Scene perception from central to peripheral vision

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When we view a real-world scene with both eyes, we see a seamless vista that covers a visual field of more than 200° diameter horizontally and 125° vertically. The entire scene generally appears to have high resolution, contrast, and color saturation, despite the dramatic changes in the optics, anatomy, and physiology of our eyes and visual pathways as the retinal images shift from the center of gaze to the periphery. Thus, a key issue in real-world scene perception is the roles played by central and peripheral vision. Central vision has the highest visual acuity and is where we pay the most attention to objects of interest. However, since central vision only extends out to a radius of roughly 5° around fixation, peripheral vision is the vast majority of our visual field. Yet, the nature of peripheral vision is mysterious, in that our common intuitions about it are often wrong. For example, most people appear to be quite unaware of the limitations of peripheral vision (Lau & Rosenthal, 2011). This is shown by how surprising viewers find demonstrations of the loss of visual resolution with eccentricity, such as failure to detect even roughly calibrated increasing blur with eccentricity using the Geisler and Perry (1998) algorithm (for a demonstration of this, see https://youtu.be/9DTHVRhBcQ0). Conversely, many people would probably be surprised to know that while driving it is possible to maintain one's lane position using only peripheral vision even while using central vision for an attentionally demanding visual task located 30° below the dashboard (Summala, Nieminen, & Punto, 1996). (Importantly, however, consistent with what one might expect, under the same conditions, drivers are also very poor at noticing potential crash hazards, such as when a car in front of them suddenly slows down—thus, driving using *only* peripheral vision is very dangerous [Summala, Lamble, & Laakso, 1998].)

The limits of peripheral vision are among the most extensively studied topics in vision research, dating back over 150 years to the pioneering work of Aubert and Forster (1857). These limits have been reviewed in detail by a number of authors (Levi, 2008; Rosenholtz, 2016; Strasburger, Rentschler, & Jüttner, 2011; Whitney & Levi, 2011; Wilson, Levi, Maffei, Rovamo, & DeValois, 1990; Yu, Chaplin, & Rosa, 2015), including a forthcoming review and synthesis paper for this special issue (Loschky et al., in press). Scene perception research is, by comparison, a far more recent area of study (Henderson & Hollingworth, 1999; Malcolm, Groen, & Baker, 2016). Interestingly, many key topics related to scene perception from central to peripheral vision are outside of the topics traditionally studied under the heading of "peripheral vision." These topics include the role of peripherally previewing objects on their subsequent recognition when fixated (Henderson, Pollatsek, & Rayner, 1989), the role of scene gist perception (based largely on peripheral vision) in eye movement guidance (Castelhano & Henderson, 2007; Eckstein, Drescher, & Shimozaki, 2006; Võ & Schneider, 2010), or the role of cognitive and foveal loads on peripheral object or event perception (Crundall, Underwood, & Chapman, 2002; Ringer, Throneburg, Johnson, Kramer, & Loschky, 2016). Thus, to understand how the limits of peripheral vision affect real-world scene perception, one must step outside of the bounds of traditional research on peripheral vision. By the same token, however, if we want to understand the roles of central and peripheral vision in real-world scene perception, it is critically important to have a

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good grasp of the research on the limits of peripheral vision from the traditional vision sciences. Unfortunately, these two research areas have thus far had too little interaction.

More generally, there is a problem that the research and theory on vision from the fovea to the periphery is splintered across a wide range of topic areas, again with little sharing of theories, constructs, terminology, or research methods. These topic areas include:

