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A Flickering Stimuli Method for Investigating Temporal Features of Binocular Vision

D. Noreika, H. Vaitkevičius, A. Švegžda, V. Vanagas, R. Stanikūnas
Department of General Psychology, Vilnius University,
Universiteto str. 9/1, LT-01513 Vilnius, Lithuania, phone: +370 5 2667619
Z. Bliznikas
Institute of Applied Research, Vilnius University,
Saulėtekio al. 9-III, LT-10222 Vilnius, Lithuania, phone: +370 5 2193096, e–mail: zenius.bliznikas@ff.vu.lt

Introduction

Stereo vision is the process in visual perception leading to the sensation of 3D space from the two slightly different projections of the world onto the retinas of the two eyes. When the differences of the projections are too large, a phenomenon of *binocular rivalry* (BR) occurs. During BR, the perception continually alternates between two different images: the one projected to the left eye, and the other, projected to the right eye.

The phenomenon of binocular rivalry is widely used in perception research – for investigating the influence of adaptation on perception [1], the interaction of different sensations [2], the role of heredity in perception [3] etc. Findings about the mechanisms of BR give insights about fundamental principles of vision and are applied for creating devices for stereovision, vision prosthesis and diagnosing diseases [4, 5, 3].

There are different viewpoints, concerning the temporal features of BR. Some of them stress the importance of coincidence in time of the presented images for BR. E.g. in the model of Lumer [6] compatibility of the signals from both eyes stems from synchronization in V1 zone and higher centres. If both eyes' stimuli cannot be agreed, BR is initiated. According to this view, any temporal differences, related to the presentation of the visual stimuli (VS) may determine, which decision – stereovision or BR – the optic system will choose.

However, other researches [7, 8] indicate that minor temporal displacement of the stimuli in millisecond range does not have any obvious influence on BR. E.g. Boxtel van et al. [8], after exploring temporal features of BR, concluded that BR is not susceptive to minor temporal displacements of VS. Only when this displacement exceeds 350 ms, BR vanishes and the images are seen when they are actually presented.

Some more explicit answers to the question, whether temporal parameters of VS are important for BR, could be achieved in experiments, where VS would be presented in series of impulses of strictly controlled frequency and the influence of the flickering frequency on BR could be measured. Such investigation has not been performed yet. We designed an experiment to test whether the temporal features of BR depend on the strictly controlled times of presentation of the displayed images. We designed a special tachistoscope (stereo projector) to present stimuli in the millisecond range and to control the displaying time of the stimuli separately for each eye. The aim of our work was to create equipment, which would be useful both for fundamental research of stereovision and for applied use in clinical practice and technical stereo vision.

Method

Our constructed experimental equipment was based on the possibilities of contemporary information and light technologies [9, 10] and its flexible use in applied research.

Two different stimuli (2.4° in diameter), generated by a stereo projector, were presented separately to each eye (Fig. 1). The stimuli were composed of black bars (0,6° in width, tilt ±45°), intersecting white circles (brightness – 0,2 cd/m^2). The contrast was 0,9.

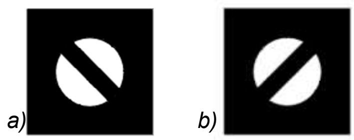

Fig. 1. The visual stimuli: a – image presented to the left eye; b – image presented to the right eye

The stimuli were presented according to a timetable shown in Fig. 2. The flash duration T_S was discretically varied so that the flash duration of the left and of the right eye $T_{SL} = T_{SR}$ was fixed and equalled: 5 ms, 7 ms, 10 ms, 12 ms, 15 ms, 17 ms, 20 ms, 25 ms and 30 ms. Also a nonflashing stimulus (without flicker) was used. During the experiment, the 10 modes of the stimuli were sequenced in a random way.

