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The tell-tale tasks: A review of saccadic research in psychiatric patient populations

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ABSTRACT

This review focuses on saccade research with adult psychiatric patients. It begins with an introduction of the various types of saccades and the tasks used to evoke them. The functional significance of the different types of eye movements is briefly discussed. Research findings regarding the saccadic performance of different adult psychiatric patient populations are discussed in detail, with particular emphasis on findings regarding error rates, response latencies, and any specific task parameters that might affect those variables. Findings regarding the symptom, neurocognitive, and neural correlates of saccadic performance and the functional significance of patients' saccadic deficits are also discussed. We also discuss the saccadic deficits displayed by various patient groups in terms of circuitry (e.g. cortical/basal ganglia circuits) that may be implicated in the underlying pathophysiology of several of these disorders. Future directions for research in this growing area are offered.

1. Introduction

The saccadic eye movement system is responsible for rapid eye movements that bring the image of an object onto the fovea (see glossary) (Leigh & Zee, 1983). Saccades are conjugate, ballistic eye movements that are characterized by short reaction times, typically around 200 ms, and brief durations, normally between approximately 20 and 120 ms (Engelken, Stevens, & Enderle, 1989; Gouras, 1985; Leigh & Zee, 1983). In humans, saccades can reach speeds of up to 600–700 deg/s, whereas monkeys can produce saccades that are nearly twice as fast (De Renzi, 1988; Gouras, 1985). Normal saccadic eye movements are characterized by an invariant relationship between their peak velocity and their size; the amplitude–peak velocity relationship is referred to as the main sequence (Bahill, Clark, & Stark, 1975).

Accuracy of saccades depends on the location of a target on the retina as well as the position of the eyes in the orbit (Gouras, 1985). There are two major classes of saccades, namely, those that are externally triggered and automatic, and those that are internally initiated and volitional (Lasker, Zee, Hain, Folstein, & Singer, 1987). Although saccadic eye movements are typically elicited by the sudden appearance of a novel auditory or visual stimulus that attracts the subject's attention (reflexive saccades), they can be produced on command, in the dark, to remembered targets, during scanning or searching of stationary visual scenes, or with closed eyes (De Renzi, 1988; Gouras, 1985; Leigh & Zee, 1983; Wirtschafter & Weingarden, 1988). Saccades can be described in terms of their reaction time, namely, the time elapsing from the command signal to shift one's gaze until the beginning of the saccade. Saccades are also described in terms of their velocity and accuracy.

Diefendorf and Dodge (1908) were the first investigators to report on the functioning of the saccadic system in schizophrenia patients. Since then, interest in the study of saccadic eye movements in schizophrenia has risen steadily and now includes a focus on volitional saccades as well as reflexive ones. Saccadic eye movements can be measured reliably and precisely. As a result of basic research including single unit recordings and lesion studies as well as clinical research and functional imaging, there is a considerable body of knowledge regarding the neurophysiology of the saccadic eye movement subsystem. Thus, the study of saccadic eye movements in psychiatric patient groups can provide a "window into the brain" of affected individuals. Over the past three decades, there has also been an increase in the number of studies of saccadic performance in other psychiatric patient groups. Much of the impetus for the focus on saccadic eye movements in these populations comes from the fact that saccades provide a non-invasive yet accessible means of investigating psychomotor functioning as well as higher-order cognitive processes and their underlying neural mechanisms.

In the following review, we summarize the extant literature regarding the study of saccadic eye movements in adult psychiatric

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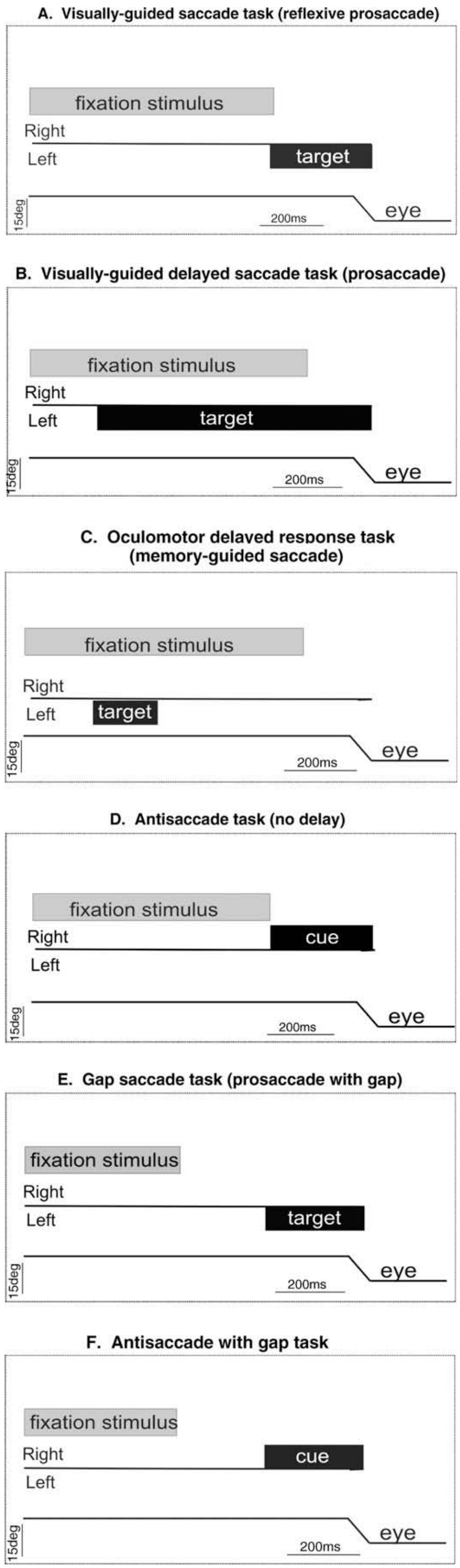

