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ABSTRACT

This paper examines the development of visually evoked EEG patterns in retarded and normal subjects. The paper focuses on the averaged visually evoked potentials (AVEP) in the central and occipital regions of the brain in eyes closed and eyes open conditions. Wave pattern, amplitude, and latency are examined. The first section of the paper reviews previous research on developmental changes in AVEP patterns. The second section of the paper presents a developmental and comparative study of the AVEPs of retarded and normal children in a closed eyes, diffuse white light flash condition. Results suggest that EEG patterns from the central region of the brain develop more slowly than those of the occipital region. Occipital patterns tend to be fairly similar for both retarded and normal subjects. Central recordings, however, indicate striking differences in the long latency negative and positive waves of the retarded subjects. The third section of the paper examines the AVEP patterns of retarded and normal subjects during two eyes open conditions: light flash (Rest) and a choice reaction task (CRT). Results from this study suggest similar but developmentally retarded AVEP patterns for the retarded in comparison to the normal subjects in the occipital region for both Rest and CRT. Retarded-normal differences are found for negative wave patterns in the central brain region by comparing CRT to the Rest condition. Results are discussed in terms of arousal and attention deviations which may be indicated in the AVEP patterns of the retarded subjects. (BD)

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The Nature and Process of Development in Averaged Visually Evoked Potentials: Discussion on Pattern Structure

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THE NATURE AND PROCESS OF DEVELOPMENT IN AVERAGED VISUALLY EVOKED POTENTIALS : DISCUSSION ON PATTERN STRUCTURE

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The topic of this paper is the discussion of normal and retarded processes concerning the development in averaged visually evoked potential, AVEP. With reference to development of AVEP, several experiments have been reported as shown in Figure 1. Those experiments mainly deal with the developmental process of amplitude and/or latency of AVEP, assuming that AVEP pattern is constant in itself. As for discussion on the detailed nature of AVEP pattern itself related to development, there are still few, with the exception of data concerning the early ontogenesis.

The following report is the result of our trying to get general prospect on the development and retardation of AVEP pattern structure, based on clarifying the trend of research and results of our recent experiments.

1. ONTOGENESIS OF AVEP AND ITS DATA TREND

Figure 1 shows the main trend of research about the development of AVEP in terms of age scope of subjects and indices discussed. Age axis starts with 40 weeks after gestation as the full-term birth, and before that point the results of premature subjects are used and shown by gestational age in weeks. As observed in the figure, the dominating ages in the AVEP data reported are before 1 and after 6 to 7. The information of AVEP between 1 and 6 is lacking.

Figures 2 and 3 depict the AVEP developmental processes which we summarized from the materials of Figure 1. They give those processes at closed eyes and at open eyes, respectively. As for the data, adjustment was made so that we can compare the incoherent points of experimental method of the original studies. Judging from the fact that generally, the spontaneous wave changes to desynchronized pattern while the eyes are open, we have to consider that the central functional system at open eyes is different from that at closed eyes. Besides such a variation of the arousal system according to the amount of visual input, there is also a reason on the function that at open eyes state the positive set (namely, attention) against stimulus is apt to take place. Therefore, we will not treat AVEPs at closed eyes and at open eyes together.

The outline of AVEP at closed eyes is as follows: The latency of wave at the early stage of ontogenesis, which is 24 - 25 weeks after gestation, is slow and the wave form constitutes a very long mono-phasic negative potential. Around 30 weeks, along with the shortening of latency, the two-peaked wave becomes more distinctive with positive deflection in slow negative wave. Between this stage and around 36 weeks after gestation, the positive deflection appears around 200 msec and gradually becomes clearer before the first negative wave. However, for the developmental process of AVEP after this, there are three series according to the difference of process of shortening of latency.

The first series is the process as shown in the left file of Figure 2. The main features are the following: Even in 39 - 40 weeks after gestation, this early positive wave is still around 180 - 200 msec, and deeper and sharper. During the following three months, there appears a sharp shortening of latency and the early positive wave and other components become about 100 msec short. After this until reaching adult age, the shortening progresses gradually. The second positive wave (Ellingson: P_3) which was at 300 msec latency at the newborn stage becomes deeper and takes place of the early positive wave to become the prominent component and the latency settles between 100 msec and 200 msec.

The second series is given at the center file of Figure 2. The characteristic of this series is that a striking shortening of latency takes place between 30 and 36 to 39 weeks after gestation. The same wave form as the first series will appear at the end.

The difference between these two series seems to come from the difference in conditions of samples at the time of 39 - 40 weeks after gestation. Actually, all the results of Series 1 at 39 - 40 weeks after gestation are recorded fairly soon after the birth of full-term newborn infants, but the samples of Series 2 are the premature newborn infants and the data which were observed at 9 or more weeks after the premature birth are used as AVEPs of 39 weeks. Hence, we can suspect that the appearance of AVEP of different qualities at the same stage is mainly caused by the fact that different processes, namely, fetal growth and growth after birth, were put together on the common axis of gestational age for convenience. Judging from the fact that in Series 2 which term of growth after birth is long the shortening of AVEP latency occurs at an earlier stage, the rate of growth after birth seems to be obviously faster than fetal growth.

Even among the full-term newborns, some show AVEP which is different from Series 1 at the time of birth. It is Series 3 which is shown on the right file of Figure 2. This series is almost the same as Series 2 in regard to AVEP pattern at 40 weeks after gestation and the process until adult. At the time of birth, positive wave around 200 msec at the peak latency is dominant, and among adults, it moves toward the value of a little over 100 msec. However, this series came out of results of full-term newborns, so it should be considered different from Series 2.

In making a summary of the above developmental process of AVEP at closed eyes, in the early stage (around 39 - 40 weeks after gestation) there are three series. Generally, we can say that striking shortening of latency emerges by the end of three months after birth and reaches at the almost adult pattern at the age of one or two. Namely, as far as visual system is concerned, response characteristic at occipital area which is a specific receiving area against stimulus does probably develop almost fully at an early stage after birth.

On the contrary, the results of development of AVEP pattern in central area which is non-specific to visual stimulus are very few as seen in Figure 1. But it is obvious that generally, the development of central AVEP occurs far later than occipital AVEP. Later, this point will be discussed again based on our experiments.

Now we would like to examine the open eyes AVEP in Figure 3. Among the past reports, none of them classified the difference in quality between AVEP with eyes closed and that with eyes open. However, when we compare Figures 2 and 3, we have to say that open eyes AVEP obviously contains different wave components from closed eyes AVEP. Comparing the open eyes AVEP of occipital area by white flash stimulus and that of closed eyes, we noticed that in adult pattern a conspicuous negative wave emerges at open eyes situation at the position of deep positive process around 100-200 msec latency of closed eyes AVEP. Since this negative process was never pointed out before, temporarily, we call this N150. The details about this characteristic developmental process of negative wave are not clear since reports of open eyes AVEP concerning low age group are very few.

However, looking into the results of Fogarty and Reuben (1969) who reported the open eyes AVEP at an early stage of ontogenesis, there is a possibility that N150 appears from an early stage of human ontogenesis. On the other hand, considering from the Komatsushiro's result (1971) which came out of observation of infants up to the age of 3, N150 is still in the stage of development at least up to the age of 3 and does not reach the stable level to appear. That is, compared to the closed eyes AVEP reaching matured pattern in a year or so after birth, it needs longer time to develop.

Apart from AVEP by simple white flash stimulus, shown at the lower part of Figure 3 are the matured patterns of cases in which the subjects are expected to be in a more positive set to stimulus. The stimulus has structure and meaning such as stimulus having pattern structure getting some sort of reaction task. Again, N150 appears conspicuously but the difference from the AVEP pattern by simple white flash stimulus is hardly noticeable. Therefore, although N150 is the expression of positive central activities which are activated for the first time at opening eyes, it does not reflect the changes of central activity process which is brought by the difference of structure and meaning of stimulus.

