REVISTA ESPAÑOLA DE FISIOLOGIA, 50 (3), 183-190, 1994

Visual Evoked Potentials in Response to Flashes in the Cat Cortex*

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(Received on April 6, 1994)

J. C. PÉREZ-COBO, M. LÓPEZ DE ARMENTIA, S. SÁNCHEZ-SUERO and M. PÉREZ-ARROYO. *Visual Evoked Potentials in Response to Flashes in the Cat Cortex*. Rev. esp. Fisiol. (J. Physiol. Biochem.), 50 (3), 183-190. 1994.

A model is presented of visually evoked potentials (VEPs) in the cerebral cortex of cats after binocular stimulation by means of flashes. The VEPs consist of four components: P_1, N_1, P_2 and N_2 which appear during the first 100 ms after the stimulation is produced. This model has been found in all the animals used in the experiments and is repeated with small variations at almost all the recording points. After studying the data obtained, a hypothesis is put forward for the possible origin of the four components in the primary visual area.

Key words: Evoked potentials, VEP, Cat, VEP to Flash, Typology of VEP, Topography of VEP.

Cats are good experimental models to study the physiology of sight because there are sufficient parallels with respect to human vision to establish good extrapolations (6). Their eyes are located at the front, they have stereoscopic vision and their brain is gyrencephalic (8).

The bibliography on evoked visual potentials in cats is extensive but only a small part of this makes any reference to what might be considered as normal visually evoked potential obtained from the cerebral cortex. Due to the wide variety of stimulation systems, the placing of electrodes, the methods used to establish the derivation (reference) and the physiological status of the animal, the descriptions offered by the literature on the subject are ambiguous and make it difficult to estab-

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* Study financed by the University of the Basque Country (Research project 89 cod. 081.123/0080/89).

** Basque Government scholarship. F.P.I.

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lish comparisons. Nevertheless, some attempts have been made to define on a universal basis what might be understood as normal visually evoked potential in the brain cortex of the cat. CREUTZFELDT and KHUNT (3) presented a review of VEPs in several different animals in which there appeared a description of VEPs in the cortex of cats and an analysis was made of the relationship which exists between these and the recording area. CREEL *et al.* published (1, 2) similar studies to the above, although with more modest objectives. Other authors (5, 9, 10) defined a $P_1N_1P_2$ model in their works. SIGÜENZA *et al.* (11-15) corroborated the $P_1N_1P_2$ model and, in addition, defined a small negative wave (immediately before P_1) which they called "a". More recently, some studies have appeared which, aimed at veterinary diagnosis and prognosis, make a modest attempt to define the normality of cortical VEPs in in the cat (4, 18).

In none of these articles is a complete, systematic record made of the entire cerebral cortex as work has concentrated on the zones nearest areas 17, 18 and 19 of Brodman. In this paper, an attempt is made to establish a normality model for VEPs produced by flashes, recorded throughout the cerebral cortex of the cat. This model may be used as a reference for later studies dealing with the potential effect which toxic substances, drugs or any other chemical substances, as well as the surgical, physical or environmental manipulations might have on the morphology of the VEP or on its topographical location. A study of this type may also be of use for work on the origin of VEP waves.

Materials and Methods

Seven young adult cats (*Felis catus*, L.) of the common variety were used, with an average weight of 3.4 Kg and of both sexes. Recordings were made on curarizated animals, with local anaesthetic on all pressure points and on the edges of wounds and with respiration by a tracheal cannula ensured by means of an assisted respiration pump (S.R.I.). This apparatus was adjusted to an impulsion volume of 50-70 ml and breathing rate of 22-24 cycles/min (10). The experiments were made in acute conditions, the animal being sacrificed by means of an overdose of pentothal at the end of the experiment.

A total of 21 electrodes were arranged as indicated in fig. 1 in order to occupy the largest active cortex area possible, and were fastened to the cranium, making contact with the dura mater. A common derivation and extracephalic method was chosen, by means of a subcutaneous electrode placed in the front right leg of the animal. It was stimulated binocularly, under conditions of adaptation to darkness, by means of flashes (Photo Stimulator LT 100, Knott Electronik) and with the eyes open. The lamp was placed in front of the animal at a distance of 50 cm. The duration of the flash was 10 ms and the stimulation frequency was 1 Hz. The stimulation intensity was 0.69 J/flash. Recording began when the animals, having recovered from the surgical anaesthesia (halothane in a mixture of N_2O/O_2), had undergone the period of adaptation to darkness and it was considered that they were in a stable physiological condition: ECG with a frequency of around 160 heartbeats per minute and a normal EEG.

