

KEEPING A TRANSSACCADIC RECORD OF OBJECTS: INTRODUCTION TO A SPECIAL ISSUE ON OBJECT PERCEPTION ACROSS SACCADIC EYE MOVEMENTS

Karl VERFAILLIE & Peter DE GRAEF
University of Leuven

In an influential paper, which appeared in a special issue ensuing from a workshop held in the Laboratory of Experimental Psychology in Leuven in 1991, O'Regan (1992) pointed out that the "real" mystery of visual perception is generally avoided in vision textbooks: "Why is it that we can see so well with what is apparently such a badly constructed apparatus?" (O'Regan, 1992, p. 461). One of the reasons for the bad quality of the visual input is the occurrence of saccadic eye movements: fast (speeds up to 1,000°/s are possible), short lasting (average duration of 40 ms), ballistic eye jumps from one fixation point to another. On the one hand, saccades are highly functional. For instance, saccadic eye movements bring new information in the small, high-acuity region in the centre of the retina. On the other hand, saccades cause a number of problems. First, the input of information is suppressed during saccades (for reviews on saccadic suppression, see E. Matin, 1974; L. Matin, 1986; also see Burr, Morrone, & Ross, 1994), so that information intake essentially proceeds during the fixational pauses occurring between saccades. As observers, we do not notice the "blind" period accompanying a saccade. The visual system seems to fill in the periods. In this sense, the phenomenon is analogous to the case of the blind spot; in fact, a saccade can be conceived of as a blind spot in the temporal domain. Second, a saccadic eye movement causes a displacement of the retinal image: The projection of an object jumps from one retinal location to another. As such, visual information is sampled in a series of different glimpses that are isolated in time. This raises the question whether the visual system integrates these different glimpses of an object and if so, how this is accomplished. This issue is known as the problem of transsaccadic object integration.

Transsaccadic object integration is frequently linked with the question of visual stability, already introduced by Helmholtz in 1866: How does the

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Correspondence concerning this article should be addressed to Peter De Graef or Karl Verfaillie, Department of Psychology, University of Leuven, Tiensestraat 102, 3000 Leuven. Electronic mail may be sent to peter.degraeef@psy.kuleuven.ac.be or karl.verfaillie@psy.kuleuven.ac.be.

visual world appear stable and continuous despite the proximal discontinuities caused by saccades? Bridgeman, Van der Heijden, and Velichkovsky (1994) and McConkie and Currie (1996) provide excellent reviews of mechanisms that have been proposed to solve the problem of visual stability. Carrying the basic assumptions of some of the theories of visual stability to their logical extreme, suggests at least two reasons for trivializing the question how presaccadic and postsaccadic views of an object are integrated. First, some theories have postulated a low-level, hard wired mechanism that ensures spatiotopic continuity of successive glimpses of the distal stimulus. If a mechanism of that kind exists, transsaccadic integration would require little more than superposition of images. Such a process of spatiotopic fusion has indeed been proposed as the basis for information integration across saccades (e.g., Feldman, 1985; McConkie & Rayner, 1976). Second, if the computational power of the human perceptual system is such that only a single fixation is needed to identify real-world scenes and the objects in it (Biederman, Mezzanotte, & Rabinowitz, 1982), there may not even be much need to integrate information from multiple fixations (O'Regan, 1992). In the latter scheme, image interpretation starts anew for each fixation and the only information that is carried across a saccade is a quasi-linguistic description of parts of the scene.

Empirical data, however, contradict the trivialization of transsaccadic integration. First, as far as the latter possibility is concerned, it has been demonstrated that various kinds of information can be integrated across saccades and that this facilitates stimulus discrimination (e.g., Carlson-Radvansky & Irwin, 1995; Hayhoe, Lachter, & Feldman, 1991; Henderson, Pollatsek, & Rayner, 1987; Irwin & Andrews, 1996; Pollatsek, Rayner, & Collins, 1984; Pollatsek, Rayner, & Henderson, 1990). Second, when transsaccadic integration takes place, it can not be characterized as a mere superposition of images. This is indicated a priori by insurmountable qualitative differences between peripheral and foveal images (Jüttner, 1994; Jüttner & Rentschler, 1996). In addition, there is a long series of studies disproving the notion of spatiotopic fusion across saccades (e.g., Bridgeman & Mayer, 1983; Irwin, Brown, & Sun, 1988; Irwin, Yantis, & Jonides, 1983; O'Regan & Lévy-Schoen, 1983; Rayner & Pollatsek, 1983).

In sum, our perceptual system does seem to have use for information integration over multiple fixations, and this integration is not based on a mere superposition of images. Rather, only what is selected and coded in one way or another, survives a saccade. This raises the question as to what informational contents are integrated across saccades and which criteria govern the selection of information that is maintained transsaccadically. The articles in the present special issue describe attempts in search of answers to that question. The authors contributed to this issue based on their participation in an

invited symposium on "Transsaccadic Object Perception" at the 27th International Congress of Psychology (Stockholm, Sweden, 23-28 July 2000), which was convened by the present guest editors.

As already spelled out, the problem of transsaccadic integration is often connected to the problem of visual stability. One influential theory of visual stability is the so-called saccade target theory (McConkie & Currie, 1996; see Deubel, Schneider, & Bridgeman, 1996, for a similar proposal). With each refixation, the visual system runs through a number of processing steps. First, the visual apparatus selects an object as the future target for the upcoming saccade and its location is noted in a relatively abstract mental representation that is built up across successive fixations. Selected visual features of this saccade target object are encoded and stored in memory. After the saccade, the visual system searches for the critical features within a restricted retinal region. In the case of successful target relocalization, the relation between the target's retinal location and its location in the mental representation is determined, which leads to the perception of stability. When postsaccadic target localization fails, the assumption of visual stability is abandoned.

