Simple and powerful visual stimulus generator

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Abstract

We describe a cheap, simple, portable and efficient approach to visual stimulation for neurophysiology which does not need any special hardware equipment. The method based on an animation technique uses the FLI autodesk animator format. This form of the animation is replayed by a special program ('player') providing synchronisation pulses toward recording system via parallel port. The 'player' is running on an IBM compatible personal computer under MS-DOS operation system and stimulus is displayed on a VGA computer monitor. Various stimuli created with this technique for visual evoked potentials (VEPs) are presented. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

Keywords: Visual stimulus generator; VEPs; Visual stimuli; Motion-onset; Pattern-reversal

1. Introduction

Many special electronic and even mechanic devices have been constructed for visual stimulation in neuroscience. They are generally developed either for electrophysiological experiments (VSG Cambridge Research Systems, UK, VENUS:S) or they are intended for clinical use. The first devices are very flexible, however, due to their complexity, it can be difficult to control them. In contrast, those utilised as a part of clinical instrumentation can be easily used, however, they are too rigid for the introduction of a new stimulation method. In addition, both of them are usually very expensive.

For these reasons, various laboratories interested in vision research developed their own stimulation systems [1,2]. Our laboratory did exactly so but then incompatibility problems arise frequently, e.g. when a stimulus should be used in another laboratory. That is why we have been employing a widely supported FLI animation file format (Autodesk) with fast graphics and 256 colours (from whole amount of 64^3 colour combination) concurrently presented on the screen (VGA mode 13) for ~ 4 years.

In the following a simple animation player is described, which offers possibility to share and to

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access a stimulus among collaborating labs or co-operating clinicians without the necessity to be equipped by an unique expensive system.

However there is a problem how to synchronise the stimulus and a recording device. Until now the synchronisation with a photocell trigger was used requiring a special photocell with an amplifier and a small part of the screen devoted to flash. Because of practical limitation to deliver multiple triggers, necessary for example in event related evoked potentials, an alternative hardware solution was developed without need of a photocell, which exploits monitoring of changes in video signal [3]. Unfortunately this solution also requires a special hardware and therefore the presented software driven triggering was developed.

2. Principle

The method is based on customised animation player of the FLI format.

To describe triggering facilities and stimulator properties it is necessary to describe shortly the organisation and encoding of the file format. The FLI format includes several coding constructions, but animation heart is in two block structures (often called 'chunks').

The most common type of chunk in the FLI file is line compression, which only saves changes between following frames of animation. It is row based, and therefore some stimuli with column based structure can be prolonged in comparison to the row based ones on slow machines (for example vertical motion of regular checkerboard would be on slow computers faster than horizontal).

The second chunk, colour palette oriented, saves changes between colour maps of following frames. Every colour is determined by red, green and blue value in the range from 0 to 63, there is a potential to differentiate among 64^3 levels. The information then goes toward the colour look up table with 256 registers [4]. The colour animation is very efficient and the pattern-reversal can be carried out by changing only two colours in the palette.

In the presented stimulator, we decided to use a second index of palette, the red colour in it (THE RED) to encode the trigger (in 63 levels). A value is sent to parallel port when THE RED is changed. A status of the parallel port is changed by logical exclusive OR operation (XOR) which implies further possible trigger combinations.

The colour chunk was used as the trigger carrier because if THE RED is not displayed, it is possible to send the synchronising pulse independently on screen contents. Moreover, it is possible to use the whole screen for stimulation (no flash for photocell).

The simplest triggering example is that THE RED is zero and in the frame when the trigger should come THE RED it is changed to one and in the following frame is again reset to zero. This action will send a positive pulse of the duration 1/(screen refresh vertical frequency) on the first pin of the parallel port. The player is synchronised with vertical retrace so that the pulse is sent during this retrace. On our equipment working with 70 Hz vertical frequency it represents less than 2 ms. THE RED can be simply changed in any animation editor, but it should not be introduced in the first frame because it is saved in BRUN compression and on a slow machine it takes slightly more time to write it into video memory than one overscan.

