

## Motion-reversal Visual Evoked Responses

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### Summary

Motion-reversal visual evoked responses (VERs) have remarkable waveform variability. In our opinion this is caused by the alternative predominance of either motion or pattern-onset/offset related components. The motion dependent component of motion-reversal VER closely resembles motion-onset VER (main negative peak with the latency of about 170 ms), the first positive peak (with the latency of about 100 ms) corresponds to the pattern-onset component and the second non-constant positive peak (with the latency of about 130 ms) seems to be identical with the pattern-offset positivity. The differences in expression of these components are dependent on some stimulus characteristics (mainly on the contrast of a structure, velocity of motion, retinal localization of the stimulus) and on substantial differences in the sensitivity of subjects to motion stimulation.

### Key words

Visual evoked responses - VEPs - Visual motion stimulation - Motion-reversal

### Introduction

Visual evoked responses (VERs) to motion-reversal are responses of the visual cortex to abrupt changes in the direction of a motion in the visual field. There are very few literature data concerning this type of VER. Probably the first reports were by MacKay and Rietveld (1968) and Rietveld and MacKay (1969). As far as we know, the only systematic studies were carried out by Clarke (1972, 1973a, 1973b, 1974). Despite the large variability in the obtained results and the discussed role of pattern-appearance and pattern-disappearance effects in motion-reversal stimulation, Clarke concluded that "the motion-reversal VERs are genuine responses to changes in the motion as such".

In the context of our interest in motion-related VERs, which display some promising features for diagnostic applications (Kuba and Kubová 1992, Kubová and Kuba 1992), we wanted also to verify the character of motion-reversal VERs.

### Methods

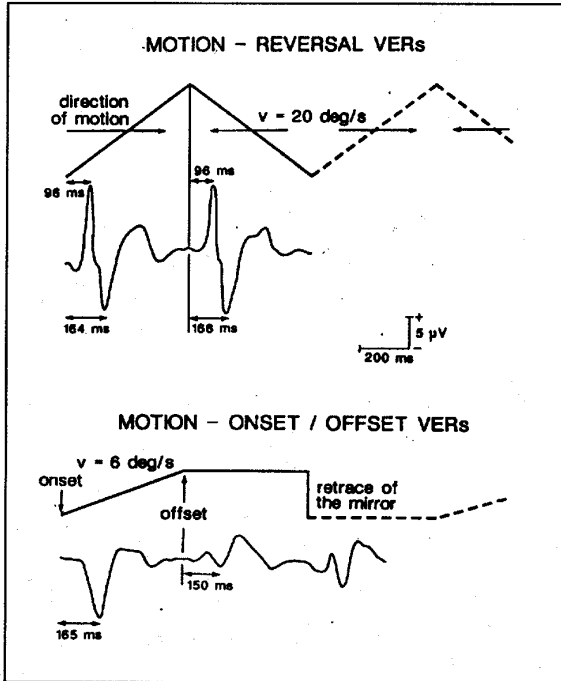
Motion-reversal VERs were tested in 20 healthy persons with an age span of 18-50 years.

The visual stimulus was back-projected via a moving mirror onto a 20° circular stimulus field and

viewed by subjects from a distance of 0.8 m. Mirror-movement was produced by an optical scanner (General Scanning Inc. - USA) controlled by a triangular waveform (Fig. 1 - upper part), so that the pattern moved horizontally at a constant speed, and at every peak of the triangular waveform the direction of motion reversed. The fixation point of 15' was placed in the centre of the stimulus field and the subjects were instructed not to follow the moving pattern with their eyes (verification with EOG was done in some cases).

Two kinds of moving structures were used: checkerboards with check sizes 7', 15', 30', 60' and random dot patterns with grain size of about 15' - 30' (structured slides), both in contrast values 95 %, 50 % and 10 % ( $C = (L_{max} - L_{min}) / (L_{max} + L_{min})$ ). Frequencies of motion-reversal from 0.4 to 6 Hz and motion velocities from 1 deg/s to 100 deg/s were tested.

Resulting motion-reversal VERs were compared with motion-onset/offset responses (which were obtained when the mirror movement was driven by special ramp pulses - see lower part of Fig. 1) and with pattern-appearance/disappearance responses (achieved by the use of electromagnetic shutters for the alternative stimulus projection).



**Fig. 1**  
 Demonstration of waveforms controlling the movement of the mirror in motion-reversal and motion-onset/offset stimulation. Resultant VEPs on an adequate time axis are presented for both types of stimulation.