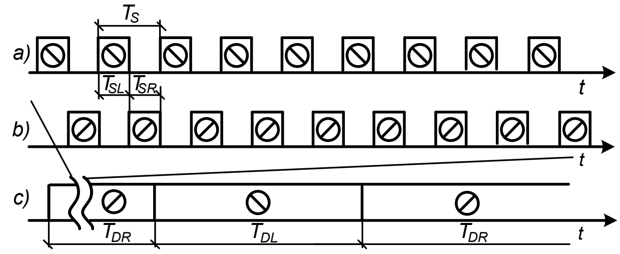

Fig. 2. Timetable explaining the process of presenting and perception of the stimuli: T_{SL}, T_{SR} – flash duration of the stimuli, projected to the left and to the right eye (T_{SL} = T_{SR}); T_S= T_{SL} + T_{SR} – period of the flashing stimulus; T_{DL}, T_{DR} – time periods when the subject perceived the stimuli, presented to the left and to the right eye

The experiment took place in a completely dark room. The subject adapted for 3 min in darkness before each experiment. Then the subject observed the images generated by the stereo projector and indicated which stimulus he was seeing by pushing a switch. A session of the experiment with one randomly chosen flash duration lasted 3 min. (around 100 switches were performed during that time). A 1 min. break followed each session, after which the experiment continued with other flash duration. 10 sessions with different flash durations were performed in such a way. Every subject repeated the experiment 4 times (at different days), and the results were averaged separately for each subject.

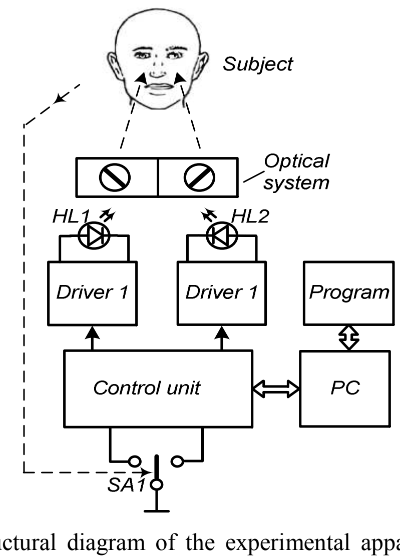

Fig. 3. Structural diagram of the experimental apparatus: HL1, HL2 – light diodes; PC– personal computer; SA1– switch

The functional architecture of the experimental apparatus is presented in Fig. 3. VS are presented with the help of high luminance LW3C type light diodes HL1 and HL2, controlled by drivers 1 and 2. The diodes emit light impulses of stable amplitude. The commanding impulses are transmitted to the drivers 1 and 2 from the control unit, which generates the impulses according to the computer program signals, transmitted through a LPT port. The devices registered time when the subject pushed the switch (SA1) and calculated the perception duration T_{DL} or T_{DR} respectively.

A computer program, operating in real time (in DOS OS) and written in C language was created for the experiment. Communication with the user is accomplished with the help of configurational files and a command line. The program sends series of impulses to the control unit and receives responses of the subject. The equipment guarantees formation of the impulses and registration of the responses with 1 μs accuracy.

4 male subjects took part in the experiments, mean age 32 y. The subjects had experience of participating in psychophysical experiments, yet only one of them knew the purpose of this particular experiment.

Experimental results

The main results are presented in Fig. 4. We calculated mean dominance duration (the mean duration of every image seen during one session) for every subject under the given flash duration. The changes of mean dominance durations were evaluated by analyzing the curve of the dominance durations versus VS duration.

It is obvious from Fig. 4 that the relation between stimulus flash duration and mean dominance duration of BR is not a monotonic function: one can observe significant differences between the dominance durations, measured at different flash durations, though the dependencies for each subject vary. The total dominance duration mean (across all flash durations) varies between 1 s and 4 s across subjects. The individual reaction times of each subject may have changed the total mean of the subject, but not the localization of peaks in the curve.

The results confirmed the main hypothesis – the VS flash duration affects the mean dominance duration of BR. The first peak of the curve usually (for 3 out of 4 subjects; less expressed in RS graph) lies in the 7 – 10 ms interval. Other peaks are more variable. The curve of subject DN has another peak at 20 ms – 25 ms. The second peak in the curve of subject LO is also vivid, yet it is located at 17 ms. In the curves of subjects RS and NK, the second peak is not so explicit.

The mean dominant durations of the left and ~~the~~ right eyes of every subject differ significantly, though the form of the curve is often similar.

Discussion

The results of the experiment may be important for understanding the temporal features of perception. There are findings that sensitivity of the input of the visual system changes in time. After each signal is transmitted to the input of the visual system, its sensitivity is reduced for approximately 7 ms [11, 12]. Moreover, there is data that the sensitivity of the visual system is modulated with some frequency (between 30 – 100 Hz) [13]. As the result, the influence of presented stimuli depends on the frequency of their presentation. The effectiveness of the stimuli would be maximal if the stimuli are displayed synchronously with the sensitivity oscillation in the visual system.

