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Development is a pathway for understanding visual attention and peripheral function --Manuscript Draft--

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Abstract:	Visual Attention in Crisis provides the reader with an alternative way to think about the visual attention phenomena - often interpretable in terms of perceptual processes and peripheral vision. We urge an extension of these considerations to developmental science. Infancy research underpins the foundations of mature attentional mechanisms. It may offer a critical test for evolving perceptual limits on attention.

Commentary on Rosenholtz's target article: Visual Attention in Crisis

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Development is a pathway for understanding visual attention and peripheral function

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Abstract

Visual Attention in Crisis provides the reader with an alternative way to think about the visual attention phenomena - often interpretable in terms of perceptual processes and peripheral vision. We urge an extension of these considerations to developmental science. Infancy research underpins the foundations of mature attentional mechanisms. It may offer a critical test for evolving perceptual limits on attention.

Main text

Rosenholtz's re-examination of visual attention stems from a clear understanding of the capabilities and limits of mature peripheral vision. This marks the starting point to uncover and challenge anomalies in attention-related phenomena. Despite this, such an understanding of peripheral function is still partial over early development. Rosenholtz's position is therefore not integrated into infant research paradigms examining visual attention. It is our view that development is critical for understanding mature attentional mechanisms. Foundations of attentional networks, such as alerting and orienting, develop in infancy, and ground mature and more complex attentional and cognitive processes (Hendry et al., 2019). Development can also help us determine how perceptual capacities and limitations impact attention. As highlighted by Rosenholtz, perceptual mechanisms tend to be included under the same umbrella definition of attention. A better understanding of early perceptual development can provide essential information on the complexity of mature phenomena.

Currently, relatively few studies have investigated peripheral processing during development. What we know is that visual fields gradually expand, particularly over the first postnatal year (Lewis & Maurer, 1992). At birth, the peripheral retina is relatively mature compared to the central/foveal retina (Hendrickson & Drucker, 1992). Accordingly, a peripheral advantage for movement detection is observable at birth (Johnson et al., 1991) and during the third trimester of gestation (Reid et al., 2017). Of note, stimuli with evolutionary significance (e.g. face-like stimuli) can be detected at higher eccentricities compared to other stimuli (Capparini et al., 2022a). Stimulus features such as size and distance also play a role in early peripheral functioning (de Schonen et al., 1978). Nevertheless, there is currently no comprehensive mapping of peripheral processing during different developmental stages. Most research focused on the first postnatal weeks, with very little investigations beyond 6-7 months. However, we know that peripheral vision is still developing at 9 months (Capparini et al., 2022b). It is therefore unsurprising that only hints are present into the relationship between peripheral information processing and attention during infancy (Johnson, 1990; Johnson & De Haan, 2015).

In stark contrast to peripheral work, infancy research abounds with visual attention studies. Examples include experiments on covert and overt attention, with tasks such as the fixation shift paradigm, the gap/overlap paradigm, or other adaptations of the spatial cueing paradigm. In preverbal participants, covert attention is often revealed by physiological variations (Finlay & Ivinskis, 1984) or changes in saccadic behaviour (Clohessy et al., 1991) following the brief presentation of a peripheral cue. Further, brain activation in the anterior cingulate cortex, as indexed by the Negative component (Nc), has been proposed to mediate early attentional orienting and to distinguish periods of focused vs. unfocused processing (Richards, 2003). All the above paradigms involve the presentation of peripheral stimuli but the limits of the developing visual field are often not considered. In parallel with Rosenholtz's reasoning, we argue that performance on attentional tasks may be explained in terms of a developing peripheral vision rather than attentional processes, and that the contributions from the perceptual and attentional systems both need to be considered. Future work is needed to clarify whether complex behaviour during development, such as rapid orientation to some emotions over others, are led by bottom-up perceptual and/or top-down attentional mechanisms.

Visual processing in the peripheral field is qualitatively different from processing in central regions. Crowding is a phenomenon that is primarily present in the periphery and impacts the detectability of objects outside fixation (Levi, 2008). Farzin et al. (2010) demonstrated that

visual experience during infancy cannot be simply predicted by developing acuity and contrast sensitivity, rather infants seem to have a coarser and more diffuse window of visual awareness than adults due to crowding. Crowding can also impact saccadic orienting behaviour towards a peripheral target and, hence, play a role in the above-mentioned visual attention studies. The effect of perceptual mechanisms such as crowding on complex attentional behaviour needs to be further explored in infancy. Infants and their developing peripheral capacities can therefore allow us to test the limits on task complexity raised by Rosenholtz and identify the nature of such a limit.

As highlighted in the target paper, a non-attentional pathway accounting for statistics of low-level visual features may explain attentional phenomena. In infancy, low-level processing has proposed cascading roles for attentional and cognitive mechanisms. An example is the relation of low-level contextual processing indicated by a slow wave ERP effect for congruent and incongruent actions (Michel et al., 2017). This then leads to an Nc attentional effect at 7 months and then an N400 semantic effect at 9 months (Reid et al., 2009; Kaduk et al., 2016). Overall, summary statistics models have had limited applications to developing populations (see Balas, 2017, with children). Whether summary statistics can explain infant behaviours, such as the preference for high-contrast information or delayed orienting responses, is still open to investigation.

On top of conceptually rethinking early attentional processes, resolving the vision-attention imbalance would be helpful in addressing newly emerging trends in developmental research. Notably, there has been increasing interest in implementing more naturalistic setups that can capture the child's naturalistic visual environment, for instance using head-mounted cameras (Anderson et al., 2022; Jayaraman et al., 2015). Such investigations are essential for generalizing laboratory findings to everyday environments. They currently operate with incomplete information about the child's visual capacities during development. How much visual information is available across the child's visual field and how is this affected by peripheral limitations or crowding? These issues cannot be addressed using a simplified camera-view. Another area that can benefit from a better mapping of perceptual limits over time are computational models of cognitive development (Mattern, 2024). Implementing immersive visual environments that capture visual capabilities and limitations across different developmental stages can therefore affect further processing and decision making.

It is our view that a comprehensive mapping of peripheral vision throughout early development could lead to a better understanding of what can be defined as *attentional* rather than *perceptual*. Beyond a theoretical rethinking of attention, perceptual capabilities and limits need to be carefully considered in the developmental sciences.

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