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Using single cases to understand visual processing: The magnocellular pathway

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Vannuscorps, Galaburda & Caramazza (2021b) report on an individual (Davida) with a developmental deficit who consistently perceived stimuli as rotated around and/or mirrored across the object's primary axes. Interestingly, Davida was unimpaired under a variety of conditions. Her ability to judge stimulus orientation was excellent when using touch without vision, for three-dimensional objects, and for two-dimensional objects that were blurred, low contrast, moving, or flickered. Her errors instead occurred for two-dimensional stimuli that were sharp, high contrast, stationary and sustained. This pattern is consistent with proposals suggesting a distinction between two visual pathways, a magnocellular pathway (M-pathway or transient system) specialized for brief, moving, low contrast stimuli, and a parvocellular pathway (P-pathway or sustained system) specialized for stationary, high spatial frequency stimuli.

Along with evidence from visual perceptual studies with neurologically intact individuals (Breitmeyer & Ganz, 1976; Breitmeyer & Ogmen, 2000), single case studies have provided additional evidence for such a distinction. A.H. (McCloskey, 2004, 2009; McCloskey & Rapp, 2000; McCloskey et al., 1995), a college student with a developmental deficit, mislocalized stimuli as reflections across attention-centered midlines, maintaining the distance and eccentricity from the midline, but not correctly representing the direction from this midline. Her performance substantially improved for visual stimuli that primarily utilize the M-pathway. In A.H., these reflection errors significantly decreased when stimuli were presented for 100 msec or less compared to stimuli longer than 250 msec, for moving stimuli versus stationary stimuli (McCloskey et al., 1995), for flickering stimuli versus static stimuli, and more versus less eccentric stimuli (McCloskey, 2004). A similar pattern was also observed in the case of P.R. (Pflugshaupt et al., 2007), an individual who demonstrated mirror reading and writing subsequent to diffuse cerebral hypoxia. P.R.'s deficit was also attenuated under similar conditions, as target saccades were more accurate for moving versus stationary stimuli, flicker versus constant stimuli, and relatively short (50-100 msec) versus longer duration (≥200 msec) stimuli.

Vannuscorps, Galaburda & Caramazza (2021b) provide evidence that these transient and sustained channels can be selectively damaged at the level of mapping intermediate shape-centered representations (ISCRs) onto higher-order (e.g., spatiotopic, body-centered) frames of reference, with Davida demonstrating a deficit selective to the parvocellular, but not magnocellular, pathway. Vannuscorps and colleagues note that this interpretation could be challenged as "most cases of patients who suffer from orientation and/or localization disorders in the context of dorsal stream lesions do not appear to show any sign of influence of visual variables" (p. 18). While possible, I believe that this may be due to the opposite pattern (damage to a magnocellular, but not parvocellular pathway) being more difficult to detect. If this M-pathway is preferential to brief stimuli, a deficit for transient stimuli may easily go unnoticed especially when compared to other impairments caused by parietal lesions (e.g., neglect).

We (Medina et al., 2016) reported an individual (K.G.) with a right-hemisphere lesion who demonstrated a deficit that may have been specific to the magnocellular pathway. In initial testing, we presented her with a standard visual confrontation task in which the experimenter separates their arms and quickly moves either the left index finger, right index finger, or both simultaneously. When the experimenter stood directly in front of K.G. (i.e., typical clinical presentation), she was accurate at detecting and localizing stimuli presented in her ipsilesional visual field. However, when doing the same task with the experimenter's hands directly over K.G.'s hands, she reported seeing the index finger of both hands move on trials in which the finger moved over her ipsilesional hand - visual synchiria. Given studies that have linked peripersonal visual space (the area near the body) with the magnocellular pathway (see Goodhew et al., 2014; Taylor et al., 2015 for reviews), we then repeated the experiment with visual stimuli (red circles) that varied in duration (50-1000 msecs) and whether they were presented on or off of the hands. For ipsilesional stimulation, we found that her synchiric percepts were most frequent (approximately 80% of trials) when visual stimuli were brief ($\leq$250 msec) and presented on the hands, with significantly lower rates of synchiria for longer stimuli and brief stimuli not presented on the hands (approximately 25% of these trials). Given previous evidence suggesting that the M-pathway is preferential to brief and peripersonal visual stimuli, we interpreted these results as a deficit that was specific to the M-pathway.

In our communications with K.G., she never reported anything out of the ordinary in daily life, which would be expected given that the deficit was quite specific (only occurring for brief stimuli presented on the body). We wanted to explore questions regarding shape representation by presenting K.G. with two-dimensional objects in different locations and orientations, but unfortunately were unable to test her further. Given that her lesion is not particularly rare, we believe that other individuals with selective deficits to the M-pathway due to dorsal stream damage likely exist, and that examining them could provide evidence regarding the nature of object representation in the M-pathway.

Second, Davida's performance provides additional support for the coordinate-system orientation representation (COR) hypothesis (Gregory et al., 2011; Gregory & McCloskey, 2010; McCloskey et al., 2006), with her deficit manifesting as errors in correctly representing the axis correspondence and axis polarity correspondence for visual stimuli that are thought to be represented by the M-pathway. One case study, B.C. (Valtonen et al., 2008), made errors that were left-right mirror reflections across a vertical, external coordinate axis. Interestingly, her deficit was manifest in both the visual and tactile domain, as similar errors were made when she was asked to reproduce the orientation of a wooden stick explored via touch only. Given that other cases with related deficits (T.M. and A.H., see McCloskey, Valtonen & Sherman, 2006 for a discussion) were not tested with tactile stimuli, one interpretation provided was that reflection errors such as those reported in these cases occurred at an amodal representational level. When asked to report the orientation of a three-dimensional wooden arrow or letter explored only via touch, Davida was perfect. While it may be possible that object orientation can be represented amodally, Davida's pattern of performance suggests that coordinate orientation can be represented specific to the visual system.

As a final point, Davida's case is an example of the importance and value of cognitive neuropsychology for our understanding of visual and cognitive processing. From the careful examination of a single individual, Davida's performance alone has strong implications for our understanding of visual processing along multiple dimensions: potential dissociations between specialized pathways for visual processing, the decompositional nature of representing object location relative to external reference frames, how object axes are represented (Vannuscorps et al., 2021a), dissociations between two-dimensional and three-dimensional object processing (Erlikhman et al., 2018; Freud et al., 2016) and our understanding of visual systems for perception and action (McCloskey, 2004). Although cognitive neuropsychological research has declined in usage relative to cognitive neuroscientific techniques (Medina & Fischer-Baum, 2017; Shallice, 2014), this study is a testament to the power of single case studies in developing our understanding of the human mind.

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