Saccades in Vision: A Summary of Ongoing Experiments

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Introduction

A *saccade* is a type of eye movement —voluntary or involuntary— that occurs when fixation is shifted from one location in the visual field to another. It consists of the muscle movements that change the direction the eyes are looking at. Saccades are an important component of the sensory system as they are closely related to attention; in other words, individuals saccade to a location in the visual field in order to pay attention to a stimulus that is present in it (Hoffman & Subramaniam, 1995).

Early Saccadic Research

The idea of saccades is not something novel in psychophysical literature. Their mechanisms and effects on perception have been studied for decades. Saslow (1967) appears to be one of the first researchers to investigate how saccades are affected by, and themselves affect, elements of vision such as latency. Saslow (1967) tested naïve participants and flashed stimuli on a display. It was found that the speed of a saccade is affected by the level of "overlap" between the starting point (where subjects were told to fixate at the beginning of the trial) and the target of the saccade (where subjects were told to move their eyes to). As such, it appears that specific characteristics of what is presented —such as how quickly a change in the visual field occurs— influence how saccades occur and how they contribute to vision. Nonetheless, Saslow's (1967) paper may be considered a primitive study due to its lack of explanatory value. However, subsequent studies have aimed to bridge this gap by looking not only at *how* saccades happen, but the implications of such saccadic movements on perception. Nowadays, there appears to be a trend in literature to study errors in vision caused by eye movement. The rest of this review thus gives a brief overview of contemporary research in the field, as well as a discussion of the mechanisms through which saccades may influence vision, with a specific focus on two phenomena: saccadic suppression and compression. Lastly, suggestions for future research are considered.

Methodology Used in Saccade Research.

Before discussing errors mentioned in the previous section, it is worth explaining the methodology used in saccadic research. Most studies —with limited exceptions— use the same general framework: stimuli are presented on a monitor by computer programs. Participants are told to fixate at a starting point, before being cued to move their eyes to what is called the saccadic target. Such movement represents the core of what saccade research tries to understand. Data collection methods vary, but most researchers use a combination of eye-trackers to track the speed and direction of saccades, and self-report to probe what participants actually perceive. In any case, the goal is to understand the relationship between eye movement and perception of specific stimuli or generic scenes.

While the abovementioned methodology is standard saccadic research, as most contemporary articles that have been published have used a similar framework, it is important to note some limitations of simply using a computer screen. For one, as Seirafi et al. (2014) imply, the ecological validity of such may be questionable. Vision occurs in a three-dimensional environment and consists not just of the dots, crosses, or bars that are presented on computer-based experiments. While there have been efforts to change this —such as experiments testing more and realistic stimuli like human faces (Seirafi et al., 2014) or the Sydney skyline (Burr et al., 1997)— contemporary literature by and large places a heavy emphasis on basic stimuli such as dots and line. This is something that must be considered in future investigations on saccades.

Saccadic Suppression

Saccadic suppression, also known as saccadic masking, is the phenomenon in which individuals often miss out salient details such a location or object properties that change in the scene during eye movement (Bridgeman et al., 1975). Such phenomenon suggests that stimuli presented - during a saccade are not processed as efficiently. Such saccadic suppression is considered a specific form of change blindness (Rensink et al., 1997). It thus often results in errors being made or other deficits in visual perception. As such, understanding it is of critical importance to the vision scientist.

Seirafi et al. (2014) conducted a study to investigate how saccadic suppression can lead to vision being inadequate. While the researchers used a typical set up with a computer screen flashing stimuli, the use of real-life stimuli —human faces with emotions— was notable. It was found that *during* saccades, distinguishing facial expressions or telling scrambles and faces apart was virtually impossible. These data suggest that humans cannot perceive visual details —a possible manifestation of saccadic suppression.

Maij et al. (2011) also discuss the concept of peri-saccadic mislocalization. As the name suggests, this refers to mistaken target localization during the time of eye movement onset. The researchers found that predictability of the target had no effect on errors; as such, it was hypothesized that suppression occurs generally and not only in specific instances. In any case, this is an example of how eye movement stymies true and veritable perception.

Saccadic Compression

Saccadic compression, in contrast to suppression, occurs when there is a bias towards the saccadic target point when an individual tries to localize a stimulus (Zimmerman et al., 2014). This means that individuals have a propensity to report the location of a stimulus not at where it actually is, but at where their eyes landed when they saccaded. Using the typical experimental setup, Luo et al. (2010) indeed found that a bias towards the target exists, specifically in localization. When participants were asked to report where they saw a bar on the screen, they systematically pointed to locations closer to where their eyes ended up fixating at (i.e. "the saccadic target") than to the actual location.