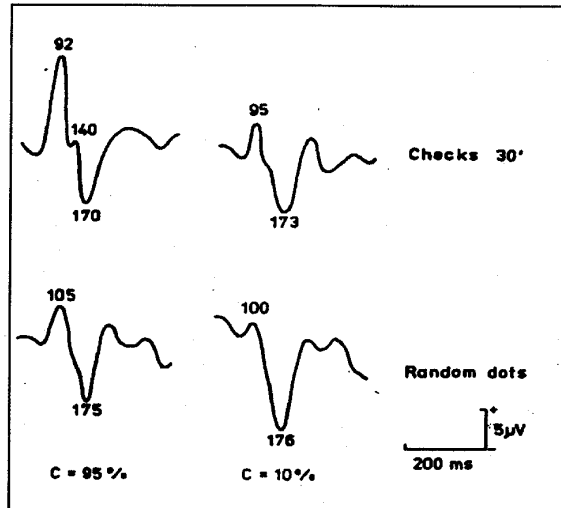
VEPs were recorded from unipolar leads  $O_z$  and symmetrical lateral occipital leads  $O_L$ ,  $O_R$  - 5 cm from  $O_z$  (linked earlobes served as reference). After amplification by Tektronix AM 502 amplifiers in the 0.1-100 Hz band, 64 single evoked responses (1000 ms segments with a resolution of 1 ms) were averaged.

Whole field stimulation (central 20° of visual field), upper and lower half-fields and paracentral stimulation (central 10° masked) were used.

**Results**

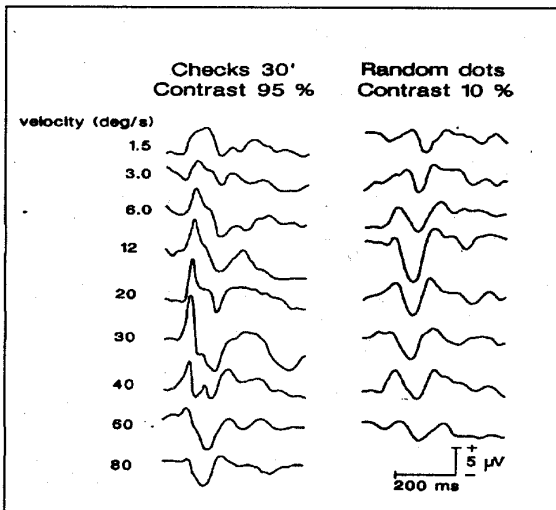
There were no substantial frequency dependent changes in the motion-reversal VEPs up to the frequency of about 5 Hz. At this frequency the shape of the VEPs changed to the sinusoid-like waveform of typical steady-state responses.

The motion-reversal VEPs did not display directional sensitivity - the responses to the change of direction of motion from right to left were the same as the responses to the opposite direction (see Fig. 1). Therefore only one average response to the whole stimulus cycle is presented in all the following figures.



**Fig. 2**  
 Dependence of motion-reversal VEPs waveform (lead  $O_z-A_{1+2}$ ) on stimulus pattern (typical case). High contrast ( $C = 95\%$ ) and low contrast ( $C = 10\%$ ) checkerboard and random dot stimulus patterns are compared.

In contrast to Clarke's data (1973b), we have not found any significant VEPs differences between upper and lower half-field stimulation.



**Fig. 3**  
 The set of motion-reversal VEPs from one subject (lead  $O_z-A_{1+2}$ ) for a high contrast checkerboard structure with check size of 30' and for a low contrast random dot stimulus, both in motion velocities from 1.5 to 80 deg/s.

There was, however, a crucial difference among motion-reversal VERs in dependence on the parameters of moving patterns. Fig. 2 demonstrates the influence of contrast and periodicity of the stimulus structure. Motion-reversal VERs were in most cases composed of two distinct peaks. Whereas in responses to high-contrast periodic (checkerboard) patterns the positive peak with a latency of about 100 ms dominated, in low contrast random dot motion-reversal stimulation negativity at about 170 ms was more distinct. Low contrast checkerboard and high contrast random dot stimuli evoked motion-reversal VERs, where both positive and negative peaks were of about the same amplitude.

Fig. 3. shows velocity dependent changes in the motion-reversal VERs. The dominant positive peak in VERs to high contrast checkerboard stimulation disappeared when the velocity of motion was higher than about 40 deg/s (with check size 30'). The waveform was then the same as in VERs to low contrast random dot stimulation, in which the negative peaks displayed a U-shaped dependence of latencies on the logarithm of motion velocity (with the shortest latency at about 20 deg/s).