The results of open eyes AVEP in central area are extremely poor. The materials are not enough to be discussed concerning the developmental process even by including some reports about adults, reports about young by Rhodes et al. (1969) and Bigum et al. (1970). As shown in the right file of Figure 3, although there is a noticeable negative wave similar to N150 of occipital area, it differs from the occipital wave in that the preceding wave component, especially the positive wave right before the negative is either small or nil. That this negative wave is the first obvious component can be considered the characteristics of AVEP pattern at central area.

2. RESULTS OF EXPERIMENTS ON CLOSED EYES AVEP

The data of AVEP development shown in Figures 2 and 3 are limited mainly to the occipital AVEP and concentrated between the time of early ontogenesis and infant period of age of 1-2. However, activities and abnormalities of functional system which include some sort of intellectual process seem to be easy to be caught in central area where non-specific evoked potential appears against various sensory stimulus than occipital area which is specific sensory area. So we examined the developmental process of AVEP in both occipital and central areas about the age group of 3 years and older, including the mentally retarded, of which reports have been few. The outline is as follows:

The subjects of the experiment were 66 normal children (age 2:11-12:4, IQ 105-155, average IQ 126), 4 normal adults (age 21:0-24:0) and 16 mentally retarded children (age 10:2-17:9, IQ 34-74, average IQ 54). Those who had visual handicap and neurological abnormality, and also those who showed abnormal brain waves, were excluded from the normal group.

Scalp electrodes were placed at C_3, O_1 and O_z chosen by the 10-20 international method, and at the left ear lobe (A_1) as reference. White diffuse flashes were delivered to the subjects with 2 second intervals, after darkness adaptation during 10 minutes. The flash illuminance at the eyelids was 12000 Lux, and the duration was 20 μsec. The lamp was settled in a container filled with fiber glass, so that no appreciable click-evoked potentials were expected.

The segments of data were amplified and recorded on the magnetic tape by using of ME-95C/R-400 system. Those segments modified by artifacts and/or drowsy conditions were excluded. The averaging of single visually evoked potentials (SVEPs) was carried out by a digital averager ATAC-501-10, with digitizing rate of 1.6 msec. For most of all subjects 128 EEG segments were averaged. The averaged digitized results were then converted again into analogue signals and plotted by a X-Y plotter XYR-2A. Furthermore, the digitized AVEPs obtained were also punched out on 8 bit paper tape for further computer processings.

Shown in Figure 4 are the process according to age between 3 and 12 concerning the closed eyes AVEP pattern which was recorded at occipital pole (O_z) of normal children. The main component of occipital AVEP appears by 400 msec after stimulation. Its basic pattern, as shown in the model below, consists of N_1 wave of a little less than 100 msec latency, deep P_1 wave between 100 msec and 200 msec, N_2 between 200 and 300 msec, and P_2 which follows. Particularly, negative-positive diphasic wave complex of N_1-P_1 is the distinctive feature. This pattern was already in our report (Mizutani et al., 1973) as Type A AVEP which is peculiar to occipital area and was checked that it is the wave of high S/N. P_1 is the biggest component of closed eyes AVEP and its peak latency is supposed to be around 150 msec. Therefore, we call this P150.

As shown in Figure 4, this basic pattern is clear at the age of 4. Although there are some modifying components depending on subjects, up to the age of 12, it is observed in all the samples. This leads up to reassurance of the results came out of Figure 2 that this basic pattern draws almost to matured pattern by one year and after that it basically does not change. But of course, it does not mean that the development of patterns stops completely at this age group. For instance, as observed in Figure 4, the amplitude of N_2 tends to become low and flat gradually starting around the age of 5-6. Also, after the age of 5, there often are cases of fairly narrow negative wave at the position of P150 trough to appear, sometimes on downward or upward slope. We once distinguished this AVEP pattern as Type B (Mizutani et al., 1973) from the basic form (Type A). This time, judging from the nature of the pattern, we took this as the variant pattern of P150 wave component of the basic form AVEP and decided to call this P150-variant AVEP. This P150-variant AVEP can be considered similar to what is called Type C by Weinmann and others (1965). They reported that it appears after the age of 3.

Figure 5 shows the plotted peak latency of four wave components, from N_1 to

P_2 according to age. The right side of the curve line shows the results of the retarded, which will be discussed later. P150-variant form is distinguished from basic form, but as the figure tells, there is not any trend to indicate the distributional difference of latency. This supports the initial hypothesis to think that P150-variant form emerged by the partial modification of the basic form. Therefore, to discuss the correlation of latency and age of the two collectively, it is noticed that components of N_1 to P_2 actually show no systematic change of latency along the age axis. This was already pointed out by the authors (1973) as the characteristics of Type A AVEP. This also suggests that in this age range, the development of latency of occipital AVEP is almost completed and reached the stationary level.

Samples of 12 years and later in Figure 4 are few and it should be left to further study. But generally among adults, it is checked that early negative component N_1 is conspicuous, so that the amplitude of N_1 could be increased gradually after the age of 12 (See the model in Figure 4). Therefore, the development of visual functional system basically completes at fairly early stage of ontogenesis, but there is still some developmental process left thereafter.

Figure 6 arranges the central AVEPs (recorded at C_3) of 3 years of age and up. The closed eyes AVEPs are given. The main components of AVEP of central area appear within 400 msec after stimulation, in the same way as occipital AVEP, and they are named N_1, P_1, N_2, P_2 as they appear. But these are not corresponding components of the same names in occipital area. As indicated in schematic AVEP patterns in Figure 6, the characteristic of the pattern made of these four components is obviously different from that of basic pattern in occipital area and the two negative waves, N_1 and N_2 appear successively. P_1 which is different from the deep P150, is just a small trough between N_1 and N_2. Actually, P_2 is deeper and wider. This pattern was in our paper (1973) as Type C pattern which is dominant at central area.

Looking into the developmental process of this basic pattern, it is not clear until around 3, that is different from the basic pattern in occipital area. From around the age of 4, N_1 and N_2 appear gradually as a little wide wave form (the left schematic pattern in Figure 6) around 100 msec and 200 msec respectively (an example : N6977-39). The latency gradually shortens (N6948-52) and at the same time N_2 becomes bigger and superposes N_1 (N6925-58, N6988-67), and often has remarkably high amplitude (N7406-101, N7401-123). On the contrary, N_1 actually retreats. For P_2, the latency markedly shortens and in the observation of adults apart from this research, it moves to around 200 msec latency and is peculiar to be quite deep. Consequently, the characteristic of matured AVEP in central area is high amplitude N_2 arou 150 msec latency and deep P_2 around 200 msec. Moreover, we especially should like to point out that the patterns are considerably similar although it is about 80 msec slower in latency than diphasic wave in occipital area.

In Figure 7, the peak latency of the main four components in central area is plotted in relation to age. Each component tends to decrease in latency along the age axis; especially, N_2 and P_2 of long latency remarkably signify such decreasing. The above s‘ ~d results of central AVEP are obviously different and its speed of development is far slower than occipital AVEP.

Contrary to the above normal AVEP development, in case of the mentally retarded, the phenomena o both areas are quite different. Figure 8 shows the closed eyes AVEP of occipital and central areas according to ages of the 16 retarded between the age of 10 and 17. In occipital area, patterns are almost the same as those of normal children, but generally, they are irregular and tend to have low amplitude. On the other hand, in central AVEP, there is a striking difference in N_2 from normal children. In contrast to normal AVEP where N_2 is superior to N_1, in the retarded, N_2 is extremely small (MR7416-110, MR7415-165) or stays the same level as N_1. Even if the case is that the clear N_2 comes to existence, there is a striking tendency that the latency is slow (MR7401-102). Considering that in normal AVEP it is usually over the age of 5 when N_2 becomes larger than N_1 (See Figure 6) and that all AVEPs of the retarded here are over the age of 10, we have to conclude that N_2 of the retarded is quite deviated.

As long as we see the developmental nature of AVEP at peak latency (Figures 5 and 7) in occipital area, there is no particular deviation among the retarded. Contrary to this, in case of central area, in components after P_1, especially in slow components of N_2 and P_2, it deviates from the regression of the normal to the upper direction, thus the irregularity of AVEP is suggested in the retarded. Accordingly, as for the closed eyes AVEP of the retarded, N_1 which is short from the stimulus point is within the normal range and there is degeneration or delay in components after P_1 of long latency. As stated below, to these abnormalities of long latency components, more distinguished process also is added in the open eyes AVEP.

