A PHOTOSENSITIVE METHOD FOR MEASURING HORIZONTAL MOVEMENTS OF THE HEAD TO VISUAL AND AUDITORY TARGETS

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Key words: movement registration, photosensitive procedure

Abstract. A simple photosensitive method to assess movements of the whole body or its parts was described. The method was applied to record head movements to target sources of visual and auditory stimuli.

In recent years an increasing interest has arisen for the development of systems to assess movements of the whole or of parts of the body. The ability of animals and human beings to localize visual or auditory targets in space may be evaluated by different movement parameters of the head, such as duration of the movement, speed, acceleration and displacement, as well as response latency.

The techniques described and used in physiological experiments are based on different physical effects (4, 5, 7, 9, 12). Often they require complicated installations and not all are capable either to measure the above mentioned parameters completely and accurately or to secure that the physical effects used for movement registration do not affect other physiological variables.

Headholders or helmets mechanically coupled to a potentiometer by a flexible bellow or cardan device (1, 3, 6, 10, 11) are frequently used to assess head movements in orienting behavior of human beings and animals. This method has two disadvantages: the relatively great weight of the helmet and the restriction of translational head movements.
The purpose of this paper is to describe a photosensitive method of simple construction that avoids many of the mentioned disadvantages.

**General characteristics of the method.** In order to study head and body movements in orienting behavior of animals and human beings, it was necessary to find a method which would allow to evaluate the following parameters: response latency, duration of the movement, speed, acceleration and displacement. The method was required to be free of feedback, with low inertial properties, without resistance to translational

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**Fig. 1.** Scheme of the experimental arrangement indicating the manner in which the defined variables were derived. Projector (1), slide (2), open field area (3), moving object (4), transducer (5), clamp amplifier (6), tape recorder (7). Angle of displacement ($\theta$), radius of rotation ($r$), width of stripes ($\Delta x$), diameter of sensitive transducer area ($d_o$).
and rotatory movements, and without influence on the simultaneous registration of other physiological parameters as EOG, EMG, EEG, single unit activity, etc.

The problem was solved by utilizing a miniaturized photosensitive element attached to the part of the body to be studied and by defining a geometrical intensity or spectral distribution of the light in the area in which the movements occur.

The movement parameters can be evaluated by analyzing the voltage changes induced in the photosensitive element.

**Description of the procedure for triggered rotatory movements.** The arrangement for measuring movement parameters during angular rotation is shown in Fig. 1. A slide with black and white stripes is projected perpendicularly to the area through which the object makes a rotatory movement in the horizontal plane. The transducer, a small photosensitive element, is attached to the object. The transducer output is connected to a clamp-amplifier which works normally as an ac-amplifier can be switched for dc-operation before the movement is triggered. The changes in light intensity can always be recorded on a tape recorder in relation to zero level of the amplified output, and the amplifier is automatically compensated between dc-operations.

An angular rotation (rotation radius, \( r \)) of the photosensitive element (diameter of the photosensitive area, \( d_o \)) in the stripe pattern (width of the stripes, \( A x \)) produces a pulse sequence such as is also shown in Fig. 1. The following movement parameters were derived and calculated from the train of impulses:

- \( t_1 \) — response latency in relation to stimulus onset,
- \( t_d \) — duration of the movement,
- \( n \) — number of impulse edges for calculating the angular displacement according to the equation
  \[
  a = \arcsin \left( \frac{nAx}{r} \right),
  \]
- \( t_o \) — time required to calculate the mean initial velocity \( v_o \) and initial acceleration \( a_o \) according to:
  \[
  v_o = \frac{d_o}{t_o} \quad \text{if } d_o \leq r,
  \]
  \[
  a_o = \frac{v_o}{t_o},
  \]
- \( t \) — time required to calculate the maximum velocity \( \dot{v} \) according to
  \[
  \dot{v} = \frac{d_o}{t} \quad \text{if } d_o \leq r.
  \]

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With the maximum angular displacement $a_{\text{max}}$ of the object and setting a limited $\Delta a_{\text{max}}$ for a minimum resolution, it is possible to optimize the wideness of stripes $\Delta x$ by

$$\Delta x = \sin a_{\text{max}} - \sin (a_{\text{max}} - \Delta a_{\text{max}}) \times r.$$ 

The minimal wideness of the stripes is technically limited by the optic properties of the projection system and the finite diameter $d_o$ of the transducer, and also physiologically limited by the movements of the object in resting position (f.i. muscle tremor). Due to the finite values of $\Delta x$ and $d_o$ an error for the results should be estimated.

The mean absolute errors for the calculated movement parameters are:

$$\varepsilon t_1 = \frac{(x - d_o) t_o}{2 d_o}$$

analogous considerations for $\varepsilon t_d$

$$\varepsilon v_o = \frac{2 d_o^2}{(\Delta x - d_o) t_o}$$

analogous for $\varepsilon a_o$

$$\varepsilon v = 0, \quad \varepsilon a = \frac{a_1 + \Delta a_{\text{max}}}{2}.$$ 

Two examples of the application of the method. A man was seated in the center of a semicircular horizontal plane ($R = 1$ m). Visual (light emitting diodes) and auditory targets (loudspeakers) were presented at different angles along the circle. The subject was instructed

Fig. 2. Example of the response of the head of a man during orientating to a stimulated visual target.
to fixate the central target at 0°, which was permanently on. At this starting position the direction of the head was parallel to the projected stripes. The subject was instructed to fix a new target, when it appeared. He was told to return the gaze to the central target between trials. The transducer was attached to the frontal part of the head in such position that the resulting radius of head rotation was $r = 100$ mm. The diameter of the sensitive transducer area was $d_o = 1$ mm. The wideness of the projected stripes was $\Delta x = 2$ mm. Figure 2 shows a trace of a recorded head movement and the calculated motor parameters.

The targeting behavior to sound sources in space in connection with habituation problems was studied in untrained freely moving cats. A stripe pattern with $\Delta x = 3$ mm was projected to the area in which the animals moved. The transducer was attached to the head of the animal. Figure 3 shows the registration of the head movements to repeated auditory stimulation during different stages of habituation.

These examples show than in spite of its simplicity, the method is very efficient in evaluating the movement parameters and is free of the disadvantages of other methods, such as the weight of the transducer, the restriction of movement, etc. This method may be useful for mea-

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Figure 2: Example of a recorded head movement with calculated motor parameters.

Figure 3: Example of the response of the head of a cat during spontaneous orienting to a stimulated auditory target source.
suring other types of total or partial body movements in human beings and animals. But if the movements are more complex (spatially organized and coupled to one another), the generation of the necessary spectral or intensity distribution of light pattern, the arrangement of the transducers and the data processing are more complicated and have to be optimally selected according to the problems to be studied.

The authors are indebted to Prof. G. Santibañez-H. for worthwhile suggestions and to G. Pavel for technical help.


Accepted 28 March 1984