A pivotal assumption of the saccade target theory is that critical features of the saccade target are used to maintain transsaccadic stability. In their article, Carlson, Covell, and Warapius report original data that support two corollaries of this assumption. First, in Experiment 1, which uses a transsaccadic version of a paradigm introduced by Luck and Vogel (1997), it is shown that visual short-term memory can encode multiple features of an object at no cost across a saccadic eye movement. In the context of the saccade target theory, this implies that, in principle, target relocalization can be based on multiple integrated features, rather than a single selected feature. This minimizes chances of a failure of relocalization due to the faulty processing of a single feature. Second, retaining features that differentiate the saccade target object from its neighboring objects would help efficient relocalization of the saccade target. This would imply that contextual cues can be used as critical features. Experiment 2, which uses a transsaccadic version of the Jiang, Olson, and Chun (2000) contextual cueing paradigm, supports the hypothesis that objects are encoded in relation to one another. Together, the two experiments suggest that features that are maximally informative for relocalizing the saccade target postsaccadically can be retained in order to bridge a saccade.

One prediction that can be derived from a strong version of the saccade-target theory is that information about the target object of a saccade will be carried more accurately or even exclusively across saccades than information about other objects. Verfaillie and De Graef (2000) reported a number of experiments that tested this prediction. Participants made a saccade from

one biological-motion figure to another. During their saccade, either the walker to which the eyes were sent (the saccade target) or the walker that served as launch site (the source) was displaced in the image plane or rotated in depth. Subjects had to detect these changes. Because of saccadic suppression, the sudden transient that normally accompanies such changes is not perceptible, and detection that something has changed can only be based on the integration of presaccadic and postsaccadic information. Contrary to what the saccade target theory predicts, transsaccadic memory for the target's position and orientation was not more accurate than memory for the source. In addition, displacements or rotations of one point-light figure towards the other figure were more detectable than the same changes away from each other, suggesting that relational coding plays a prominent role in the integration of information across saccades (also see Verfaillie, 1997, Experiment 2). In the present issue, De Graef, Verfaillie, and Lamote report original data from a follow-up study with full-color pictures of real-world objects instead of point-light walkers. Subjects were presented with three objects arranged in a triangular configuration and transsaccadic memory for the position of the saccade target, the source, and the bystander object was probed. In line with earlier findings (Verfaillie & De Graef, 2000), transsaccadic integration of object position was not limited to the saccade target, but was also found for the saccade source and for the bystander object.

In the experiment sketched in the previous paradigm, subjects were asked to detect changes that occurred during their saccadic eye movement. This procedure involving explicit detection of so-called intrasaccadic changes is a common methodology in the study of transsaccadic integration (e.g., Henderson & Hollingworth, 1999; McConkie & Currie, 1996). In their contribution, Hayhoe, Karn, Magnuson, and Mruczek point out that the analysis of more implicit measurements of transsaccadic memory (parameters of the eye movement behavior) reveals that visual scene representations that are built up across a series of fixations can be much richer and more detailed than studies with explicit detection suggest. Hayhoe and colleagues also stress that, in order to fully understand the mechanisms underlying transsaccadic integration, one should take into account the task context: The requirements of the task determine what spatial regularities of the scene are coded transsaccadically. This is demonstrated by an analysis of saccadic targeting in two natural situations: the task of making a peanut butter and jelly sandwich and the task of copying a pattern of colored blocks.

The starting point of Pollatsek and Rayner's contribution is the observation that, even when the paradigm of explicit detection of intrasaccadic changes is used, there are circumstances under which quite accurate visual information can be carried across saccades. More specifically, Pollatsek and Rayner cite two studies that suggest that motion information has a special

status in transsaccadic integration. In the first study (reported by Verfaillie et al., 1994, Experiment 1), participants had to detect intrasaccadic changes in the posture of a moving point-light walker. In comparison to a control condition in which the posture change occurred during the observer's fixation, intrasaccadic posture changes were detected quite accurately. Second, Pollatsek and Rayner (submitted) made a very similar observation in a study in which participants had to detect changes in the orientation of a continuously rotating line. These two studies contrast with experiments that show that during reading, "visual" information is not carried across a saccade in a way that it can help the reading process. Studies with stationary objects and scenes also frequently indicate that intrasaccadic changes are difficult to detect. The contrast with the accurate transsaccadic memory for motion information suggests that there may be fundamental differences in the way in which motion and static information are retained and integrated across saccades (also see Gysen, De Graef, & Verfaillie, submitted).

The final contribution in this issue by Verfaillie, De Graef, Germeys, Gysen, and Van Eccelpoel presents an overview of the main themes on transsaccadic integration that appeared on the research agenda of the Laboratory of Experimental Psychology of the K.U.Leuven during the last four years. Emphasis is placed on clarifying the thread connecting different sections of this research program, i.e., the hypothesis that the degree to which information is diagnostic for the object's identity is an important determinant of what information is selected for transsaccadic integration.

Finally, we would like to take this opportunity to acknowledge the colleagues who helped to shape our work on transsaccadic perception. Specifically, we want to thank George McConkie for introducing us to the problem of transsaccadic integration during his 1992 sabbatical at our lab, and Heiner Deubel, John Henderson, and David Irwin who, together with the contributors to this issue, were always eager to share and discuss their views.

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