2.1. Software

The player TFLI was written in Borland Pascal 7 (Borland) and assembler language—the video and triggering procedures. It works under MS-DOS system (for unpredictable delays it is not reasonable to run the TFLI under a multit-asking environment) and currently it is able to run a stimulation FLI file with following parameters:

s_n speed of replay, where $n = 1–999$ and represents the number of overscans before the next frame is proceeded;

l_n loops of replay, where $n = 0–999$. If $n = 0$ or -1, the parameter is omitted, then the FLI is replayed until any key on keyboard is pressed;

p_n pause inserts $n * 100$ ms of delay between loops;

path name, a full MS-DOS path of the FLI file to be run.

The TFLI program is freeware and can be obtained on aforementioned mentioned address and any further TFLI improvements are encouraged.

2.2. Hardware

The TFLI program runs on IBM compatible personal computer (PC) equipped with VGA graphics card. The accurate replay with unwanted delays between frames is insured on computers with 80 386 and higher processor. For the same reason, it is generally recommendable to save the FLI file on a fast hard disk or ramdisk (a logical disk created in random access memory—RAM). Any VGA computer monitor can be used.

When the trigger is synchronised to vertical retrace then the average method gives better results but it is necessary to keep in mind the well known deficiencies of monitor stimulation [2]: (1) interference of electromagnetic field from vertical deflection coils which can be removed with a proper shield; (2) flicker response in higher stimulus luminance (60 cd/m^2)—it is not prominent in low luminance intensities.

2.3. Stimuli

The FLI format stimuli can be easily developed in the autodesk animator. There are almost no restrictions in sense of shapes, colours (parallel presentation up to 255 colours from 64 hue of red, green and blue which offer 262 144 combinations) and movement directions but the resolution is restricted to 320 * 200. This resolution is crucial only when non rectangular stimulus paradigm is used. The pixel size also slightly reduces the set of screen velocities for a low n:

{velocities} = $n *$ pixel size/($m *$ 1/frames frequency),

where n represents translation in pixels within m frames.

However, for our purposes, which is to create pattern-reversal, pattern-onset (offset), motion-onset (offset) and motion oriented stimuli, this way of stimulation gives quite satisfactory results.

The TFLI player provides an accurate triggering when THE RED (second red colour in palette) is set for the desired frame to a value different from surrounding frames. For a detailed description, see Section 2.

2.4. Stimulus and recording examples

The set of transient records, obtained with further specified conditions, is presented to demonstrate usefulness of the presented stimulation technique. The acquisition was performed in darkened, electromagnetically shielded room with a background luminance of 1 cd/m^2. The viewing distance was 0.5 m—all velocities and angle sizes are related to that distance in the following text. Explicit contrast is counted according to Michelson formula:
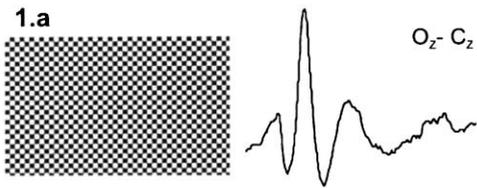
$$C = (L_{max} - L_{min})/(L_{max} + L_{min}) * 100,$$

where C is contrast (%) and L is luminance (cd/m^2). All evoked potentials, with the exception of second order ones, were obtained from a single subject, recorded from standard 10–20 electrode places expanded for Or position 5 cm to the right from Oz.

The stimuli were presented on a 21 in. computer monitor ViewSonic (USA) driven by PC 80 486 with 66 MHz of clock speed and 16 MB of random access memory. Stimulus luminance and contrast were measured by the digital photometer J16 Tektronic (USA). The stimuli were stored on the RAM disk for replay.

3. Pattern-reversal stimulus

Regular checkerboard of 40 arc min checks with the mean luminance of 17 cd/m^2 and 96% contrast was used. The pattern reversal rate was 1 Hz, i.e. two reversals per second. The stimulus FLI file occupied 76 kB. The response to the stimuli is presented in Fig. 1(a).

