Consciousness, Coordination, and Two Visual Streams

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ABSTRACT: Milner and Goodale's (1995) influential theory of visual processing suggests that only the ventral stream is directly associated with explicit conscious experience. However the implicit/explicit distinction does not map clearly onto the two visual streams. Whilst there is good evidence for the non-conscious nature of dorsal stream processing, evidence suggests that substantial processing in the ventral stream also occurs in the absence of conscious awareness. An alternative view is considered in which it is assumed that conscious awareness is not a property of specific processing systems (leading to multiple forms of conscious awareness) but where there exists a single conscious awareness system capable of interacting with the various processing streams.

In a highly influential paper, Ungerlider and Mishkin (1982) argued that there are at least two functionally distinct systems involved in processing visual information within the mammalian cortex. One, a ventral system, is specialized for processing information about object identity (a "what" system). The other, a dorsal system, specialized for processing information about object location (a "where" system). However, based on their own

studies, along with a substantial review of the literature, Milner and Goodale (1992, 1995) have argued for an alternative conceptualization of the role of the ventral and dorsal systems. According to this view, the ventral system codes for perception (object identification) and the dorsal system codes for action without perception.

In their analysis of these two systems, Milner and Goodale (1995, p.179) ask a number of key questions, for example, "How do the two stream interact in the production of integrated patterns of behavior? How do the phenomena of visual attention and consciousness map onto the two visual streams?".

In attempting to answer the first of these questions, the relationship between the two visual streams and conscious awareness, Milner and Goodale (1995, p.183) argue that only processing associated with the ventral stream results in the phenomenological experience associated with conscious awareness and that the dorsal stream normally operates in the absence of conscious awareness. Consciousness is thus a property of the ventral system and not of the dorsal system. Milner and Goodale appear to be making an implicit assumption that conscious awareness can be a property of a specific processing system (Farah & Feinberg, 1997). The implication of this assumption is that separate processing systems may (or may not) have their own form of consciousness, in other words, there may be multiple forms of consciousness awareness. Tulving (1985) adopts a similar position when discussing the properties of episodic, semantic, and procedural memory. Each of these memory systems is characterized by a different form of consciousness. Episodic memory is characterized by autonoetic (self-knowing) consciousness, semantic memory by noetic (knowing) consciousness, and procedural memory by anoetic (not knowing) consciousness.

However the view that conscious awareness is a property of the ventral system and not of the dorsal system needs to be examined. There is good evidence that, as Milner and Goodale argue, the dorsal stream is capable of operating in the absence of the phenomenological experience of awareness. For example, Castiello, Paulignan, and Jeannerod (1991) provide evidence from normal participants that appropriate reaching movements can occur in the absence of conscious awareness. In their study participants were able to compensate following the initiation of a grasping movement when the target was suddenly moved. Participants were able to make these compensatory adjustments in grasping behaviour much faster than they were able to report (by saying "Tah") that the object had moved (on average 107 msec vs. 420 msec). However within the literature on implicit memory, there is also good evidence that quite sophisticated processing of object identity (processing associated with the ventral system) can occur in the absence of conscious awareness. For example, Cooper and Schacter (1992) have demonstrated that structural encoding of objects can occur in the absence of conscious awareness. This encoding is thought to occur via a structural description system that computes object representations that do not include information on size or left/right reflection but which do include information specifying the relationship between the object's parts and between the object and its principle axis and frame of reference. There also appears to be evidence that object identity information can be accessed in the absence of conscious awareness (e.g. Gordon & Irwin, 1996). Considering the properties associated with the information

derived from the structural description system, these have been taken as suggesting that the neural locus of this system is within the inferior temporal cortex (Biederman & Cooper, 1991) which in turn might suggest that the system forms part of the ventral stream. Together then it appears that, up to a quite high level of encoding, conscious awareness is not a property of the ventral system. If it is the case that both the ventral and dorsal systems do not themselves necessarily possess the property of conscious awareness then this leaves open the question of how conscious awareness arises and why does it appears to arise more easily from processing associated with the ventral system.

As an alternative to assuming that conscious awareness is a property (or not) of a processing system some authors (e.g. Schacter, 1989, 1990, 1994) have argued for what appears to be a more unitary consciousness. A similar view has been expressed by Rozin (1976) who argued that evolution would give rise to a series of adaptive specializations. These will be highly modular processes that are initially inaccessible to other processes (what Fodor (1983) would refer to as information encapsulation), and they are often hardwired. Together this collection of hardwired, limited access machinery forms the 'cognitive unconscious' (Rozin, 1976). Part of the evolution of more intelligent organisms would be increased communication between these unconscious modular processes. This would result in the development of the conscious executive controls that mark intelligent behavior (Rozin, 1976). This view of consciousness implies something that exists over and above the modular processes and appears to be the view of consciousness adopted by Schacter (1989).

Schacter (1989) proposes a model, Dissociable Interactions and Conscious Experience (DICE), in which a number of knowledge modules connect to a conscious awareness system (CAS). [Schacter argues (p.369) that the concept of CAS can be viewed as short hand for the idea that conscious awareness of a specific bit of information requires processing beyond the modular level.] In turn there are then reciprocal connections between the CAS and a separate executive system. We can use this framework to interpret the relationship between the two visual systems and conscious awareness and to see how the coordination of these two systems may be brought about. Within this framework both the dorsal and ventral systems might be characterized as modular and these modules then potentially interact with the CAS. This obviously leaves unanswered why the output of the dorsal system seems to gain access to conscious awareness less easily than the output of the ventral system. The answer to this probably lies in the direct connection of the dorsal system to motor output system.

Milner and Goodale point out that it also important that the two visual systems are coordinated. Again there appears good evidence for a role for the ventral stream in mediating dorsal stream behavior. Sirigu, Cohen, Duhamel, Pillon, Dubois, and Agid (1995) describe a patient who can both identify objects correctly and organize her hand to grasp the object. However whilst her grasp may be efficient it often does not reflect the common usage of the object. Again using Schacter's model as an interpretive framework, we can see how the self initiated actions can be integrated into the motor behavior via the reciprocal connections between the executive, CAS, and modules.

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