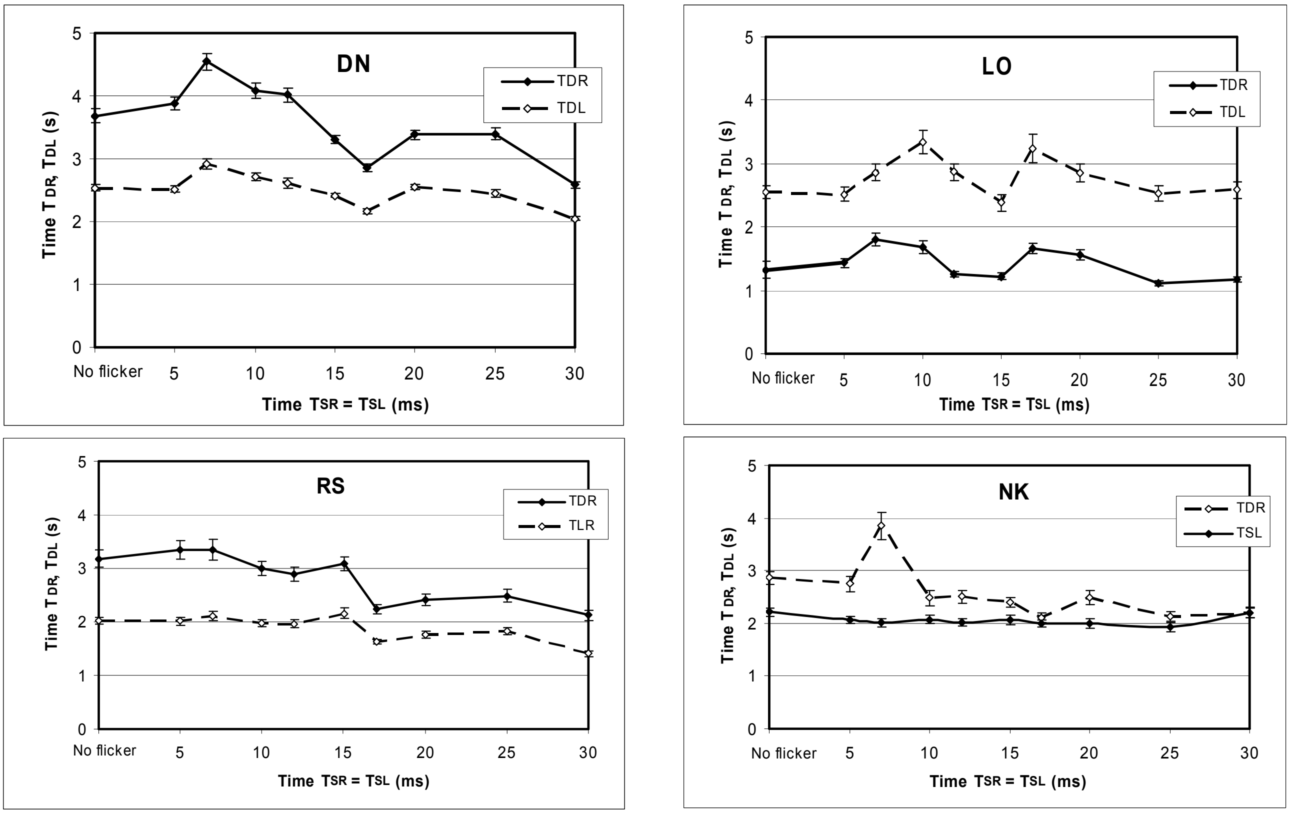

Fig. 4. Mean dominance durations of the left eye T_{DL} and the right eye T_{DR} as a function of stimulus flash durations $T_{SL} = T_{SR}$. Each diagram presents data of a different subject. Vertical bars denote 95% confidence intervals

The effectiveness of stimuli is maximal when the rate of the stimuli presentation coincides with the rate of the sensitivity oscillation (stimuli should be presented when the sensitivity of the system is maximal).The differences of the mean dominance duration that we found in our experiment may have appeared because different flash durations changed the level of coincidence of the stimulus presentation rate with the rate of sensitivity oscillations of the sensory system. The maximal places of the curves are often at the flash durations of 7 – 10 ms, i.e. the frequency of the presentation of VS is about 50 - 70 Hz, and these values are close to the ones found by aforementioned research.