Earlier, Burr et al. (1997) used a mathematical model to analyze compression in visual tasks, and concluded that the same effect as Luo et al. (2010). But more interestingly, they found —in particular— that compression peaks between 0ms to 25ms before a saccade begins. This suggests that existence of a "critical period." Outside this period, perception is described as being "veridical", meaning that participants' report of location or other details matches the actual characteristics of the stimulus. This finding is significant in the literature as it implies that such effect occurs only within discrete intervals of time. While the implication of this remains to be clear, it provides an area of research that must be considered in future investigations.

Future Directions of Research

While the concept of saccades in vision is not new, a review of the literature reveals that gaps in knowledge still exist. Furthermore, such deficit in research is not only in the depth of the studies available, but also in their breadth. Saccades are phenomena that have multiple applications not only in vision science, but also in daily life; as such, a clearer understanding of them will definitely be invaluable. As it stands, it appears that the research is lacking in areas such as testing naturalistic stimuli, real-life scenes, or visual tasks other than simple ones. There is also a need to use different techniques instead of simply relying on computer-based presentation to ensure that observed results are true effects of the saccadic phenomenon and not simply of experimental design. This, if considered in new studies, will increase understanding not only of saccades, but also of the intricate and complicated nature of visual perception.

Materials and Methodology

In light of the literature gap discussed above, a series of experiments were designed in the Johns Hopkins Vision and Cognition Lab, under the supervision of principal investigator Jonathan Flombaum. The following experiment is currently in the pilot stage; as such it is important to note that the materials and methodology are subject to change.

Participants

Participants were recruited through the online system, SONA. With few exceptions, most subjects were Johns Hopkins undergraduate students between the ages of 18 and 22. Participants were compensated with one research credit per hour spent completing tasks; such credits could be used to increase a grade in a particular class.

Materials

To minimize distractions and noise, each experiment occurred in a dark, quiet and private room. For stimulus presentation, 21-inch Apple iMac computers were used. A MATLAB program was used to present the fixation point and the relevant stimulus (a Gabor patch) on the screen. Participants reported the location using a standard computer mouse.

Procedure

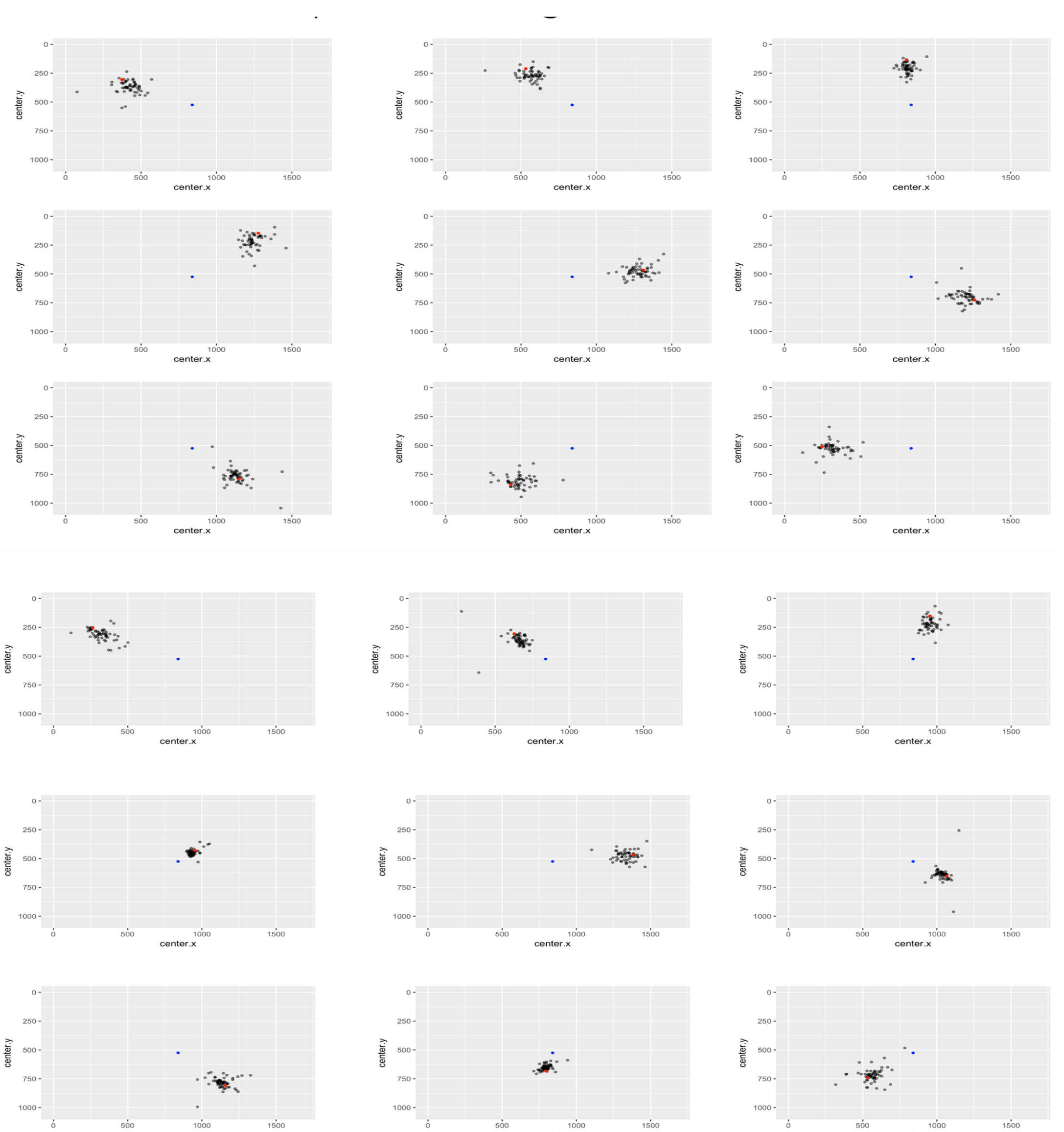
Participants were informed of the purpose of the experiment and told that the study was of minimal risk. Participants signed electronic consent forms and filled in demographic information sheets indicating their age, gender, ethnicity, and eyesight (i.e., whether they had normal or corrected-to-normal vision).

