grounds. The evidence demands instead that a distinction be made between action planning and the specification of the initial kinematic parameters. It is this distinction, along with Glover's failure to acknowledge it, that lies at the root of our disagreement.

The organization of action representations in posterior parietal cortex

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Abstract: Glover suggests that representational systems for planning versus control are mapped exclusively to the inferior (IPL) versus superior (SPL) parietal lobules respectively. Yet, there is ample evidence that the IPL and SPL both contribute to action planning and control. Alternatively, I distinguish between the parietal-frontal systems involved in the representation of acquired manual skills versus nonskilled actions.

Glover advances an interesting and provocative hypothesis concerning the organization of visual representations for action planning and control and their underlying neural substrates. Glover makes a strong case that action planning and control can be dissociated behaviorally, implying that these processes may depend on functionally dissociable representational systems. When the systems for planning versus control are respectively mapped to the inferior (IPL) versus the superior (SPL) parietal lobules, however, the theory goes awry. As I selectively review below, there is ample evidence that both the IPL and SPL contribute to action planning and control in primates. Based on this evidence, I offer an alternative model that distinguishes between parietal mechanisms involved in representing previously acquired skills versus those contributing to the planning and control of nonskilled actions.

Electrophysiological studies in macaques indicate that a variety of visually guided actions are planned in and controlled by functionally specialized parieto-frontal circuits involving both SPL and IPL regions. Accumulating evidence from functional neuroimaging suggests a similar organization in humans (see review by Culham & Kanwisher 2001). Counter to Glover's assertions, regions within the IPL are involved in movement control. For example, saccadic eye movements involve the lateral intraparietal area (LIP) in macaque IPL, and a putative homologue in humans has been identified (Sereno et al. 2001). Likewise, another IPL region – the anterior intraparietal area (AIP) – controls visually guided grasping in macaques. A probable homologue of AIP is also associated with grasping in humans (Binkofski et al. 1998). Furthermore, regions within the SPL participate in movement planning. The parietal reach region (PRR), located within the medial intraparietal sulcus (IPS) of macaque SPL, is involved in the control of visually guided reaching (Andersen et al. 1997). A homologous area has also been reported in humans (Kertzman et al. 1997). Importantly, cells in the PRR also engage in premovement planning; during multi-step actions, they represent forthcoming, intended movements (Batista & Andersen 2001). Consistent with this hypothesis, we have observed activation in human medial IPS (putative PRR), during mentally simulated reaching (Johnson et al. 2002).

Contrary to Glover's interpretation, the human lesion data also do not support the hypothesis that planning occurs exclusively in the IPL and control in the SPL. Patients with optic ataxia have difficulties controlling reaching toward and/or grasping objects located in peripheral vision. Optic ataxia is associated frequently, though not exclusively, with damage to the SPL (Perenin & Vighetto 1988). Given the substantial variation in naturally occurring brain injuries, this disorder is often likely to reflect damage to regions within IPL as well (Guard et al. 1984). For instance, one would expect IPL lesions in putative AIP to be an important factor in cases of optic ataxia where visually guided grasping is compromised (Goodale et al. 1994c; Jeannerod 1986). Indeed, Binkof-

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