

Two parts to a double dissociation



“ Organisms, at one level, are obviously collections of parallel systems that are potentially independent, although normally interactive.” (Weiskrantz, 1990)

The argument of separate visual processing streams is a long and turbulent one, which stems largely from Ungerleider and Mishkin's (1982) early work with monkeys. Following this research, Mishkin, Ungerleider, and Macko (1983) suggested two streams of processing. They characterised the ventral stream as the “ what” route, used to analyse visual characteristics of objects, and the dorsal stream as the “ where” stream, which calculated the spatial relations of the object. However, in 1992, Milner and Goodale proposed a reinterpretation of the dual pathway model (Goodale & Milner, 1992, 2004; Milner & Goodale, 1993, 2006). In this new model, the ventral stream was concerned with the visual perception and processing of object form and object recognition, to transform visual information into a ‘ perceptual representation’ of the world (Goodale & Milner, 1992).

Importantly, it also encoded spatial relations of objects in an allo-centric sense. This allows us to think about our world, its objects, and the placement of objects. In contrast, the dorsal stream was involved in the controlling actions interacting with the goal object. The dorsal stream calculates spatial relations in an ego-centric view, using accurate and precise measurements. In more general terms, it can be stated in short, that this new model suggested that differences between the two streams should be evaluated, not in terms of visual inputs, but as the output systems which the two streams serve. Both streams receive the same visual information, but they ‘ interpret’ it in different ways (Milner & Goodale, 2008).

In their study of this model, researchers searched for the ideal complementary double dissociation which would unequivocally support Milner and Goodale's claim that these streams are completely separate entities, which receive visual information, and then interpret and react to this information in very different ways. They found support for these claims by the flagship double dissociation studies using neuropsychological patients. The key conditions in these case studies and experimental research studies are Optic Ataxia (OA) and Visual Form Agnosia (VA). These neuropsychological disorders are, to Milner and Goodale, the quintessential case for a double dissociation.

The term of double dissociation is an elusive idea in neuropsychology, with clear and concise dissociations difficult to come by. In a single dissociation, damage to a particular brain region interrupts one function, but not another function. This implies that these two functions are independent of each other in some form. The most commonly referenced single dissociation is the condition VA, in which the patient perceptual abilities are impeded, but not the visuomotor abilities.

Furthering on from single dissociations, interest has turned to finding double dissociations. These double dissociations, as originally described by Teuber (1955) are seen as powerful tools in neuropsychological research, to discover and study the separate functional modules and to strengthen the evidence for a single dissociation. However, double dissociations can be very difficult to prove, as to be a true double dissociation it must be shown that two different external manipulations will affect two patients differently. That is, the first manipulation will affect patient A, but not B, whereas the second

manipulation will affect patient B, but not A. This can be used as a starting block to make inferences of the modular functions of brain areas. The dual visual systems double dissociation of OA and VA, or perception of objects with mis-reaching and inability to perceive with successful grasping became the workhorse of Milner and Goodale's model. They based much of their early findings upon studies carried out with patient D. F which showed a single dissociation (James, Culham, Humphrey, Milner, & Goodale, 2003; Goodale, Milner, Jakobson, & Carey, 1991).

Patient D. F. is the most researched neuropsychological patient in the study of dual visual streams, and it is from research carried out with her that led to the fruition of Milner and Goodale's model (Goodale et al., 1991). D. F. suffered bilateral lesions of the occipito-temporal cortex, considered to be the ventral stream area, which resulted in a profound case of "Visual Form Agnosia" (Milner et al, 1991). That is, she was incapable of visually perceiving the form of objects and yet she could accurately make visually guided movements and grasp objects (James et al., 2003; Goodale et al., 1991). It was argued that this research indicated that D. F.'s visuomotor skills were left intact, implying firstly, that there was evidence for a single dissociation, and secondly, that D. F. could show pure visuomotor skill without the interference of perception. In other words, she could show what the dorsal stream in Milner and Goodale's model was capable of achieving (Milner et al., 1991).

This original study was quickly followed by a stream of research which investigated the visuomotor capabilities of D. F (Goodale, 1994b; Milner et al, 1991) and a second VA patient; S. B. (Dijkerman, Le, Demonet, & Milner,

2004). The further research illustrated that D. F.'s visuomotor skills allowed her to scale her grip and orientate her wrist correctly, similarly to controls (Milner & Goodale, 1995). In matching orientation tasks D. F. failed, appearing to choose orientations at random, yet when asked to reach towards a slot and 'post' an item she performed at a similar level to controls (Goodale et al., 1991). Studies illustrated her ability to use visual information involving the orientation and shape of a particular object for online corrections of hand movements and in an object grasping task for regular shapes, (Dijkerman, Milner, & Carey, 1996; Carey, Harvey, & Milner, 1996), and irregular shapes (Goodale et al., 1994c). These findings were later replicated with S. B. (Dijkerman, McIntosh, Schindler, Nijboer, & Milner, 2009; Dijkerman et al., 2004). The interpretation given to D. F.'s visuomotor abilities suggested that the undamaged dorsal stream was controlling the visuomotor abilities, without the input of the damaged ventral stream. This was a powerful argument for Milner and Goodale's model as it emphasised the functional dissociation within the visual system.