The signal was amplified in an Alvar electroencephalograph, Minihuit Reega TR. The experiment was recorded on magnetic tape (Hewlett Packard, 3986A

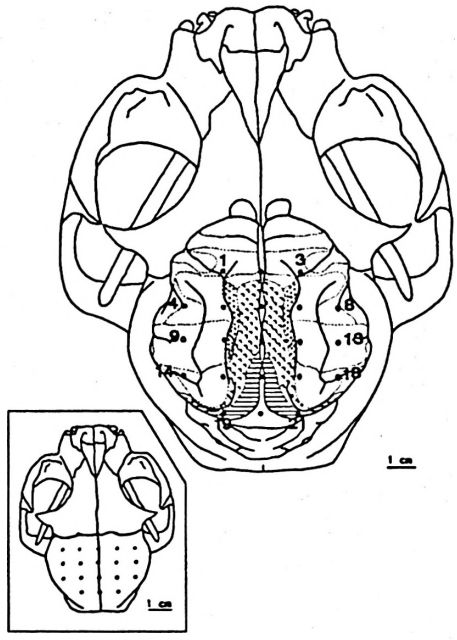

Fig. 1. *Location of recording points in cerebral cortex of the cat.*
The square corresponds to the location of the electrodes on the surface of the cranium.

recorder). The trigger signal which came from a pulse generator (Digitimer, D100), was recorded on tape and provoked the flash and activated the averager (Hewlett Packard, Spectrum Analyzer, 3582A). The averager began to take samples 10 ms before the flash was triggered, this preliminary average being used as the base line. The average was of 128 or 256 samples. Data was sent to a Hewlett Packard microcomputer HP85F. Non-filtered recordings were made on magnetic tape, although a system of filters (Digitimer, Neurolog System NL 125) adjusted to leave a bandpass of between 10 and 1000 Hz was used to analyze these.

Results

The visually evoked potentials obtained on the cerebral cortex of cats show both interindividual and intraindividual variability which affects the amplitude and latency of the components. All the recordings, however, showed a similar morphology in the first 100 ms. Based on this data, a VEP model was defined in the cerebral cortex of cats which was repeated with small variations throughout, depending on the placing of the recording point.

The figure 2 shows the average of the VEPs obtained at the two electrodes

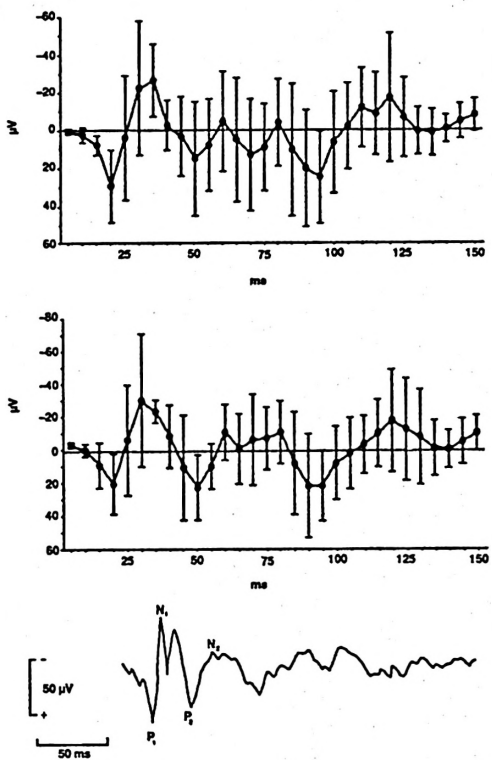

Fig. 2. *Average VEPs and model VEP in the cerebral cortex of the cat by means of binocular stimulation with flashes.*
The graphs at the top show the averages and standard deviations of 14 VEPs (two for each cat used) obtained in electrodes 11 and 16. The four tendencies which are observed in both cases during the first 100 ms correspond to the larger components indicated in the VEP model obtained at point 15 (lower graph).

located on the primary visual area, with their standard deviations with respect to amplitude. In both cases, they were processed from 14 VEPs, two for each cat used. Four tendencies appeared in medium potentials: two positive and two negative, clearly defined during the first 100 ms and which correspond to the larger components, P_1, N_1, P_2 and N_2, of the experimental potential shown on the lower part. The proposed model is based on this idea.