The largest motion-reversal VERs were acquired with velocities of about 30 deg/s for the high-contrast checkerboard structure and with velocities of about 12 deg/s for low-contrast random dots.

An attempt to find the probable origin of the two different types of VERs to motion-reversal stimulation is characterized in Fig. 4. The shape of three variants (I.a, I.b, I.c) of the first type of motion-reversal VERs (large positive peak) is very similar, differing only in the expression of the small second (intermediate) positive peak. The common subjective perception during motion-reversal of a high contrast checkerboard at higher velocities is a completely blurred structure during motion and only a short appearance of the structure at the moment of motion reversal. In comparison to the real pattern-appearance/disappearance VERs, this type of motion-reversal VERs - Type I. - seems to be some combination of pattern-on and pattern-off related responses. The first positive peak probably corresponds to the positive component of the pattern appearance response and the second positive - intermediate peak - has the same latency (if present) as the pattern-disappearance positivity.

Using the low contrast random dots stimulation, no blur effect is perceived during the motion, only changes in motion direction are distinctly visible. The resulting motion-reversal VERs - Type II. - are practically identical to motion-onset VERs. Motion-offset VERs had about the same character in our findings but they were much smaller or even missing in some subjects (Kuba *et al.* 1992).

In Fig. 5 an explanation is suggested for the change in the character of checkerboard motion-

reversal VERs at high velocities of motion (case II.a in Fig. 4). Probably the more pattern-dependent Type I. of motion-reversal VERs is obtained when the pattern appears for a sufficiently long time (more than 10 ms - Clarke 1972) at the moment of motion-reversal. This depends on the combination (multiple) of pattern element size and velocity (= temporal frequency). At high velocities or when a fine periodic pattern is used, no clear stationary structure can be seen and thus the predominantly motion-dependent Type II. of motion-reversal VERs is produced.

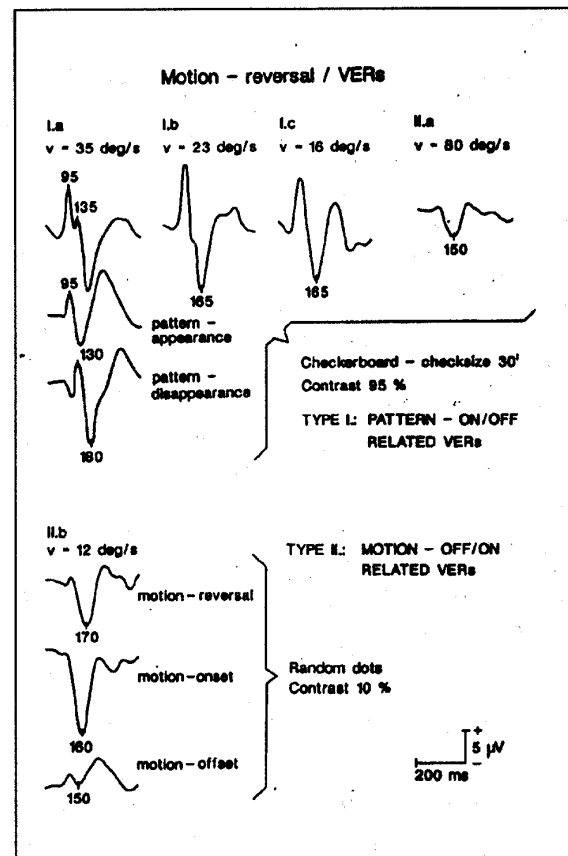
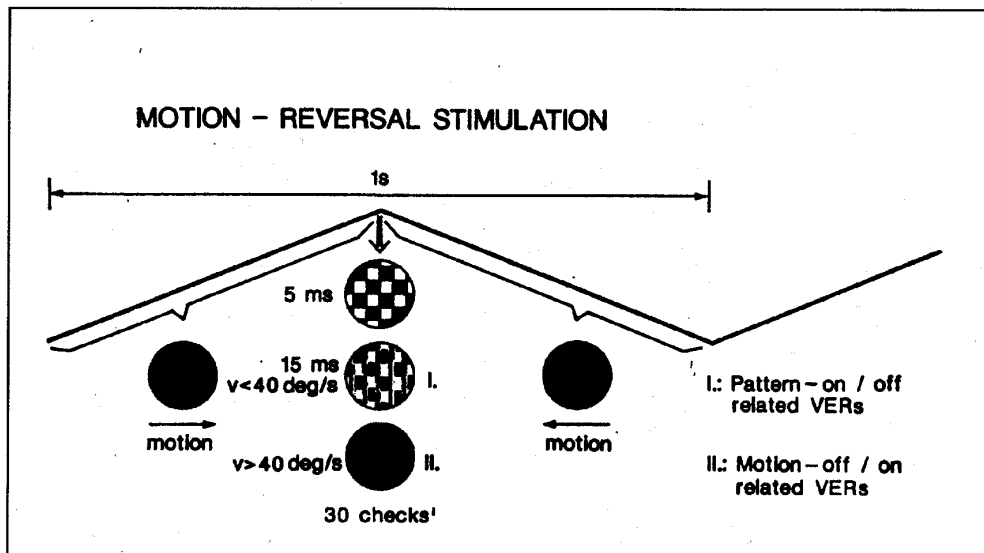