3. CHANGE OF AVEP IN VIGILANT STATE

So far, we observed the closed eyes AVEP at rest when the stimulus does not require special intellectual task. As compared with this, Figures 9 and 10 are showing the change of AVEP caused by opening eyes. While eyes are open, as stated already on page 2, attention process is necessarily apt to take place, moreover in case that some behavior response is required to stimulus presentation, the central intellectual process will be added. Accordingly, it is naturally expected that such central activities could be reflected in the open eyes AVEP. From this viewpoint, we tried to discuss the nature of the open eyes AVEP when the positive attention to stimulus and the stimulus selection are required, by employing the task situation of choice reaction time (CRT) with flash stimuli.

Among the subjects whose closed eyes AVEPs were recorded, 6 samples of normal children (age 10:1-12:4), 3 normal adults (age 21:0-24:0) and 10 samples of the retarded(age 10:2-16:8) were chosen for experiments. The subjects sat on a sofa in a dim room, gazing a round semi-transparent cream color window which is 6 cm in diameter and about 80cm away from the subject, where the subject watches either red flash light (30 μsec, 480 Lux) or blue flash light (30 μsec, 270 Lux). These two flash lights are shown with eneven time intervals around 5 seconds, where red and blue are given at equal probability and at random order, and the subjects choose only red light to hit the key. The electrode location and recording/data-processing system are the same as experiment for the closed eyes AVEP. Summing of AVEP was performed separately according to reactions by different color stimuli. Because the artifacts by key-reaction were mixed in AVEP by red stimulus, discussion was limited to AVEP by blue without accompanying response activities.

Figure 9 shows the occipital open eyes AVEP by blue stimulus in CRT experiment (hereafter AVEP/CRT) in comparison with the closed eyes AVEP (AVEP/Rest) in the same area. The left two files and right two files are the results of the normal and the retarded, respectively. In normal AVEP/CRT, what is obviously distinct from AVEP/Rest is that the remarkable negative component appears around 150 msec at the position of deep P_1 of AVEP/Rest (within 100-200 msec after stimulation). This is exactly the N150 which was pointed out in the open eyes AVEP in Figure 3. However, it is observed that P_1 is smaller at the same time, so that there could be a change in basic pattern itself besides the appearance of N150.

When we observe the data about the retarded concerning such nature of AVEP/CRT, it is found that N150 is either almost lacking or quite unclear until 14-15 years and becomes clear at 16. The appearance of this N150 in the retarded is at least 6-7 years behind the normal.

The AVEP/CRT as compared with AVEP/Rest in central area is given in Figure 10. In normal samples, the negative component N_2 can be observed already at rest with eyes closed at the same position where N150 appeared in occipital area. Moreover, this N_2 tends to increase in AVEP/CRT. Therefore, we can say that the increasing of negative component while eyes are open is common in both occipital and central areas. In addition, following N_2, there comes a slow but conspicuous negative wave which is around 300 msec peak latency. We call this N300.

As against this, in case of the retarded, such change at CRT is not clear. Generally, it is an irregular change and N_2 tends to wide, pointed round shape rather than the change of amplitude. Besides, as for the wave components following N_2, the irregular negative wave tends to appear instead of distinguished N300.

Since in AVEP/CRT there are specific patterns which are not found in AVEP/Rest, we have to discuss the mechanism for organizing this pattern. First of all, it should be considered that in AVEP/CRT the intensity of stimulus input is fairly different from that at closed eyes state. Systematic studies on the relation of stimulus-intensity of light and AVEP are found in the results of open eyes AVEP by Armington (1964), Wicke et al. (1964), Vaughan and Hull (1965), Tepas et al. (1974). But there is no report which tells that the basic pattern changes according to the change of light-intensity. If that is the case, in organizing AVEP/CRT pattern, it has to be thought that the central process closely related to CRT situation probably is concerned.

In CRT experiment, not only that there is a positive attention to both red and blue stimuli, the set to reaction is also accompanied to the red stimulus. When we examined the AVEP/CRT by red, if there is some difference, it could be that in the AVEP by red the latency of N150 in occipital area or that of N_2 in central area is shorter by 10 to 20 msec. However, this also could be by the difference of stimulus-intensity (red : 480 Lux, blue : 270 Lux). Consequently, in AVEP basic pattern, the set to reaction might be not reflected, and it should be considered that the colors of stimulus also are not so effective to pattern organization.

Supposing that the AVEP/CRT patterns are same either in red with reaction or in blue without, it could be told that the attention which is common in both stimuli contributes to pattern organization. Accordingly, in the same stimulus condition as CRT experiment, we observed the open eyes AVEP without reaction task in a different experiment. In this experiment, it was proved that the AVEP is not particularly different from AVEP/CRT either in occipital or in central area.. It is the same with open eyes AVEP by white flash without task. As shown in Figure 3, the clear N150 is in evidence in occipital area just like in AVEP/CRT. From above, it can be assumed that the AVEP/CRT pattern is rather common phenomenon in open eyes state than reflection of attention to specific stimulus urged by task. But actually, even in the open eyes state without task, it is true that some sort of attention is apt to take place by being urged by object which comes in sight. In conclusion, the open eyes state itself should be considered to be a vigilant condition including attention process.

While the eyes are open, it is obvious that the brain stem reticular system is activated with afferent continuous stimuli coming in even during the intervals of flash stimulation, and consequently, the arousal level is raised at the cortex. The attention may be the cortical process which occurs with rise of arousal level to certain extent, and it seems to work to make the arousal level much higher through activating the arousal system efferently. Therefore, it must be expected that attention necessarily has to do with organizing the open eyes AVEP.

Considering the relation of arousal mechanism to organization mechanism of AVEP pattern based on the previous experimental results, since the central N_2 is the long latency component to appear in the non-specific receiving area, it can be thought of as the component developed by the activities of non-specific projection system, probably, diffuse thalamic projection system. Contrary to this, in case of the occipital N_1-P_1 complex, it appears mainly in the visual area and its latency is about 80 msec shorter than the central N_2-P_2 complex, so that it can be considered the response through specific projection system. However, even in the occipital AVEP, N150 which appears at open eyes state, could be through the non-specific projection system. This is based on the fact that an increasing of this kind of long latency negative process occurs simultaneously in the central area where there has to be an expression of activities of the non-specific system (increasing of N_2 and appearance of N300 at open eyes state). Also, the fact that wave form itself of N150 is similar to N_2 in central area could be another proof.

It is naturally expected for the retarded to have an abnormal process of AVEP pattern development; since there are various influential central mechanisms in appearance of AVEP pattern. In the open eyes AVEP of the retarded, there is decidedly a tendency of low amplitude and some disorders in pattern, but the basic pattern is kept and the latency goes along with normal development. On the contrary, as for the central area, which is non-specific area, the development of N_2 is far behind the normal and its latency tends to be in behind in components after P_1, especially in N_2 and P_2 of long latency (See Figures 5 and 7). Therefore, among the mentally retarded, it may be quite all right to assume that there is not conspicuous obstruction in visual system itself, rather, implication is that the functional development of non-specific projection system is not good. Comparing the change of AVEP patterns at higher arousal level with eyes open to that of the normal, many of them lack occipital N150 and central N300. Accordingly, it could be that the rise of arousal level is not enough. But if there is not any conspicuous obstruction in visual system, it is satisfactory to consider that there is a hindrance at least in one of the followings : arousal system, mechanism to activate it afferently, mechanism to activate it efferently from cortical process of attention, or cortical process itself of attention.

There has been no morphological proof to support the above discussed neurological presumption about the central mechanism of the retarded. However, recently, there were reports confirming the noticeable malformation of dendrite in the mentally retarded of pathological type in terms of motor area (Marin-Padilla, 1974) and hypocampus (Purpura, 1975). The future tasks should be to examine further the nature of AVEP development and retardation in relation to behavior; that the foregoing discussion on the open eyes AVEP was based on the data obtained through reaction time paradigmn is primarily for aiming to investigate the relation. Details about it will be reported at a later date.