- The role of retinal topography on visual acuity in scenes (Rovamo, Virsu, & Naesaenen, 1978; Wilkinson, Anderson, Bradley, & Thibos, 2016);
- Object recognition in peripheral vision for scenes (Boucart et al., 2016) and the role of crowding and texture perception in that process (Ehinger & Rosenholtz, 2016; Toet & Levi, 1992; Wallis, Bethge, & Wichmann, 2016);
- The distribution of covert attention across the field of view in scenes (e.g., the useful field of view (UFOV)/functional field of view (FFOV)/perceptual span; Ball, Beard, Roenker, Miller, & Griggs, 1988; Cajar, Schneeweiß, Engbert, & Laubrock, 2016; Crundall, Underwood, & Chapman, 1999; Nuthmann, 2013; Ringer et al., 2016);
- Attentional guidance during fixations to the next-to-be-fixated location as a function of retinal eccentricity and the information available in the periphery (Cajar et al., 2016; Huestegge & Böckler, 2016; Loschky & McConkie, 2002; Nuthmann, 2014; Nuthmann & Malcolm, 2016);
- Scene gist extraction in peripheral vision (Boucart, Moroni, Thibaut, Szaffarczyk, & Greene, 2013; Eberhardt, Zetzsche, & Schill, 2016; Larson, Freeman, Ringer, & Loschky, 2014; Larson & Loschky, 2009) and its use in guiding eye movements in scenes (Castelhano & Henderson, 2007; Hillstrom, Scholey, Liversedge, & Benson, 2012; Võ & Schneider, 2010);
- The roles of central and peripheral vision in understanding events and determining memory for scenes (Eisenberg & Zacks, 2016; Fortenbaugh, Hicks, Hao, & Turano, 2007; Geringswald, Porracin, & Pollmann, 2016);
- Eccentricity biases in different areas of the brain, and their relationship to the functional architecture of the brain (Arcaro, McMains, Singer, & Kastner, 2009; Baldassano, Fei-Fei, & Beck, 2016); and
- The roles of central versus peripheral vision in performing actions in the world (e.g., grasping objects, locomotion, navigation, balance; Chessa, Maiello, Bex, & Solari, 2016; Fischman & Schneider, 1985; Piponnier, Hanssens, & Faubert, 2009; Ryu, Mann, Abernethy, & Poolton, 2016; Turano, Yu, Hao, & Hicks, 2005).

In fact, a *back-of-a-napkin* investigation of articles that cited seminal references from more than just one of the above topics revealed very little cross-fertilization of those topics. Specifically, to empirically get a handle on how much cross-fertilization there is across these disparate research areas, one can ask how many articles cite key works from more than one of the above research topics. To get an idea of this, the lead author of this editorial (Loschky) chose one seminal article each from four of the above research areas: (a) the UFOV (Ball et al., 1988; 305 citations at the time checked), (b) crowding (Bouma, 1970; 425 citations), (c) dynamic gaze guidance as a function of retinal eccentricity (McConkie & Rayner, 1975; 366 citations), and (d) the use of central versus peripheral vision for action (Previc, 1998; 233 citations). Then, using Scopus, a search for articles citing each of the six possible pairings of two of the four seminal articles was performed, which produced the following frequencies:

$a \cap b = 5$ articles citing both
$a \cap c = 6$ articles citing both
$a \cap d = 1$ article citing both
$b \cap c = 20$ articles citing both
$b \cap d = 0$ articles citing both
$c \cap d = 1$ article citing both
Total = 33 articles citing two of the four seminal articles.

This quick perusal of cross-cutting citations reveals the lack of interaction between these areas. First, for three of the six the pairings, specifically among articles citing Previc's (1998) seminal theory of central versus peripheral vision for action, there was at most one article that also cited one of the other three seminal papers. This suggests that research and theories on the roles of central and peripheral vision in ventral functions (e.g., object and scene recognition) have little interchange with research and theories on the roles of central and peripheral vision in dorsal functions (e.g., grasping, locomotion, navigation, and balance). Second, there were only five to six articles for the other two pairings of articles citing Ball et al.'s (1988) seminal work on the UFOV, which also cited the seminal articles on crowding and dynamic gaze guidance. This suggests that researchers investigating the UFOV seldom cite articles on these other topics and vice versa. Finally, the most jointly cited seminal articles were for crowding (Bouma, 1970) and dynamic gaze guidance as a function of eccentricity (McConkie & Rayner, 1975), with 20 articles citing both seminal articles. While the last pairing shows some cross-fertilization of these research areas, overall, this very preliminary investigation suggests little such cross-area interaction.

It was with the intention of fostering greater cross-area interaction that the lead author of this editorial (Loschky) organized this special issue on scene perception from central to peripheral vision. Specifically, the hope is that bringing together articles from this wide array of interrelated topics, all dealing with scene perception in central versus peripheral vision, but from each of the above-listed different viewpoints, will foster a synthesis across these research areas. Only by creating such a synthesis will we be able to have a more complete understanding of how vision differs from the fovea to the far periphery as we explore and interact with our visual world. The articles in this special issue were chosen in order to facilitate such a synthesis. For this reason, at the beginning of 2017, we will create the *Scene Perception from Central to Peripheral Vision Collection*, which will include additional articles, including a review and synthesis paper for the collection that is currently in preparation (Loschky et al., 2016).

Keywords: central vision, peripheral vision, fovea, periphery, scene perception, retinal eccentricity, retinal topography, UFOV, FFOV, perceptual span, scene gist recognition, attentional guidance, scene memory, crowding, object recognition, cortical eccentricity biases, navigation, optic flow, vision for action

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