**Specific Aims Page:**

While central vision resolves the fine details of discrete objects of interest, peripheral vision plays an outsized role in mapping and monitoring the surrounding space, *capturing rich temporal information about the scene-state of the environment*. It is well-established that the retina does not process light uniformly across its surface. The concentration of spatially-sensitive photoreceptors (cones) is highest in the center of the retina (fovea) and falls off toward in the periphery, where less-spatially-sensitive rods are the dominant photoreceptor. Rods and cones primarily connect to two distinct neural pathways, the magnocellular and the parvocellular pathways, respectively. The parvocellular pathway processes color and fine detail but is comparably slower to integrate temporal changes. The magnocellular pathway is less sensitive to fine spatial detail, but processes motion at a faster rate. Accordingly, while central vision is far more sensitive to spatial information, the gradient of temporal sensitivity follows a much shallower slope. Finally, the distribution of photoreceptor types varies not only as a function of eccentricity, but also as a function of polar angle.

My current work aims to address two major gaps in the study of peripheral motion perception. First, we must extend the investigation of peripheral motion perception out of psychophysics and toward naturalistic stimuli and freely-looking behavior. Second, to understand the perception of environmental motion, we must extend study of motion perception beyond rigid-body translational motion, into the domain of complex motion. While the movement of an object of attention is often smoothly tracked in the center of vision, the natural environment seethes with complex motion, such as particle motion, oscillatory motion and turbulent flow.

*Without a comprehensive understanding of how humans perceive peripheral environmental motion, our models of visual cognition will be fundamentally incomplete*. Additionally, failure to develop scientific understanding of environmental motion perception means that we are missing a critical component in the psychology of visual attention, at a moment when attention disorders represent an urgent national health crisis. Further, we are in an age characterized by relentless efforts to create technologies that seamlessly integrate with human sensory capabilities. --Understanding environmental motion perception is critical for the responsible advancement of virtual and augmented reality experiences, therapeutic or otherwise.

My *long-term goal* is to accurately model the processing of environmental motion in the human visual system. The *objective of this application*, which is the next step toward attainment of my long-term goal, is to map complex motion sensitivity across the retinotopic field, model these dynamics computationally, and test the relationship between the retinotopic mapping and higher-order (aesthetic) perceptual judgments in naïve observers. The *central hypothesis* driving this application is that temporal and spatial sensitivities are independently distributed across the visual field, exhibiting distinct patterns of sensitivity that do not conform to a singular, unified gradient. When the cortical magnification factor (CMF) is considered, I hypothesize that far-peripheral regions of the visual field will demonstrate enhanced task-related motion sensitivity compared to near-peripheral regions. *The rationale* driving the proposed research is that the perception of complex environmental motion is a blank spot both in vision science and ecological psychology. By characterizing the role of peripheral vision in detecting complex dynamics within natural scenes, our findings promise to address a substantial knowledge gap and provide a foundation for more detailed neuroscientific investigation of the topic.

I plan to test my central hypothesis by pursuing the following specific aims:

1. Map the relative spatiotemporal sensitivity across the peripheral visual field, using expert observers and two types of naturalistic dynamic stimuli. Based on preliminary data, my working hypothesis is that retinotopically-mapped spatial and temporal sensitivity gradients will exhibit independent and significantly different slopes and polar angle asymmetries, and that these mappings will vary by stimulus type.
2. Develop a simple computational observer model to bridge behavioral outcomes and neurobiological models of peripheral motion perception. Based on my understanding of the neurophysiology of the early visual system, my working hypothesis is that a computational observer model of the system will require independent representation of both Magno-type retinal ganglion cells and Parvo-type retinal ganglion cells (and their respective pathways) to agree with the behavioral spatiotemporal sensitivity mapping at above-chance accuracy.
3. Test whether the measured spatiotemporal sensitivity maps predict responses in a subjective visual judgement task. My working hypothesis is that the retinotopic sensitivity map generated in Aim 1 will predict the relative magnitude of subjective aesthetic responses to naturalistic dynamic stimuli, in a group of naïve observers.

The proposed research will use naturalistic stimuli to produce detailed mappings of spatiotemporal sensitivity across the peripheral visual field, and a novel computational model of peripheral motion perception. The research will reveal the relative impact that both eccentricity and polar angle asymmetries in the visual system have on task performance and subjective judgement of naturalistic dynamic stimuli. The anticipated outcomes will not only advance scientific knowledge but stand to inform innovations in virtual/augmented reality, improve therapeutic interventions in that arena, provide insight related to pathologies that selectively affect macular or peripheral vision, and influence the design of both virtual and built environments.