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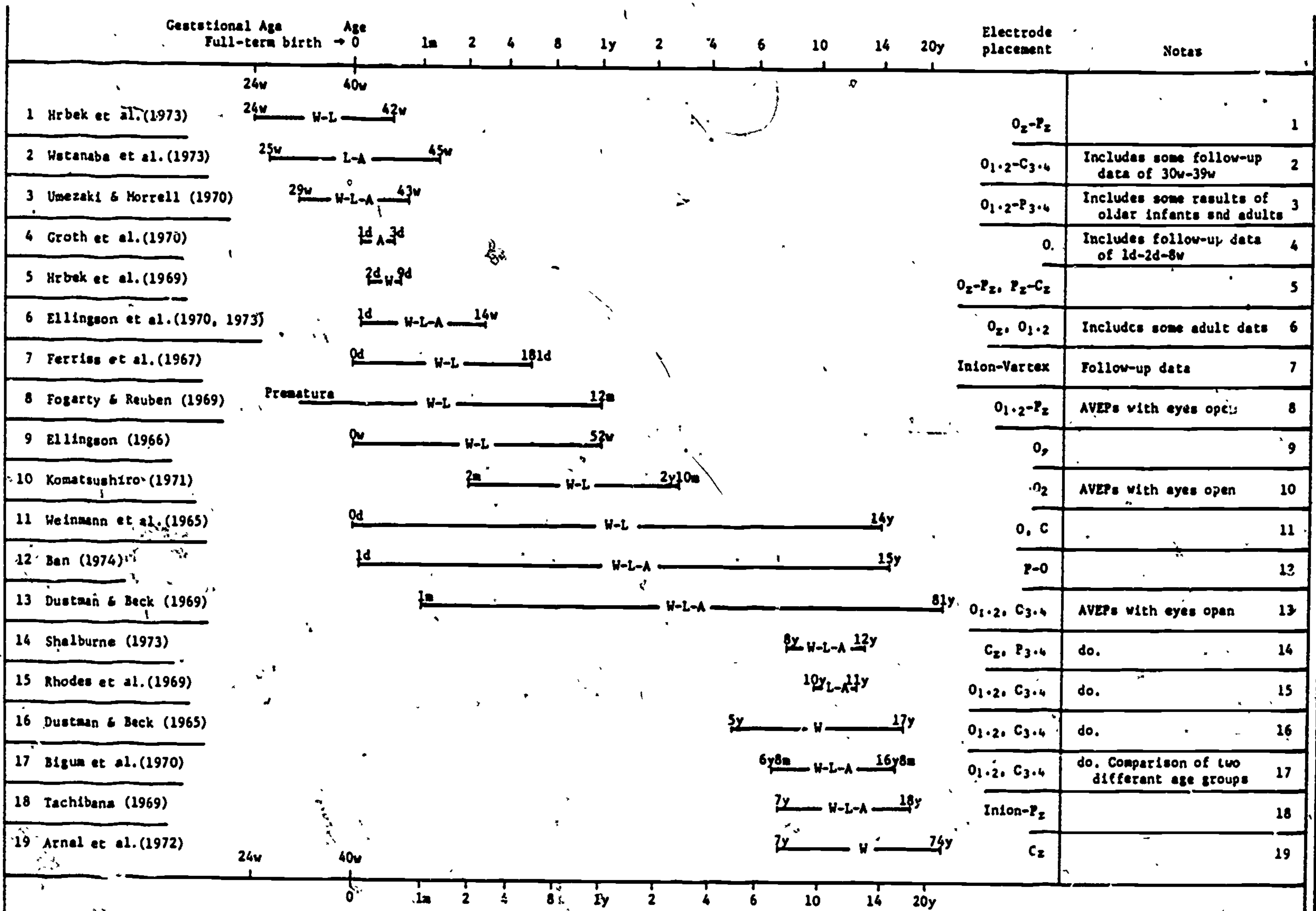

Figure 1. Trend of research on AVEP development. Age range of subjects and indices used in each study are shown. W, L and A denote waveform, latency and amplitude, respectively.

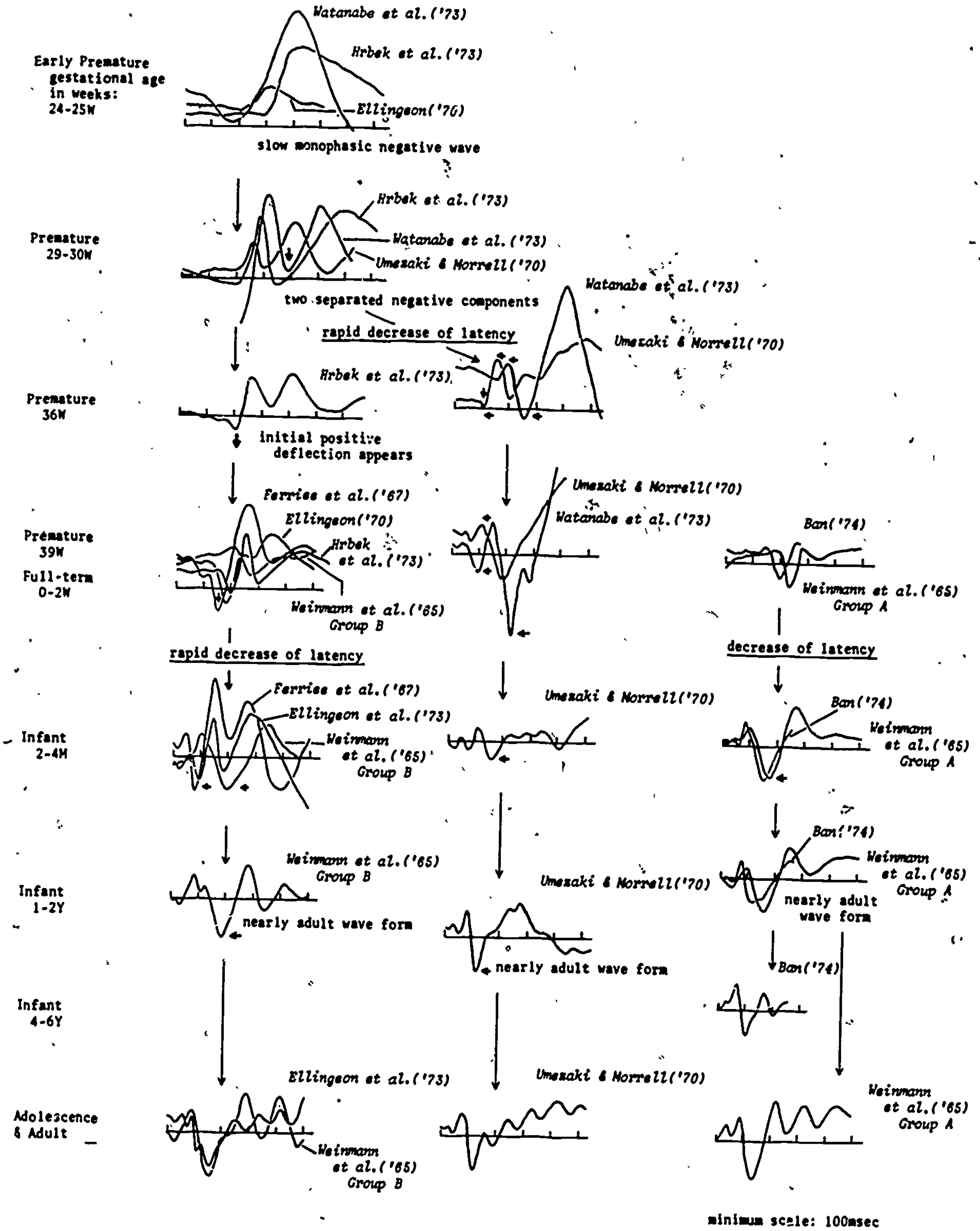

Figure 2. Process of development of closed eyes AVEP at occipital area. Small arrow added to each wave component denotes portion and direction of change against the preceding stage.