patients. In order to appreciate the growing complexity of the area and the various ways in which psychiatric patient groups differ in terms of their saccadic task performance, we introduce the major saccadic paradigms prior to summarizing the studies for each diagnostic group. Given the disproportionately large corpus of literature on saccadic performance in schizophrenia and schizophrenia-spectrum populations, this area will receive particular emphasis in our review. Findings regarding the symptom, neurocognitive, and neural correlates of saccadic performance, as well as hypotheses regarding the functional significance of patients' saccadic deficits are also discussed. In the final section of the review, we integrate across findings, and provide a comparative analysis of saccadic deficits in the different psychiatric disorders. This discussion is used as an opportunity for hypothesis generation and recommendations for future directions.

2. Different types of saccade paradigms

Because of the versatility of saccades, a number of different behavioral tasks have been developed over the years to probe different underlying mechanisms. Below we review some of the most commonly used saccadic eye movement tasks. The different saccade tasks include visually-guided, memory-guided, gap, overlap, and antisaccade tasks. Each task has different demands allowing for the assessment of the integrity of brain pathways in health and disease. For example, to assess the integrity of saccade-generating circuitry subjects may perform a visually-guided saccade task. In this task (Fig. 1A), a fixation stimulus appears initially at the center of a screen. After a timed fixation period a second stimulus (target) appears at a peripheral location. At the same time, the fixation stimulus disappears and the subject must initiate a saccade to the peripheral target. In this most simple version of the visually-guided saccade task, the appearance of the peripheral tar-

Fig. 1. Saccadic eye movement tasks. Each panel shows the salient events occurring in different saccade tasks over time. The line marked Right and Left in each panel indicates the hemifield in which the target appears. The bottom line labeled 'eye' in each panel is a schematic of the eye position. Upward deflections of the eye position trace indicate rightward eye movements and downward deflections indicate leftward eye movements. The gray bar in each panel labeled 'fixation' indicates the onset and duration of the fixation stimulus, usually located in the center of a screen. The black bar labeled 'target' in each panel indicates the onset and duration of the target which is usually located in the periphery. (A) Visually-guided saccade task. The fixation stimulus appears (gray bar) and the subject is required to maintain gaze on its location. After a fixation time a peripherally located target (black bar) appears and at the same time the fixation stimulus disappears. The subject is required to make a saccade to the target. This task is also referred to as a reflexive prosaccade. (B) Visually-guided, delayed-saccade task. The fixation stimulus appears and after a fixation time the target appears. A further delay is imposed during which the subject maintains fixation. After the delay, the fixation stimulus disappears signaling the subject to make a saccade to the target. (C) Memory-guided saccade task. The fixation stimulus appears and the subject is required to maintain gaze on its location. After a fixation time a target appears transiently. The subject is required to maintain fixation and only after another delay does the fixation stimulus disappear signaling the subject to make a saccade to the location of the previously flashed target. This task is also referred to as the oculomotor delayed-response task (ODR). (D) Antisaccade task. This task is identical to the reflexive saccade task except that a peripheral stimulus appears in one hemifield (now called cue) and the required saccade is to the opposite hemifield. In this example, the cue appears in the right hemifield and the saccade is leftward. (E) Gap saccade task. The fixation stimulus appears and after a fixation time it disappears. The subject maintains gaze at the center where the fixation stimulus was. After a 'gap time' a second stimulus appears in the periphery and the subject is required to make a saccade to the location of the second stimulus. Note that this task differs from all others in that the cue to make a saccade is the onset of the peripheral stimulus whereas in the other tasks the cue to make a saccade is the offset of the fixation stimulus. (F) Antisaccade with gap task. This task is a combination of those shown in (D) and (E). The peripheral stimulus (cue) appears in one hemifield and the saccade occurs toward the opposite hemifield. The onset of the cue occurs after a 'gap time' in which the fixation stimulus is no longer present on the screen.