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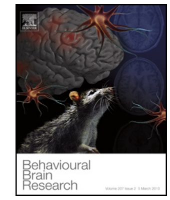

Research report

Internally versus externally mediated triggers in the acquisition of visual targets in the horizontal plane

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HIGHLIGHTS

- We studied eye–head coordination during visual target acquisition.
- The motor pattern of target acquisition depends on the way of triggering the command.
- There is difference in performance between a verbally given and a memorized command.
- The difference concerns latency, head velocity, acceleration and amplitude.
- The results from this investigation have operational importance.

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ABSTRACT

In an operational setting acquisition of visual targets using both head and eye movements can be driven by memorized sequence of commands – internal triggering (IT) or by commands issued through secondary operator – external triggering (ET). The primary objective of our research was to examine differences in target acquisition using IT compared with ET. Using a forced time optimal strategy eight subjects were required to acquire targets with angular offsets of ±20°, 30° and 60° along the horizontal plane in both IT and ET conditions. The data showed that the eye/head latency difference in IT condition is longer than that for ET, the target acquisition time is also longer for IT commands. Consistent with this finding were similar results when examining the peak head velocity and peak head acceleration. Under IT protocol head amplitude is higher than when using ET.

In conclusion, the study demonstrates that the pattern of performance of target acquisition task is influenced by the way of command triggering.

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1. Introduction

This experiment was driven by a requirement to determine if eye and head movements to known visual targets would be modified under conditions where the subject was commanded to acquire a specific target when instructions to that target were verbally given by the experimenter as opposed to a condition where the subject acquired the same target using a memorized sequence without the experimenter's command (self-paced). Specifically our concern was not only the characteristics of the head and eye sequence to known visual targets, but also in the potential delay in acquiring a target of interest. The promptness of acquiring visual targets with both the head and eye arose when it was discovered that during space flight there was often a delay of 1 to >1.5 s (measured from the onset of either the head or eye movement toward the target) before gaze could stabilize on the target [1,2]. This delay has several operational implications, but most important among them are those that would impact timely capture of information conveyed via digital instrumentation when the spacecraft can travel thousands of feet in the time that target acquisition can be stabilized sufficiently for accurate visual foveation.

Aside from the operational implications associated with space flight we often perform tasks in our daily life that are initiated either spontaneously (e.g. checking the time on a wall clock), or by command given by somebody else, (e.g. 'look at that sign on your left'). In the former case the process is triggered internally (IT) while in the latter – externally (ET). It is important to investigate whether these two ways of triggering could influence the timely acquisition of critical targets if they are mediated through the central nervous system to produce a difference in the pattern of target acquisition. This knowledge may change the approach of selecting candidates for some professions. For instance pilots of jet aircraft

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or spacecraft, operators of military or civil platforms, etc., who in certain critical situations, due to operational circumstances, have to perform complex actions driven by commands from an external operator. The knowledge of these two ways of triggering, especially if they are performed by different motor patterns, may also argue for a separation in the functional neural networks controlling coordinated actions, not only eye–head coordination but also others. In support of this assumption are several earlier studies [3,4]. For example Vasudevan and Bastian [3] studied locomotion – learning new walking pattern using a split-belt treadmill that controls the speed of each leg independently. They tested healthy adult subjects walking at different split-belt speed combinations and then assessed after effects at a range of speeds. Their result suggests a separation in the functional neural networks used for fast and slow walking. In analogy, in building the hypothesis of present study, we presumed that eventual difference in the performance pattern of ET and IT will support the existence of a functional separation of eye–head coordinated actions.

The experiments [1,2] that identified the delay in target acquisition during space flight testing typically had an operator call out a target location in the horizontal plane for the subject to acquire. However, when an operator was not available during flight the subject used a memorized sequence of targets to be acquired (the same sequence issued through a verbal command). It was hypothesized that knowledge of target location and self-paced acquisition could result in a more rapid acquisition of a given target than when the acquisition was initiated by a verbal command even when the reaction time typically associated with response to a verbal command was not considered in the analysis of the data. That is, when the time to target acquisition was determined by time to final head or eye position relative to whichever began moving to the target location first; head or eye.