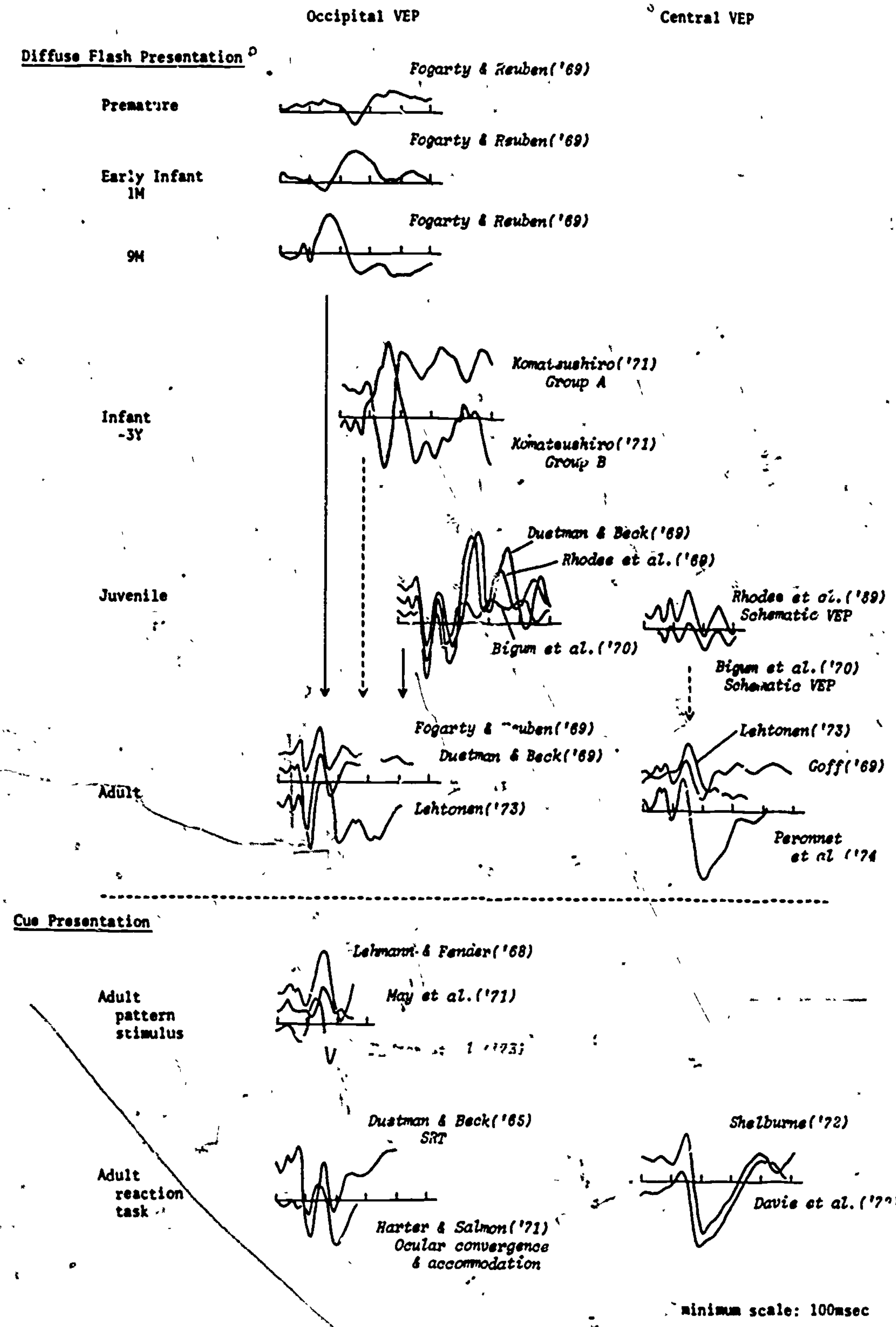

Figure 3. Process of development of open eyes AVEP. AVEPs to white flash stimulus (upper section) and to pattern or task stimulus (lower section) are shown.

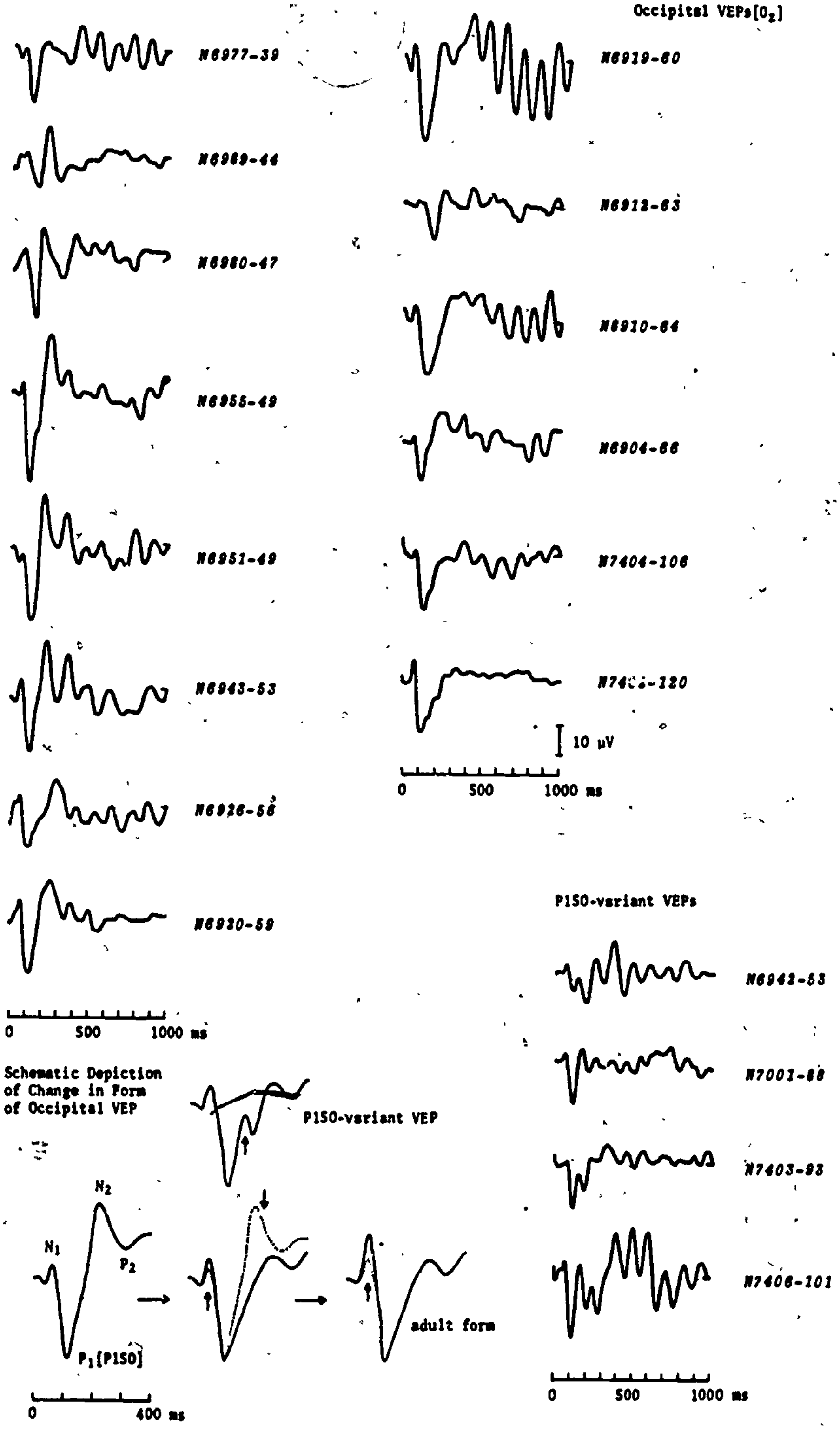

Figure 4. Process of development of occipital AVEP in normal children. Subject code is described at right side of each wave. Last two or three digits of code denotes age in decimal system: N6955-49 suggests 4.9 years of age, for example.