The first component which characterizes this model, P_1, is of positive polarity. Its latency at different recording points ranges between 21 and 29 ms (table I). The amplitude of this wave is medium if it is compared with those of the other three components.

Immediately afterwards, there is a negative, high amplitude wave, N_1, which appears between 32 and 43 ms (table I). In some cats, N_1 consists of a single peak while in others it is formed by two con-

Table I: *Average latencies and standard deviations (ms) of the four components defined in the VEP at different recording points.*
The data obtained at recording points 1, 2 and 3 is not significant as it was determined only from clearly-defined VEPs.

	POINT 1	POINT 2	POINT 3		
	P_1: 22.25 ± 4.49	P_1: 18.25 ± 0.95	P_1: 22.40 ± 4.55		
	N_1: 38.75 ± 4.13	N_1: 32.75 ± 4.71	N_1: 39.50 ± 6.88		
	P_2: 54.12 ± 2.53	P_2: 49.75 ± 5.31	P_2: 53.90 ± 3.92		
	N_2: 69.77 ± 7.17	N_2: 71.28 ± 10.40	N_2: 71.33 ± 7.53		
POINT 4	POINT 5	POINT 6	POINT 7	POINT 8	
P_1: 25.81 ± 5.01	P_1: -22.91 ± 4.64	P_1: 25.41 ± 3.87	P_1: 23.75 ± 4.49	P_1: 29.95 ± 7.22	
N_1: 39.18 ± 8.36	N_1: 38.66 ± 5.80	N_1: 37.33 ± 8.13	N_1: 39.33 ± 5.89	N_1: 43.75 ± 10.21	
P_2: 55.27 ± 7.22	P_2: 55.58 ± 4.79	P_2: 55.16 ± 6.57	P_2: 54.75 ± 5.22	P_2: 59.50 ± 11.49	
N_2: 70.45 ± 11.00	N_2: 74.83 ± 14.79	N_2: 70.83 ± 12.47	N_2: 71.33 ± 6.05	N_2: 73.41 ± 16.61	
POINT 9	POINT 10	POINT 11	POINT 12	POINT 13	
P_1: 27.25 ± 5.61	P_1: 24.25 ± 4.59	P_1: 22.91 ± 3.72	P_1: 23.75 ± 4.49	P_1: 29.25 ± 6.61	
N_1: 36.75 ± 7.73	N_1: 39.25 ± 6.79	N_1: 34.25 ± 7.05	N_1: 34.83 ± 6.60	N_1: 40.50 ± 10.07	
P_2: 58.08 ± 7.98	P_2: 55.16 ± 5.71	P_2: 52.50 ± 6.62	P_2: 54.33 ± 5.54	P_2: 56.75 ± 10.72	
N_2: 70.08 ± 8.60	N_2: 68.33 ± 8.17	N_2: 67.16 ± 11.79	N_2: 70.33 ± 8.66	N_2: 72.83 ± 15.00	
POINT 14	POINT 15	POINT 16	POINT 17	POINT 18	
P_1: 27.25 ± 5.29	P_1: 23.00 ± 3.83	P_1: 24.41 ± 3.60	P_1: 24.16 ± 3.56	P_1: 27.58 ± 5.23	
N_1: 38.08 ± 8.53	N_1: 33.16 ± 6.45	N_1: 32.00 ± 5.44	N_1: 33.41 ± 6.48	N_1: 35.91 ± 7.48	
P_2: 54.16 ± 7.13	P_2: 52.83 ± 5.04	P_2: 50.00 ± 7.33	P_2: 53.66 ± 4.69	P_2: 54.75 ± 6.49	
N_2: 73.41 ± 7.56	N_2: 67.00 ± 7.68	N_2: 65.33 ± 9.89	N_2: 74.50 ± 13.26	N_2: 71.66 ± 5.34	
	POINT 19	POINT 20	POINT 21		
	P_1: 23.33 ± 3.05	P_1: 21.16 ± 3.88	P_1: 24.66 ± 4.73		
	N_1: 33.16 ± 6.45	N_1: 32.33 ± 5.39	N_1: 32.66 ± 5.82		
	P_2: 52.41 ± 4.58	P_2: 50.16 ± 6.92	P_2: 51.50 ± 3.08		
	N_2: 72.66 ± 15.81	N_2: 69.08 ± 25.80	N_2: 71.83 ± 8.46		

secutive high amplitude, short duration peaks. In the case of VEPs showing a N_1 wave with two peaks, the first of these was taken as the latency value.