Pattern-reversal stimulus and response

1.a

$O_z - C_z$

Motion stimuli and motion-onset responses

1.b
high contrast checkerboard

$O_R - A_2$

1.e
expansion

$O_R - A_2$

1.c
low contrast isolated checks

$O_R - A_2$

1.f
second order

$O_R - A_2$

1.d
random dots

$O_R - A_2$

1.g
masked motion

$O_R - A_2$

1.h
motion oriented perimetry

$O_R - A_2$

0 - 3.5°

3.5 - 7°
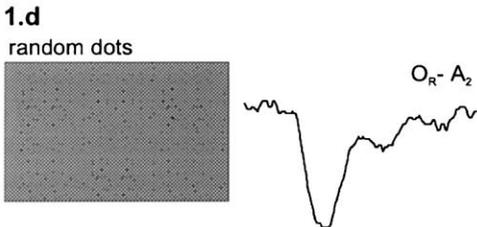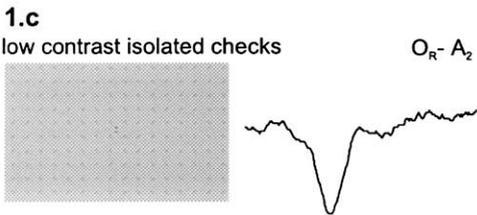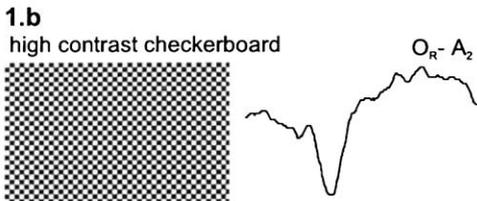
7 - 14°

14 - 28°

28 - 42°

10 µV

100 ms
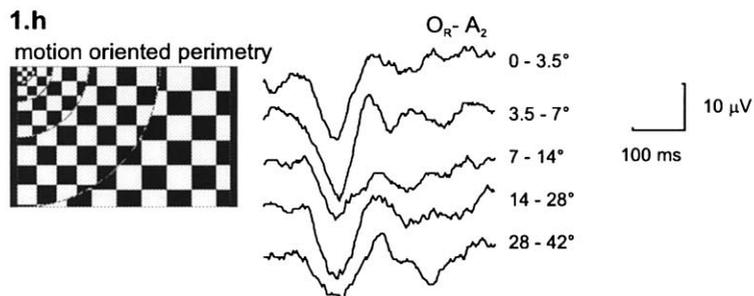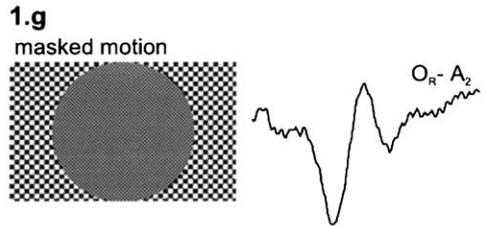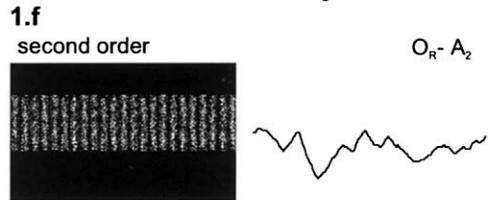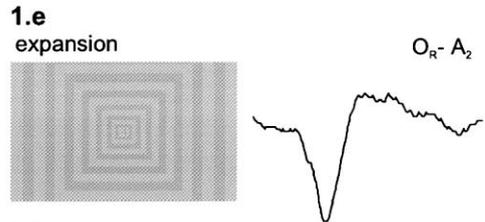
Fig. 1.

4. Motion-onset stimuli

Our laboratory is specialised in an examination of the magnocellular pathway, using various kinds of motion oriented stimuli [5–7]. Some of them are presented in the following text. Common stimulus timing used in all stimuli is ~200 ms (14 frames) of the movement and 1 s of the inter-stimulus interval. Mean luminance is kept at 17 cd/m^2.

(1) High contrast checkerboard. This is a regular high contrast (96%) 40 arc min checkerboard moving with a velocity of 10°/s. The evoked potential (EP) differs substantially from the pattern-reversal EP—a dominant negative peak at ~160 ms seems to be specific for perception of motion onset (Fig. 1(b)).