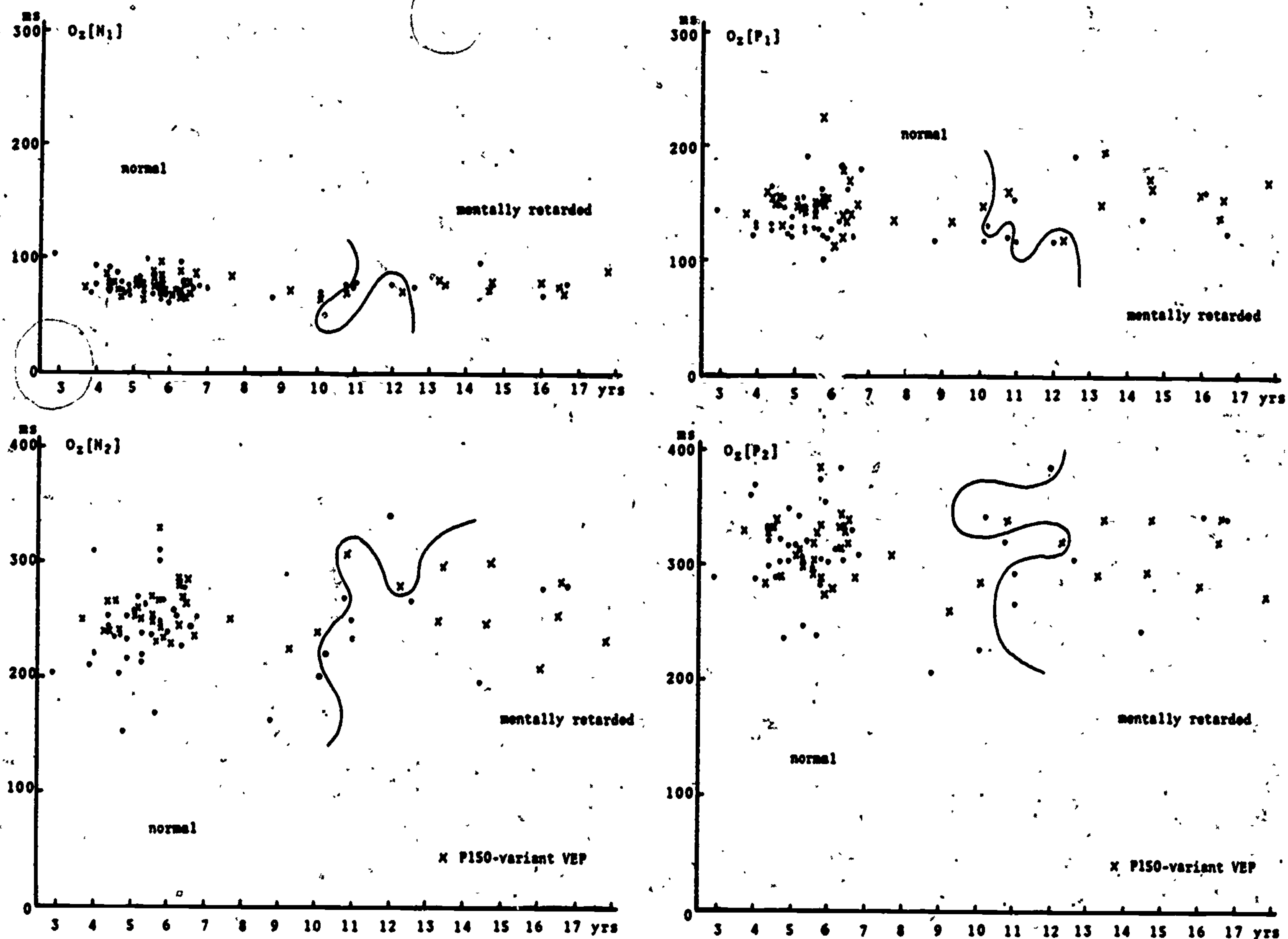

Figure 5. Scatter diagrams showing relations between latency of occipital AVEP and age. Marks of • and x denote the basic form and the P150-variant form, respectively. Curved line drawn in each figure indicates the boundary of samples between normal and mentally retarded children.

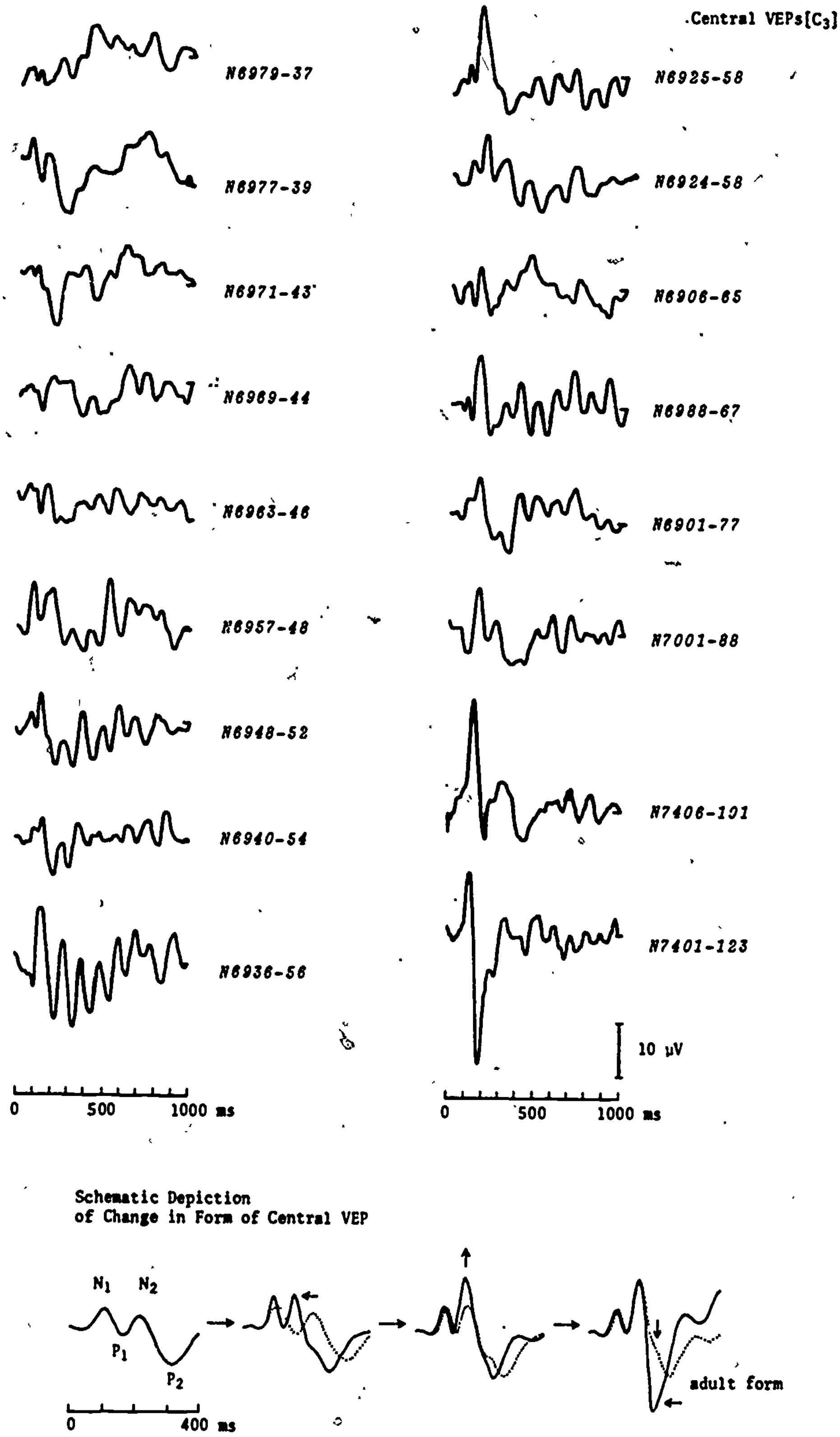

Figure 6. Process of development of central AVEP in normal children.