At the beginning of each experiment, participants sat down while the experimenter, an undergraduate research assistant, ran through the standardized instructions embedded in the MATLAB program. Participants were told to fixate at the center throughout the experiment and report the location of the Gabor patch that was to be flashed at eighteen random points in the periphery. After a "gun-loading" sound was played, participants were told to click on where they perceived the stimulus to be. After clicking, a gunshot sound was played so that participants knew that the specific trial was over. After two practice blocks in which the experimenter ensured that instructions were understood, participants were left alone in the room to complete ten blocks of one hundred trials each, for a total of one thousand trials.

Results

The aim of the experiment conducted was to gather pilot data that can be used in designing future methods to probe saccadic compression, suppression or mislocalization. It is worth nothing that although participants were not told to saccade in the present experiment, the results may still be useful in understanding the phenomenon in question. For instance, the results still showed a bias towards the fixation, a form of compression, as shown in the following charts:

Figure 1: Cartesian scatterplot showing where participants fixated (blue), where the stimulus was flashed (red) and where their location was reported in each trial (black). Graphs courtesy of Feitong Yang.



While most participants reported seeing the Gabor patch within a reasonable distance from the actual site of presentation, the Cartesian plots suggest that mislocalizations are usually compressions; that is, participants tend to click towards locations closer to fixation than to those farther from it.

Discussion

Because participants were specifically told not to move their eyes, this suggests that compression may be a phenomenon that is not limited to peri-saccadic tasks. However, given that the study is still in its early stages, methodological issues must first be addressed before conclusions can be inferred from the data.

One major concern with the experiment was that there was no reliable way to ensure that subjects were fixating at the center throughout. As the task took over an hour, it is not unreasonable to assume that participants would get tired and simply move their eyes instead of using peripheral vision. Indeed, there may have actually been saccades that occurred but were not accounted for. A possible solution to this is to use an eye-tracker and exclude trials in which peripheral vision was not used from analysis. This will improve the quality of data, making it easier to draw conclusions.

Another possible confound is the motor response component required when participants were made to click using the mouse. In comments gathered after each experiment, participants often complained that the mouse was difficult to control. An implication of this is that there might be a discrepancy between what the computer records and where the Gabor patches are perceived by participants to be located at. In future designs, this may be avoided or minimized by exploring different input methods, such as oral report, track pads or touch screen monitors. If a triangulation of distinct techniques yields similar results, then it may be concluded with greater confidence that the compression towards the fixation is a result of a natural tendency and not simply a manifestation of experimental design falls.

As such, if the improvements suggested above are implemented, then future experiments can better provide insight into and explain the phenomena of saccadic mislocalization, compression or suppression. Given the wide literature gap and problems associated with present research, findings gleaned from these future studies will be extremely useful in informing the scientist's understanding not just of peripheral or peri-saccadic vision, but of perception and psychophysics in general.

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