On the opposite side of this dissociation, researchers studied patients (I. G. and A. T.) with Optic Ataxia (OA); a visuomotor disorder. This involves gross mis-reaching for visual targets, usually most severe in the peripheral visual field, can manifest in the contralesional visual field and the contralesional hand (Perenin & Vighetto, 1988). However, patients can identify objects normally; unlike patient D. F., OA patients can discriminate the size, shape, and orientation of objects. However, these patients have difficulty in grasping objects correctly or in a functionally correct manner. OA patients will not appropriately scale their grip during reaching; they open their finger

grip too wide, and close it once they reach contact with the object (Jeannerod, Decety, & Michel, 1994). In addition, their reaching duration is increased, their peak velocity is lower than controls, and they misplace their fingers when they have to visually guide their hand towards a slit (Gréa et al., 2002). Similarly, in reaching tasks with target jumps, both A. T. and I. G. failed to show online adjustment of movement like healthy controls (Pisella et al., 2000; Gréa et al., 2002). This indicates a feed forward and feedback deficit in OA. More simply, OA patients do not possess the capabilities to quickly alter their movements; they rely on the involvement of slower and later visual and motor feedback.

However, does all this research lead onto the conclusion of a classic double dissociation? Milner and Goodale argue that no clearer evidence could be shown; one condition (VA) leads to inability to perceive items, yet can act on these items, and the other condition (OA) shows an inability to grasp an item, and yet they can perceive all their features. The problem is, this case of double dissociation may not be as straight forward and concise as Milner and Goodale assume. There is a new stream of research showing the exceptions and difficulties in the dual visual system assumption.

A classic dissociation calls for one function to be within normal performance range and the affected function to be far below normal performance (Shallice, 1988). In relation to D. F.'s visuomotor abilities, more recent research has highlighted difficulties in claiming a classic dissociation.

Although D. F. does manage to grasp items in most cases, this is not to the level of normal range; she makes semantic errors in grasping tools in non-functional ways (Carey, Harvey, & Milner, 1996). However, she also fails to

grasp neutral laboratory blocks using the most comfortable grasp (Dijkerman, et al., 2009), and she fails to complete visuomotor guiding or grasping tasks with any shapes of significant complexity (Goodale et al., 1994a; Carey et al., 1996; Dijkerman et al., 1998; McIntosh, Dijkerman, Mon-Williams, & Milner, 2004). In fact, more recent research has found restrictions to D. F.'s grasping abilities, showing that she does not automatically select a grip posture which minimises awkward and uncomfortable grasps, like control subjects (Dijkerman et al., 2009).

Furthermore, even in successful completion of simplistic tasks, D. F. may not use the same visual cues that healthy controls use. When prisms were used to perturb D. F.'s vision, it was found that D. F. relies almost exclusively on vergence angle and vertical gaze for establishing object distance in reaching tasks (Mon-Williams, McIntosh, & Milner, 2001; Mon-Williams, Tresilian, McIntosh, & Milner, 2001). In fact there have been reports of the daily difficulty in carrying out actions for VA patients, namely S. B. showing at times greater peripheral misreaching than OA patients (Lé et al., 2002; Pisella, Binkofski, Lasek, Toni, & Rossetti, 2006). VA patients use compensation techniques such as, moving their head to focus the target in central vision and slowing their goal directed movements (Rosetti, Vighetto, & Pisella, 2003; Pisella et al., 2006). Dijkerman and colleagues found that patient D. F. could perform a grasping task well when she could use binocular viewing, even when her head position was fixed on a chin rest. However, she could not complete the task under monocular viewing unless she could tilt her head to compensate (Dijkerman et al., 1996). Specifically, D. F. needs to use either binocular disparity or motion parallax to recover the

depth of an object and successfully carry out a grasping task. The empirical evidence illustrates that patients with VA struggle with many visuomotor tasks and in many cases can only complete simple tasks. Therefore, their performance is far from within the normal range, shown by control tasks with uninjured brains. Firstly, this puts into question the strong single dissociation thought to be illustrated by VA. However, even more importantly and secondly, these findings cast doubts on the pure dorsal abilities, suggesting that even with an uninjured dorsal stream visuomotor skills are affected, which in this case prevents the possibility of a double dissociation.

The past research of OA has equally been viewed only through the eyes of the dual processing model, excluding the finer details. For example, clinically, a diagnosis of OA requires for all other perceptual deficits to be excluded. Specifically, issues with visual acuity, visual neglect or injury to the eye itself must be ruled out as explanations for misreaching with visual guidance. However, these diagnostic guidelines have not always been followed, and assessments of such issues have been absent or carried out in approximations (Schenk & McIntosh, 2010). Stricter assessments have recurrently shown impaired discrimination of object location or orientation, particularly in the extra-foveal visual field where OA symptoms are most severe (Michel & Henaff, 2004; Pisella et al., 2009).