Fig. 4

Comparison of two velocity-dependent types of motion-reversal VERs, pattern-appearance/disappearance and motion-onset/offset VERs in one subject (lead  $O_z - A_{1+2}$ )

- Type I. (I.a, I.b, I.c) is similar to the combination of pattern-appearance/disappearance VERs.
- Type II. (II.a, II.b) seems to be identical with motion-onset/offset related VERs.

In all subjects the distinct pattern related (checkerboard) motion-reversal VERs (Type I.) were obtained. However, latencies and shape of these pattern-related components were interindividually very



**Fig. 5**

A tentative explanation of the change of checkerboard high velocity motion-reversal VERs (from Type I. to Type II. - case IIa from the Fig. 3). The direction reversal of the mirror in every velocity of motion lasts maximally for about 5 ms. This duration is not sufficient for the generation of pattern-appearance response. However, at lower velocities (under about 40 deg/s), the displacement of the structure from the stable picture in the moment of reversal is not so fast, so that minimally for about 15 ms some partial structure is still visible, which is sufficient for generation of pattern-on/off related response. At higher velocities the reversal is so rapid that besides the afore-mentioned 5 ms of the stable picture, only the motion of a blurred gray field is visible. Effective pattern appearance is dependent on the temporal frequency of the moving checkerboard, so that with larger checks the pattern related VERs can be obtained at higher velocities.

different and so the corresponding peaks could not be identified in the whole group (therefore no normative data of latencies can be given here). Most frequently (in 50 % of subjects) a waveform with positivity at about 100 ms and negativity at about 170 ms was found, but sometimes even the opposite polarity of responses was observed (these polarity differences were not caused by horizontal hemifields stimulation - both half-fields produced identical VERs). The average amplitude of the most prominent positive peak of this type of motion-reversal VERs ( $12.6 \pm 4.5 \text{ V}$ ) was slightly but not significantly larger than the average amplitude of P100 peak in comparable 2 Hz pattern-reversal VERs ( $10.7 \pm 4.5 \text{ IV}$ ).

Random dot motion-reversal VERs (motion dependent Type II.) displayed a more constant waveform but their amplitudes were smaller (larger motion specific negative peaks are obtained only when a sufficient interstimulus interval between two consecutive periods of motion is used - at least 5 times longer than the concrete motion duration (Kuba and Kubová 1992).

The maximum amplitude of the motion-reversal VERs was lateralized in a majority of the subjects - mainly to the right occipital area (as is the case in motion-onset/offset responses - Kuba and Kubová 1992), regardless of the handedness of the subjects.

Stimulation of the retina with the masked macular area produced even larger motion related components in some subjects with substantial reduction of the first positive peak in the pattern-related type of response.

## Discussion

In contrast to Clarke (1972, 1973a, 1973b, 1974) we cannot generalize that motion-reversal VERs are genuine responses to changes in motion. We believe that some pattern-on/off related components are displayed in these VERs whenever a high velocity of the contrast stimulus pattern is used - especially if the macular area is stimulated selectively (the upper or lower half of a  $4^\circ$  visual field was used in Clarke's experiments).

Clarke's findings of small motion-onset VERs with main positive peak and larger negative motion-offset VERs are in agreement with Spekrijse *et al.* (1985), Dagnelie *et al.* (1986), De Vries *et al.* (1989) but they are strongly discrepant with the results of Yokoyama *et al.* (1979), Gallichio and Andreassi (1982) and Göpfert *et al.* (1983). In all these reports the three-peak curve of motion-onset VERs is described, with a dominant negative peak with a latency in the range of 150 - 190 ms. Our own data (Kubová *et al.* 1990, Kuba

and Kubová 1992, Kubová and Kuba 1992) show the same findings.