The extremum places of the curves are not stable across subjects and even vary in different experiments of the same subject, and this may be related to the fluctuating nature of the sensitivity of the visual system. Even when the same mode of stimulus flashing was used, it may have coincided with different sensitivity of the input system, so the effectiveness of the stimuli varied.

The results of the experiment attest, that the new equipment has enough accuracy and reliability to use it for investigating the temporal features of visual perception. Further research is going to be conducted to expand its range of application.

For further research, it would be advisable to explore the dependency of mean dominance duration on the flash durations of the stimuli in a narrower range (e.g. 5 – 30 ms), but varying the flash durations in intervals of one millisecond. Such research could examine the fluctuation of the mean dominance durations in a more precise way.

Conclusions

1. The constructed method and equipment, enabling to present stimuli and register the responses with 1 μs accuracy, are suitable for investigating the temporal characteristics of binocular vision in an accurate and reliable way.
2. Mean dominance duration of binocular rivalry depends on the flash duration of stimuli presented for 5 ms – 30 ms.
3. The first peak of the dominance duration curve mostly occurs in the 7 ms – 10 ms interval. Other peaks are more variable.

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A flickering stimuli method for investigating temporal features of binocular vision is introduced and experimental results of the use of the method for investigating binocular rivalry are presented. Binocular rivalry is a phenomenon of visual perception in which perception alternates between two different images, presented to each eye. The results attest, that the new method and apparatus are suitable for investigating the temporal characteristics of binocular rivalry in an accurate and reliable way. The flash duration of the stimuli influences the dominant time of binocular rivalry. The first peak of the dominance duration curve (3,5 s – 4,5 s) mostly occurs in the 7 ms – 10 ms interval. Other peaks are more variable Ill. 4, bibl. 13 (in English; abstracts in English, Russian and Lithuanian).

Д. Норейка, Г. Вайткевичюс, А. Швегжда, В. Ванагас, Р. Станикунас, З. Близникас. Метод мерцающих стимулов для исследования временных особенностей бинокулярного зрения // Электроника и электротехника. – Каунас: Технология, 2010. – № 7(103). – С. 35–38.

Представлен метод и устройство, для исследования временных характеристик бинокулярного восприятия. Представлены результаты исследования явления бинокулярной конкуренции глаз. Бинокулярная конкуренция – это феномен зрения, когда при наблюдении двух разных изображений глазам, они не сливаются в единое целое, как в случае обычного стереозрения, а воспринимаются попеременно между изображениями, представляемыми левому и правому глазу. Результаты исследования показывают, что созданные средства дают возможность с достаточной точностью определять временные характеристики процессов, связанных с бинокулярной конкуренцией. Среднее время восприятия доминирующего изображения зависит от длительности предъявления изображений. Максимальные значения этого времени (3,5 с–4,5 с) наблюдаются, когда длительность предъявления изображений находится в интервале от 7 ms до 10 ms. Ил. 4, библ. 13 (на английском языке; рефераты на английском, русском и литовском яз.).

D. Noreika, H. Vaitkevičius, A. Švegžda, V. Vanagas, R. Stanikūnas, Z. Bliznikas. Mirksinčiųjų dirgiklių metodas binokulinės regos laikinėms savybėms tirti // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 7(103). – P. 35–38.

Pristatomas mirksinčių dirgiklių metodas, skirtas binokulinės regos laikinėms savybėms tirti, ir rezultatai eksperimento, kuriame šis metodas buvo taikomas akių konkurencijai tirti. Akių konkurencija – tai suvokimo reiškinys, kai į akių tinklaines projektuojami nesutampantys vaizdai, regos sistemoje ne suliejami, o suvokiami pakaitomis. Gauti tyrimo rezultatai rodo, kad sukurta tyrimo metodika ir matavimo aparatūra leidžia gana tiksliai tirti akių konkurencijos reiškinio laikines savybes. Konkurencijos vidutinė dominavimo trukmė priklauso nuo regimųjų dirgiklių pateikimo trukmės. Dominavimo trukmė esti didžiausia (3,5 s–4,5 s), kai dirgiklis veikia nuo 7 ms iki 10 ms. Kitų maksimumų vietos labiau varijuoja. Il. 4, bibl. 13 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).