It has been argued that in truth, OA is more closely linked to attentional disorders, such as visual neglect or visual extinction (Michel & Henaff, 2004; Pisella et al., 2009; Streimer et al., 2007, 2009). A. T.'s attentional visual field was described as being narrowed to a functional tunnel vision (Michel & Henaff, 2004). The confusion of OA's true origin comes from the fact that

misreaching occurs in extra-foveal vision, when patients cannot fixate on the object. The visuomotor abilities of OA patients in central vision show little to no deficits in carrying out visually guided grasping tasks under normal conditions, unlike the misreaching that is present in the peripheral visual field (Gréa et al., 2002; Pisella et al., 2000). More recent studies have suggested that misreaching also affects proprioceptive targets which are not in the direction of gaze (Jackson et al., 2009; Blangero et al., 2007). Jackson et al. (2009) argue that this indicates a difficulty in representing several locations simultaneously, indicating that OA is not simply a visuomotor problem. Similarly, recent papers have shown that perception itself is also impaired in the peripheral visual field (Michel & Henaff, 2004; Rosetti et al., 2005). These findings plunge the status of OA as a visuomotor disorder into uncertainty; and it unquestionably casts doubts on optic ataxia being considered as evidence of a dissociation of perceptual and motor functions within visual processing. Furthermore, with a growing number of researchers questioning the clarity of OA's strict visuomotor deficits, the argument of a double dissociation loses even more conviction.

Many years of research have emphasised an impairment of actions in OA, and an impairment of perception in VA. However, are the differences between these two conditions and the empirical evidence strong enough to support a case for a double dissociation? As Pisella and colleagues (2006) highlights, looking over past research on the vision for action studies on OA patients and VA patients; it becomes obvious that these sets of patients have not been tested in identical settings. As previously noted, vision guided grasping movements are impaired in the peripheral vision of OA patients;

however, these same abilities have only been tested in the central vision for VA patients (Pisella et al., 2006). As indicated earlier, OA patients have been shown to deal with visually guided grasping to a successful level in central vision and ecologically valid conditions (Gréa et al., 2002; Pisella et al., 2000). Without empirical evidence to indicate the true abilities of VA patients reaching in peripheral vision, it cannot be concluded that their reaching is unaffected. Similarly, OA patient's perceptual abilities have not been significantly studied. It is assumed that their perception is at normal levels, however, this same assumption was given to VA reaching until it was more closely studied. Thus, this major fault in the claim for a double dissociation does not take into account the fundamental assumption for double dissociations; that testing of the function must be carried out in the same conditions (Teuber, 1955).

Given the arguments presented, it seems unlikely that OA and VA are a complementary double dissociation reflecting the inner workings of a separate vision for action and vision for perception processing routes. This suggestion is much too simplified. It is much more likely that the vision for perception and vision for action streams interact a great deal, and thus both streams have an effect upon each of these two conditions. We are unclear of VA patient's peripheral visual abilities, and thus they cannot be truly compared to OA patient's extra-foveal misreaching. In fact, with doubt mounting about OA's actual link to the vision for action stream, the argument becomes even more clouded. Diagnostically, this must be cleared up before any conclusions of its involvement can be made.

In a comparable trend, patients with VA do not perform as well in visually guiding grasping tasks as originally claimed; they in fact perform well below normal levels (Goodale et al., 1994a; Carey et al., 1996; Dijkerman et al., 1998; McIntosh et al., 2004). Furthermore, under normal conditions and in central vision, OA patients actually perform better than previously claimed, due to their compensatory techniques (Gréa et al., 2002; Pisella et al., 2000). This coupled with recent findings of OA patients perceptual difficulties in peripheral vision, (Michel & Henaff, 2004; Rosetti et al., 2005), it becomes an extremely difficult task to claim a double dissociation. Although, it may be extreme to claim no interaction between these conditions, they are not completely separate entities either. The fact remains that both conditions allow us to learn a great deal about the visual system under the Milner and Goodale model, and there is certainly a complementary divergence of symptoms in part. However, the issue lies in attempting to construct these components into a complementary double dissociation; the components just do not add up.

Hence, it is necessary to move beyond the rudimentary dichotomy of vision for action and vision for perception, and consequently the supposed double dissociation and simplification of OA and VA. Despite previous conventions on the unification of these deficits as one dissociation, as has been shown deeper research is beginning to highlight the cracks in this dissociation. It is necessary to advance the Milner and Goodale model beyond the research reliance on the OA and VA double dissociations. It is important that the assumptions made of OA and VA being clear and concise indicators of each visual stream's abilities is eased. Although individually, patients such as D. F.

and S. B., who have perceptual deficits as found in VA, can be useful indicators of the most basic abilities of the dorsal stream, this cannot be guaranteed to indicate workings of the ventral stream. As shown previously, the interaction between the two streams may be greater than previously thought. Thus higher functions of the dorsal stream may fail in patients with VA without the necessary interactive involvement from the ventral stream. Similarly in cases of OA, moreover, this may be in even more doubt with the disagreement of attention deficits playing a vital role in OA symptoms. In essence, the fixation on a double dissociation between OA and VA is hindering future research and the advancement of the dual visual processing model. This simplistic idea of the absolute double dissociation must be abandoned, and a more interactive approach taken to achieve research advancement.