(2) Low contrast isolated checks. The grey, 10% of contrast structure moving in four cardinal directions with 20°/s velocity is created as a net of isolated, darker, 20 arc min checks (with 60 arc min distance between each other) on brighter background. The size of the FLI file is 170 kB (Fig. 1(c)).

(3) Single moving dots represent very strong stimulus for subjects with sufficient visual acuity. The 5 arc min dots move coherently in squares (6° edge) with the velocity of 10°/s. The four fundamental directions of motion are combined not to be the same in any of neighbourhood squares. Between the following stimuli the motion direction is changed in pseudorandom way in one square. The FLI animation is saved in 233 kB file (Fig. 1(d)).

(4) Expanding structure. This is a stimulus very powerfully capable of evoking the motion-onset responses in almost whole population consists of expanding, 10% contrast grey frames. The frames are increasing in the width toward the periphery from 20 to 210 arc min and also the velocity increases in the same manner from 10 to 80°/s. The FLI file is ~53 kB and for typical EP, see Fig. 1(e).

(5) Second order motion-animation is also a convenient style for many psychophysical examinations. The EP in Fig. 1(f) was recorded as a response to texture–contrast modulated grating moving at 10°/s velocity. A little different shape of response is caused by the fact that another subject sat for this examination. The FLI file took ~345 kB of disk space.

(6) Masked motion. This animation technique offers a simple way to create any masked stimuli for selective examination of the visual field. The stimulus parameters for EP displayed in Fig. 1(g) are the same as in the case of the high contrast moving checkerboard but here the central 20° is masked.

A specific application of the masking represents a whole visual field examination, i.e. the perimetry. One quadrant stimulus and motion-onset VEPs based objective perimetry is presented in Fig. 1(h). The stimulus contains five concentric fields with decreasing spatial frequency (increasing checks size 40–200 arc min) and increasing motion velocity (10–50°/s) from the centre toward the periphery.

5. Conclusion

The choice of the FLI-widely spread animation file format with existing interactive graphics editor

Fig. 1. Visual evoked responses recorded to stimuli generated by proposed stimulator are listed together with screen snapshots of given stimuli: (a) the pattern reversal stimulus and EP with dominant positive peak. The response was recorded from bipolar lead Oz–Cz; (b) the linear motion stimulus of the same spatial characteristic as (a) ones with EP recorded to onset of stimulus motion offer different information describing mainly the magnocellular system. Negative components at ~160 ms is characteristic for motion–onset oriented response. The unipolar EP was recorded from the right lateral occipital lead Or (5 cm from Oz); (c) linear motion of 10% contrast structure in one of four directions (in pseudorandom order) also gives the motion oriented negativity; (d) stimulus screen consisting of 24 squares of coherently moving dots is another efficient motion–onset stimulus; (e) 10% contrast expanding structure, the most efficient stimulus, with increasing velocity, a decreasing spatial frequency toward the periphery; (f) second order motion elicited smaller, but distinct negativity. Stimulus was created as contrast modulated texture driven in one direction; (g) 20° central mask of motion structure evokes a regular negative response (see (b)); (h) the consequently stimulated annual fields of the right down quadrant of visual field with eccentricities up to 42° produce the motion response even in the most peripheral stimulation part. The stimulus represents one quarter of the objective motion oriented perimeter.

autodesk animator supports the idea of easy development of new stimuli, however the available players are not able to generate trigger. The new solution for visual stimulation introduced here brings several benefits: (1) possibility of various stimuli, i.e. no problem with disparate motion, masking, non-linear velocity; (2) fast stimulus realisation and its easy modification; (3) multiple trigger possibility; (4) cheap non-single task stimulation device; and (5) the possibility of sharing the same stimuli among laboratories and a quick introduction into the clinical practice.

The selection of this animation technique is balanced by relatively low resolution 320×200 pixels (enable enough fast graphics on widely accessible computers).

The player TFLI is available free of charge on request at the following e-mail (mail) address: jan.kremlacek@lfhk.cuni.cz.

Acknowledgements

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