2. Subjects and methods

2.1. Subjects

Eight subjects (4 males and 4 females) ranging between 25 and 35 years of age successfully passed an Air Force Class III physical exam required for participated in this investigation. None of the subjects had any ocular motor, vestibular abnormalities or were taking any drugs with effects on the nervous system. Subjects with vision correction were allowed to participate with the corrective lenses or contacts in place. Alcohol consumption was prohibited within 48 h of participating in the experiment. All subjects gave written, informed consent in accordance with the Johnson Space Center's Institutional Review Board and the tenets of the Declaration of Helsinki.

2.2. Hardware/apparatus

The acquisition targets were permanently fixed to a tangent screen at predictable angular distances (±20°, ±30°, and ±60°) in the horizontal plane based on the subjects' position relative to the tangent screen. To easily differentiate between targets, each target corresponding to its degree of angular offset from center was color-coded (±20° green, ±30° red, ±60° blue).

Eye movements were measured using standard electro-oculography (EOG). Disposable infant non-polarizing electrocardiography (EOG) electrodes were applied to the outer canthus of each eye and the ground electrode was applied to a neutral surface behind the right ear. The EOG was DC amplified and directly digitized at a sampling rate of 500 Hz. Extraneous high frequency noise was digitally removed by filtering before processing with a finite impulse response (FIR) low pass Hamming window filter with a normal cutoff frequency of frequency of 30 Hz. All (including measurement of head parameters) data were then passed through the filter twice (forward then backward) to eliminate phase shifts and double the stop-band attenuation. Distance from the outer canthus of the right and left eyes was determined using a gun site laser mounted perpendicular to the subject and held constant at 86.36 cm across subjects. Eye movement calibration was accomplished using a dynamic technique that measured the EOG signals generated when the eyes remained fixed on the central acquisition target located on the tangent screen while the subjects slowly oscillated their heads at approximately 0.25 Hz maintaining a peak displacement of ±30° in the horizontal plane. This technique generated a basic visual-vestibulo-ocular reflex (VVOR). Based on the VVOR generated the angular head position was used to determine the expected eye position required to maintain fixation. These expected eye positions were compared with the corresponding measure of EOG voltage to yield the volts-to-degree relationship necessary for calculating a calibration curve that was obtained from cubic polynomials of lower orders when possible.

Active head movements were measured using a triaxial rate sensor fixed to the head with the webbing from a hardhat liner. The rate sensor was located approximately on the apex of the skull and adjusted prior to each test session to minimize cross-talk between all three axes. To prevent phase shifts the digital stream from the head worn rate sensor was recorded and filtered like the data taken from the eyes. Head movement measurements were calibrated using a low power laser mounted on the hardhat liner that could be adjusted so that the laser was located centrally on the forehead between the two eyes. When activated the laser point was placed by the subject on the central target and then using active head movements it was moved to each of the color-coded targets in succession. Head velocity was taken directly from the rate sensor after filtering and eye movement velocity along with gaze (post filtering) was obtained through differentiation of the filtered eye position signal.

2.3. Procedures

The 8 subjects participating in this experiment were divided into two groups; IT and ET acquisition. Random assignment to one of the two groups was done using an ABBA randomization method. The subjects in a particular group completed all trials required for a specific treatment and then returned the next day to complete the trials associated with the second treatment. For the ET group target acquisition was paced by the experiment operator beginning with the 20° targets and continuing until all targets had been acquired a minimum of four times each. The specific instructions called out by the operator were "Right Green, Center, Left Green, Center, Right Red, Center, Left Red, Center, etc". Upon return to center there was a pause of approximately 10 s before the next target in the sequence was acquired to ensure that acquisition of the next target would not be compromised by the semicircular canal time constant or other unknown variables. The IT trials followed the same strategy and target acquisition sequence without the support of the operator. Subjects maintained fixation on a specific target for a minimum of 1.5 s. All target acquisition was accomplished using a time optimal strategy that required the subjects to look from a central fixation point to a specified target as quickly and accurately as possible using both the head and eyes to acquire the target.

2.4. Data analysis

Fig. 1 is representative of a typical target acquisition the selection of parameters chosen for analysis. The analog data were imported into MatLab®, digitized and displayed for analysis. The specific parameters chosen for analysis included: peak gaze velocity, peak eye velocity, peak head velocity, peak head acceleration,

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