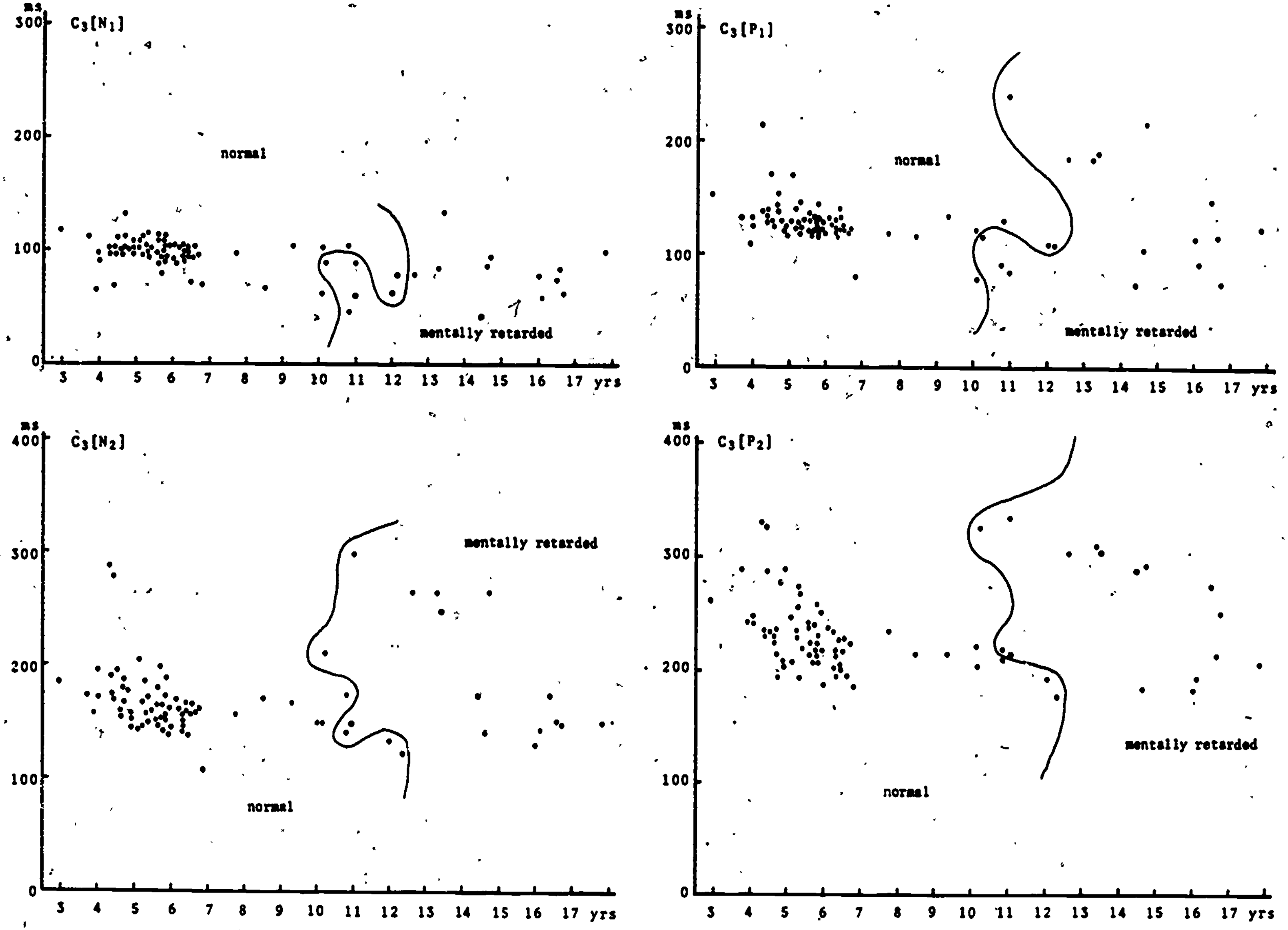

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Figure 7. Scatter diagrams showing relations between latency of central AVEP and age.

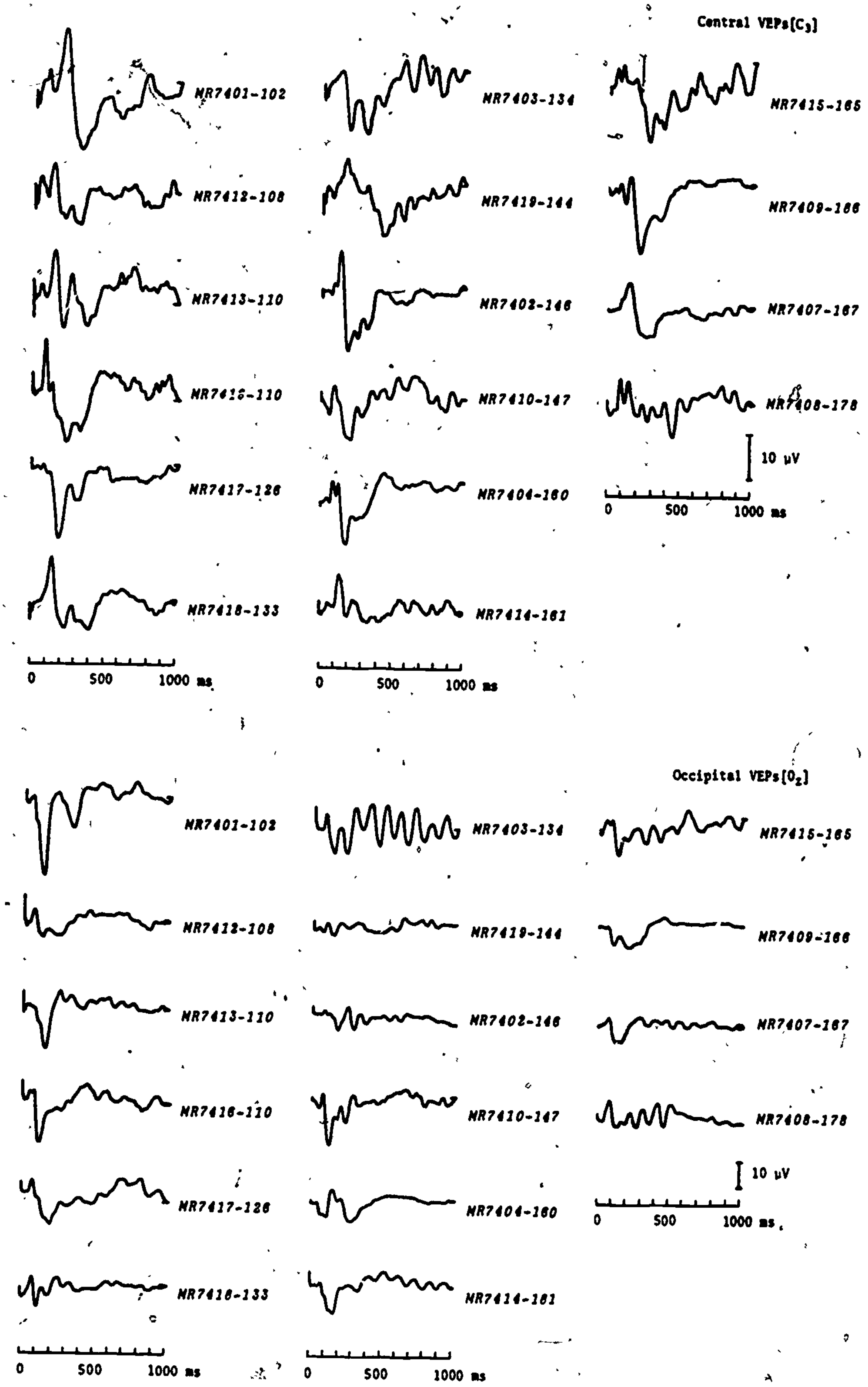

Figure 8. Process of AVEP development in the mentally retarded.