Subsequently, the second positive component, P_2, could be seen, with a latency which varied between 50 and 60 ms (table I). The amplitude of this wave was often similar or greater than P_1 and was always formed by a single peak.

The last component, which was common to all the VEPs obtained, was N_2. With negative polarity and variable latencies of between 65 and 75 ms, it showed lower uniformity with regard to duration, amplitude and latency.

The latencies of the four components defined were lower and more uniform, interindividually and intraindividually, at recording points situated in area 17 of Brodman and increased, their uniformity diminishing, the further the recording points were away from area 17 (table I). Moreover, a similar phenomenon occurred with the amplitude of the VEPs: this was lower the further the recording point was away from the primary visual area (fig. 3).

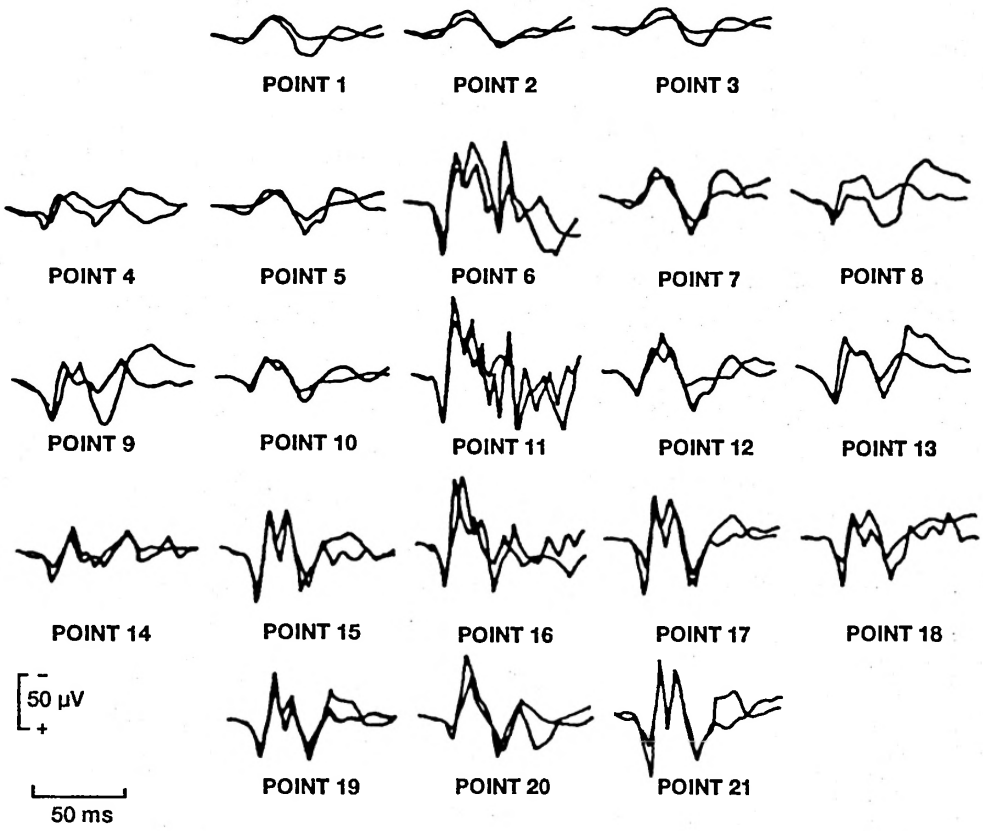

Fig. 3. *General topography of cortical VEPs in cat obtained with binocular flashes.*

Therefore, a topographical description can be made of the incidents which occurred in the cerebral cortex of the cat during the 100 ms following the binocular flash. It should be pointed out that significant VEPs were only recorded behind the coronal suture and that the recording on this suture did not reveal clearly-defined components.

In accordance with the data presented in table I and fig. 3, it seems very probable that the focal point of the four waves which make up the VEP is situated in the primary visual area. It is here where it shows greater amplitude and lower latency.

An analysis of the results shows that the development of waves in the cerebral cortex, with respect to latencies and amplitudes, was similar. A symmetrical propagation was produced for the four waves from the primary visual area to the remainder of the cortex. The propagation of each component over the entire cortical surface lasted approximately 7 ms.