**Overall Scientific Premise:**

Classic studies found little variation in psychophysical temporal contrast sensitivity as a function of eccentricity (Virsu et al., 1982, Rovamo & Raninen, 1984) indicating highly independent mapping of spatial and temporal contrast sensitivity across the visual field. A recent fMRI psychophysical study on temporal contrast sensitivity in peripheral vision indicated that in the early visual system, peripheral regions of the cortical retinotopic map demonstrate relatively increased temporal contrast sensitivity compared to regions that represent the fovea (Himmelberg & Wade, 2018). However, the same research showed that by visual area hV4 temporal contrast sensitivity appears to be relatively uniform across eccentricities, agreeing with earlier behavioral studies of peripheral temporal contrast (Koederink et al., Wright & Johnston, 1983) that showed little difference in foveal and peripheral performance. *This has led me to the question of how peripheral motion sensitivity is mapped in the context of naturalistic stimuli and behavior*. While psychophysical methods are an incredibly useful tool for measuring the capabilities of the visual system, they tend to treat behavior as a confound, paring down experiments so that the visual system can be treated separately from the mind and the environment. All the work I have just cited utilized flickering sine wave gratings, an excellent stimulus for establishing psychophysical thresholds, but far from ecologically valid. The primary motivation of my proposed research is to carefully introduce aspects of naturalistic scene perception, to examine how prior psychophysical and neurophysiological results relate to tasks involving the perception of naturalistic motion and behavior.

Scientific Premise for Aim 1: The scientific premise of Aim 1 is that while peripheral sensitivities are well established in the context of critical flicker frequency (CFF), *the visual system does not process all types of temporal information uniformly*. While CFF stimuli are an excellent tool to measure temporal contrast sensitivity, they do not represent motion in the ecologically valid sense. Limited studies of peripheral motion using translational motion have produced important results. fMRI investigation of motion response anisotropies using 100% coherence RDKs found bias for either centripetal or centrifugal motion that changed systematically with eccentricity in visual areas V1-V3 and hV4 (Maloney et al., 2014). Earlier behavioral psychophysics demonstrated polar angle anisotropies in observer sensitivity to noise stimuli moving in one of eight cardinal directions (De Grind et al., 1992). These studies indicate that there are yet-to-be understood interactions between motion type and location in the visual field. To begin to address this question, I will task observers with discriminating spatial and characteristics of two types of dynamic stimuli: coherent motion RDKs and dynamic fractal noise.

Scientific Premise for Aim 2: Kupers et al., 2022

Scientific Premise for Aim 3: Hassan et. al, 2016

(Hassan et. al, 2016) is scientific premise for Aim 3

flicker frequency sensitivity maps separately from spatial sensitivity. (cite Himmelberg, and alspo the temporal contrast dot paper

**Research Strategy**

**Significance & Innovation:**

Cite Articles to establish the scientific premise. Discuss the strengths and weaknesses of existing literature.

In innovation, cite articles to establish the status quo. –The platform for your innovation

Significance: the impact that something will have on some other thing

It’s important that we validate what we have learned from psychophysical experiments by extending the experimentation toward naturalistic behavior. Importantly, if findings using naturalistic tasks and stimuli appear to contradict findings from temporal contrast psychophysics studies, this would indicate a missing layer in our models of perceptual motion. If on the other hand results did agree, it would validate the psychophysical methods as a predictor of naturalistic behavior.

Innovation: a new way of addressing something that opens up new horizons.

**Approach**

**Each Aim**

* Introduction
* Research Design
  + Refer to literature to establish methodological feasibility.
* Expected Outcomes
* Potential Problems & Alternative Approaches

**Timetable**

**Future Directions**

**Innovation:**

While I have taken care to design my experiments rather conservatively, I will take advantage of state-of-the-art VR technology to present stimuli using an innovative method that was not possible until recently. Since the 1960s, psychophysics has been an incredibly fruitful field, replete with reliable and increasingly precise findings regarding the mechanisms and capabilities of primate visual perception. In the 1980s, innovations in computationally-driven stimulus creation and presentation amounted to a huge boost for the field (Burr & Thompson, 2011). At present, vision science is on the brink of a new burst of innovation made possible by another mainstream technological advancement: *foveated rendering*. Until recently, almost all vision-relevant psychology research has demanded that participants are constrained to a chinrest or head restraint system and asked to fixate on a centrally located marker. Foveated rendering obviates the need for restraint or fixation by precisely tracking the participant’s gaze inside a VR headset*, allowing precision-delivery of stimuli to specific locations on the retina, regardless of where the participant shifts their gaze*. Rather than forcing the participant to lock their gaze relative to a stimulus, we can now lock the stimulus to the “freely-behaving” participant.

My interest in freely behaving vision science is motivated by my experience in systems neuroscience, where thanks to behavioral quantification tools such as DeepLabCut, (Mathis et al., 2018) and continued miniaturization of neural probes (Jun et al., 2017) freely moving behavioral research has picked up a huge amount of momentum over the last decade. Recent findings have made it clear that neural activity in the early visual system is richer in freely moving animals than in head fixed ones (Parker et al., 2022, Meyer et al., 2020). It is imperative that perceptual psychology moves out of the head fixed era wherever feasible. Foveated rendering enables a new level of ecological validity for psychophysics and perceptual psychology at large. Not only will foveated rendering allow me to conduct vision science in unconstrained participants, it will allow me to densely and precisely map sensitivity across the retinotopic field in a tightly-controlled experimental set up.