The results presented above demonstrate that the motion dependent component of motion-reversal VERs closely resembles the motion-onset VERs (negative peak with a latency of about 170 ms). In suitable stimulus conditions (low contrast random dot pattern, velocity 10 - 20 deg/s) the motion-reversal VERs can consist solely of this motion-onset related response.

The observed lateralization of motion-related VERs supports the theories of extrastriate origin of these potentials (e.g. Newsome *et al.* 1986, Newsome and Paré 1988).

Even the first positive peak, which is hypothesized to be predominantly pattern dependent,

was lateralized in some subjects. Therefore our classification of two different types of motion-reversal VERs does not seem to be completely satisfactory. More likely, in some cases no strictly separate responses, either pattern or motion related, are in existence.

The positive effect of macular masking (decrease of the pattern related positive peak and increase of the motion related negative peak) is good evidence for the prevailing extramacular source of motion-related VERs, and it is a promising feature for some diagnostic applications when more peripheral parts of the visual field must be tested (Kubová and Kuba 1992).

## References

- CLARKE P.G.H.: Visual evoked potentials to sudden reversal of the motion of a pattern. *Brain Res.* 36: 453-458, 1972.
- CLARKE P.G.H.: Visual evoked potentials to changes in the motion of patterned field. *Exp. Brain Res.* 18: 145-155, 1973a.
- CLARKE P.G.H.: Comparison of visual evoked potentials to stationary and to moving patterns. *Exp. Brain Res.* 18: 156-164, 1973b.
- CLARKE P.G.H.: Are visual evoked potentials to motion-reversal produced by direction-sensitive brain mechanisms? *Vision Res.* 14: 1281-1284, 1974.
- DAGNELIE G., DE VRIES M.J., MAIER J., SPEKREIJSE H.: Pattern-reversal stimuli: motion or contrast? *Doc. Ophthalmol.* 61: 343-349, 1986.
- DE VRIES M., VAN DIJK B., SPEKREIJSE H.: Motion onset-offset in children. *Electroenceph. clin. Neurophysiol.* 74: 81-87, 1989.
- GALLICCHIO J.A., ANDREASSI J.L.: Visual evoked potentials under varied velocities of continuous and discrete apparent motion. *Intern. J. Neurosci.* 17: 169-177, 1982.
- GÖPFERT E., MÜLLER R., MARKWARDT F., SCHLYKOWA L.: Visuell evozierte Potentiale bei Musterbewegung. *Z. EEG-EMG* 14: 47-51, 1983.
- KUBA M., KUBOVÁ Z.: Visual evoked potentials specific for motion-onset. *Doc. Ophthalmol.* 80: 83-89, 1992.
- KUBOVÁ Z., KUBA M.: Clinical application of motion-onset VEPs. Accepted by *Doc. Ophthalmol.*, 1992 - in press. 81: 209-218
- KUBOVÁ Z., KUBA M., VÍT F., HUBÁČEK J.: Properties of visual evoked potentials to onset of movement on a television screen. *Doc. Ophthalmol.* 75: 67-72, 1990.
- MACKAY D.M., RIETVELD, W.J.: Electroencephalogram potentials evoked by accelerated visual motion. *Nature, Lond.* 217: 677-678, 1968.
- NEWSOME W.T., PARÉ E.B.: A selective impairment of motion perception following lesions of the middle temporal visual area (MT). *J. Neurosci.* 8: 2201-2211, 1988.
- NEWSOME T.W., MIKAMI A., WURTZ R.H.: Motion selectivity in macaque visual cortex. III. Psychophysics and physiology of apparent motion. *J. Neurophysiol.* 55: 1340-1351, 1986.
- RIETVELD W.J., MACKAY D.M.: Evoked responses to acceleration and to tachistoscopic presentation of patterned visual stimuli. *Electroenceph. clin. Neurophysiol.* 26: 537P, 1969.
- SPEKREIJSE H., DAGNELIE G., MAIER J., REGAN D.: Flicker and movement constituents of the pattern reversal response. *Vision Res.* 25: 1297-1304, 1985.
- YOKOYAMA M., MATSUNAGA I., YONEKURA Y., SHINZATO K.: The visual evoked response to moving pattern. *Proc. 16th ISCEV Symposium, Morioka*, 207-214, 1979.

## Reprint Requests

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