The propagation process of the four components on the cerebral cortex after a binocular flash is as follows. Approximately 21 ms after the stimulus is produced, there is a positive wave (P_1) in the primary visual area which, 7 ms later, occupies the whole cortex. Ten ms after the appearance of P_1, a negative wave (N_1), which also has its focal point in the part more to the rear of area 17 of Brodman, begins to invade the cortex, taking 7 ms to propagate itself over the entire cortical surface. Following this, P_2 is shown as a positive wave, the focal point of which is generated 50 ms after the stimulus is produced. After another 7 ms has elapsed from its appearance, P_2 extends throughout both hemispheres.

Finally, 66 ms after the flash, wave N_2 begins to generate in area 17. The propagation of this cerebral cortex is somewhat slower than the previous ones.

Discussion

A "w"-shaped model is presented in the bibliography of the VEP of the cat, characterised by $P_1N_1P_2$ waves. The model which is proposed in this paper coincides with the "w" model cited in the literature, although this includes a negative component later than P_2 which was registered within the first 100 ms after the stimulus was produced.

CREEL *et al.* (1, 2) define a model made up of four components, $P_1N_1P_2N_2$, with latencies lower than those found in this experiment. The differences in the stimulation system and the placing of electrodes, both for recording and reference, justify these variations.

The small negative "a" wave which SIGÜENZA *et al.* (11-15) define and which precedes P_1, appears in the recordings of the electrodes relating to the primary and secondary visual areas, i.e., at electrodes 11, 16, 20, 19 and 21. Nevertheless, it is not considered to be sufficiently stable in order to be defined as a "component" of the normal VEP of the cerebral cortex of cats.

Other results which appear in literature also coincide with those put forward in this paper, such as in a work published in 1991 by SJÖSTRÖM *et al.* (16) in which the latency which is defined for component P_1 is similar to the one proposed in this model. The same year, TAGUCHI *et al.* (17) published a paper which only recognised components N_1 and P_2. The latencies which they attribute to these components coincide with the highest values which are given for these same waves in table I.

It is important to establish the relationship which exists between the amplitudes

and latencies of components which make up the VEPs and the areas where these have been recorded.

From table I and fig. 3 it can be seen that both the amplitude and the latencies and their standard deviations varied in accordance with the area recorded and that, in addition, these variations follow a very apparent symmetrical distribution which has its axis in the sagittal suture. On the other hand, it may be assumed that the focal point for the appearance of the four components is the rear of the primary visual area (electrodes 20 and 16) as here, lower latencies with higher uniformity can be observed, i. e., smaller standard deviations.

After studying the data obtained in this experiment, it seems very probable that the components defined here represent, basically, a cortical processing of the signal, although interferences from signals originating in the subcortex or retina cannot be ruled out. The data of the CSD of MITZDORF (7) and others, which determine the arrival of the nerve signal at layer IV of the primary visual cortex prior to the 15 ms after the stimulus, justify this idea. In accordance with this reasoning, P_1 would be generated with the arrival of the thalamic information at the cortex and N_1, P_2 and N_2 would correspond to the initial moments of the cortical processing. This hypothesis is supported by the fact that these waves appear with greater definition in the areas more directly involved in the primary visual process (areas 17, 18 and 19 of Brodman).

On the other hand, from this data it is impossible to determine with precision whether the origin of the more peripheral waves corresponds to the cortical processing of these secondary visual areas and/or of association, or to a simple volume conduction.

Acknowledgements

The authors wish to thank J.M. Rodríguez Robledo for his collaboration in the extraction and subsequent analysis of the data.

J. C. PÉREZ-COBO, M. LÓPEZ DE ARMENTIA, S. SÁNCHEZ-SUERO y M. PÉREZ-ARROYO. *Potenciales evocados visuales de respuesta a destellos en la corteza cerebral del gato.* Rev. esp. Fisiol. (J. Physiol. Biochem.), 50 (3), 183-190, 1994.

Se presenta un modelo de potenciales evocados visuales (PEV) obtenidos en la corteza cerebral del gato tras la estimulación binocular mediante destellos. Los PEV estn formados por cuatro componentes: P_1, N_1, P_2 y N_2 que aparecen durante los primeros 100 ms después de la estimulación luminosa. Este modelo se ha encontrado en todos los animales usados en los experimentos y se repite con ligeras variaciones en casi todos los puntos de registro. Del estudio de estos datos, se deduce la hipótesis de que el posible origen de los cuatro componentes está en el área visual primaria.

Palabras clave: PEV, Gato, PEV por destellos, Tipología de los PEV, Topografía de los PEV.

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