Extended Abstract
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Pediatric Ophthalmology 2018: Cerebral visual impairment: Dorsal stream vulnerability from amblyopia and autism to attention

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Abstract

Research in the Visual Development Unit on ‘‘dorsal stream vulnerability’ (DSV) arose from research in two somewhat different areas. In the first, using cortical milestones for local and global processing from our neurobiological model, we identified cerebral visual impairment in infants in the first year of life. In the second, using photo/video refraction in population refractive screening programs, we showed that infant spectacle wear could reduce the incidence of strabismus and amblyopia, but many preschool children, who had been significantly hyperopic earlier, showed visuo-motor and attention deficits. This led us to compare developing dorsal and ventral streams, using sensitivity to global motion and form as signatures, finding deficits in motion sensitivity relative to form in children with Williams syndrome, or perinatal brain injury in hemiplegia or preterm birth. In current research, we find that individual differences in motion coherence sensitivity in typically developing children are correlated with MRI measures of area variations in parietal lobe, fractional anisotropy (from TBSS) of the superior longitudinal fasciculus, and performance on tasks of mathematics and visuo-motor integration. These findings suggest that individual differences in motion sensitivity reflect decision making, attentional control.

Introduction

Emerging cortical function and infant cortical impairment

The work will discussed at the beginning of the review arose out of the first twenty years of my research with Oliver Braddick and our team in the Visual Development Unit in the Cambridge, particularly John Wattam Bell and Shirley Anker. We began by devising new methods, both behavioral and electrophysiological to measure the normal visual capacities of infants such as acuity and contrast sensitivity, over the first years of life. We then looked at the time scale of development with basic visual cortical function’s: binocularity, orientation and direction selectivity, symmetry of monocular optokinetic nystagmus and control of visual attention. This research led to be neurobiological model of the course of visual cortical brain development, in which an initially subcortical system came under the control of progressively emerging cortical functions. The milestones of this sequence provided the basis for identifying the cortical visual impairment in infant’s with early brain injury. This is the starting point for extended the collaboration’s with paediatric neurologist’s including the extensive studies of visuo-cognitive consequences of perinatal brain injury in infant’s were identified with hypoxic ischemic encephalopathy and in infant’s with very preterm birth.

- Infant refractive screening
- Infant motion sensitivity
- Dorsal and ventral streams in infancy
- Development of global form and motion sensitivity in childhood
- Global motion and global form in Williams syndrome
- Dorsal-stream vulnerability: A widespread feature of developmental disorders
- Broader dorsal stream functions
- Visuomotor control and spatial cognition in Williams syndrome
- Visuomotor and spatial deficits in other developmental disorders
- Brain structure associated with global motion performance in typical development

Overview

I have been ranged widely through the evidence for particular vulnerability of the dorsal cortical stream in development, and the value of relative sensitivity to global motion and form as a measure of this vulnerability and of variations even in the typical development. However, given the very different cognitive and social-behavioural profile’s in the phenotypes of different developmental disorder’s and the commonality of deficits in the global motion processing, there must be much debate as to whether the deficit originates across all disorder’s at the same neural level of visual processing, within the complex dynamic cascade from retina to cortex and within the cortex itself—whether we talking about top-down constraint’s or bottom up, or both. There is an added problem of identifying whether a deficit in early life at a relatively low level of processing has a knock-on effect at later ages at ‘‘higher’’ levels in the visual and visuo-cognitive system’s. Lack of space prevents these issues from being fully explored here. However, from our own work with typically and atypically developing the infants and children, we would argue that there is unlikely to be a single limiting constraint at one level in processing global motion across all disorders, unless it is a very early developing visual attentional deficit, such as infant ‘‘dis-engagement’’ in selective attention task’s. When added to the different perceptual biases across different disorders, this leads to an apparently common deficit in global motion sensitivity and to other ‘‘higher level’’ deficits in spatial, mathematical, and attentional cognition.

So we are left with many unanswered questions including the following:

- Is "dorsal vulnerability" determined by shared anatomy and neural processing of motion, attention, visuo-motor control, numerical cognition—or are the developmental cascade's between these functions?
- Does "dorsal stream vulnerability" have the same underpinning in terms of faulty neural networks across all the disorder's in which it has been demonstrated? Or can this vulnerability occurs in different areas and branches of the network, from the magnocellular system in the geniculostriate pathway, to target area's in frontal lobe for top-down decision making or even in separate pathway's through the MT/V5 avoiding V1 via the pulvinar or other routes?
- Why the attention processes that will appear to be vulnerable specific to global motion, and not shared with global form? Is this vulnerability really one of the dorsal/ventral stream integration in motion task?
- Are there difference's at a very early stage of development of motion processing which fundamentally change the course of complex development, underpinning later intelligent behaviour?
- How do genetic and environmental difference's interplay in determining the brain structure?
- Do we know how system with the properties of Duncan's adult multiple demand system develops in childhood?

These questions, and many more, are need to be answered by inter-disciplinary team's in developmental vision from psychology, cognitive neuro-science, genetics, paediatric ophthalmology and optometry, paediatric neurology, developmental computational science, and education, especially if we are go on to find child friendly, reliable intervention's to reduce and overcome these visually related problems, which may affect many aspects of everyday life. The exploration of global motion sensitivity is a signature of some of these wider cognitive processes, and their vulnerability in atypical development, provides the goal's for future research.

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