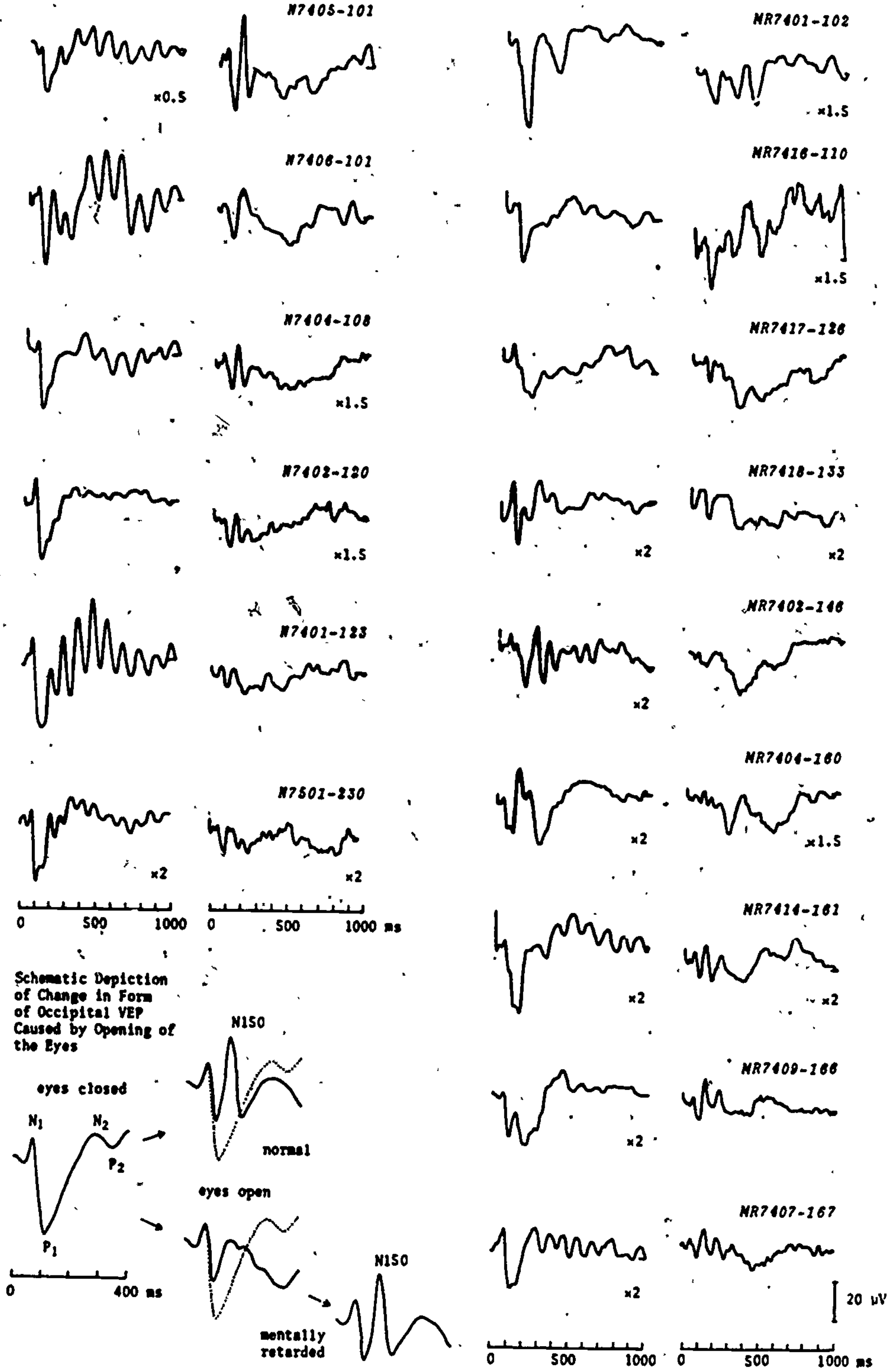

Figure 9. Open eyes AVEP at CRT experiment in comparison with closed eyes AVEP in occipital area. Left two files and right two files are AVEPs of the normal and the mentally retarded, respectively. Left of each two files shows closed eyes AVEPs and right shows open eyes AVEPs at CRT experiment.

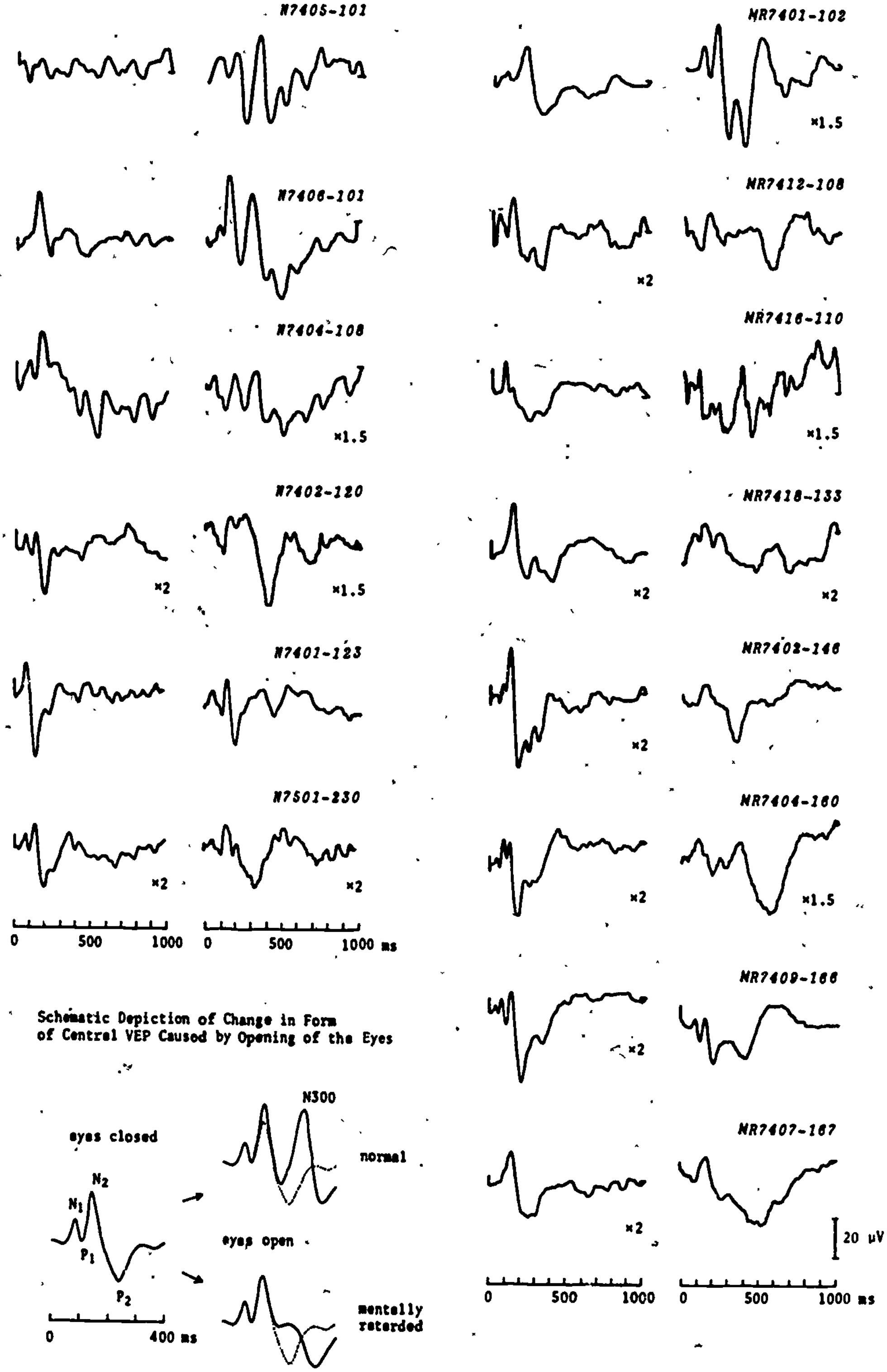

Figure 10. Open eyes AVEP at CRT experiment in comparison with closed eyes AVEP in central area.