PRESTIMULUS EEG-ACTIVITY STRONGLY INFLUENCES THE AUDITORY EVOKED VERTEX RESPONSE: A NEW METHOD FOR SELECTIVE AVERAGING

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A new algorithm for averaging of evoked potentials (EPs) is introduced and compared with the conventional method. The root mean square (rms) values of the alpha and theta band EEG activities 1-s preceding stimulus presentation were computed: stimuli were blocked during phases of high prestimulus activity, thus evoking auditory responses selectively during periods of low activity. Ten volunteers were stimulated with tone bursts of 2000 Hz, 80 dB and 1-s duration. The main results were: (1) The averaged EPs showed an increase in amplitude of nearly 40% in comparison to experiments with conventional stimulation. This increase was in the range of 30% when an ISI correction was taken into account. (2) Single trials tended to form patterns of damped oscillations of e.g., 7–8 Hz, thus revealing a high correlation to the averaged EP. In alpha or theta band contingent experiments, correlation coefficients between single trials and averaged EPs were significantly higher ($p < .01$; $p < .05$).

Keywords: Prestimulus EEG; auditory evoked potential; selective stimulation; single-trial evoked potentials; alpha response; theta response.

Analysis of averaged evoked potentials (EPs) provides an efficient tool for investigation of sensory information processing by the brain. In this study a new algorithm for averaging of EPs is introduced which enables the investigator to obtain increased averaged responses. Repetitive auditory stimuli elicit in the human EEG potential changes with considerable variability in latency, amplitude and shape. Averaging of single epochs gives rise to evoked potentials consisting of a negative wave peaking approximately 100 ms after the stimulus onset (N1) and a positive wave peaking at 150–200 ms (P2) with an amplitude maximum in the vertex region.

Based on results of longstanding investigations both in animals and human subjects, Başar et al. (1975) and Başar (1980) outlined the working hypothesis of an inverse relationship existing between the magnitude of the prestimulus EEG and the maximal time locked amplitude of the single epoch EP. That means, the existence of a synchronized pattern EEG reduces the probability of marked, time locked responses upon sensory stimulation. In this sense, EPs do reflect manifestations of resonance properties of the EEG within different frequency channels.

Interactions between prestimulus EEG parameters and the N1–P2 configuration seem to attract increasing attention. Some groups analyzed the relationship between different levels of CNS activation, as indexed by the spontaneous EEG activity, and human EPs (Fruhstorfer & Bergström, 1969; Romani et al., 1988), others studied the effects of presence or absence of occipital alpha activity (Maras et al., 1990).

Brandt et al. (1991) demonstrated a consistent relationship between occipital prestimulus relative alpha power and visual EP amplitudes. McDonald (1964) succeeded in computing responses to auditory stimuli with low intertrial variations in the cat brain by stimulating during defined levels of minimal background activity. In a former study of our group (Başar et al., 1989) the dependence of single responses on prestimulus conditions was tested by averaging two subsets of single trials classified by prestimulus EEG voltage: The resulting EPs showed different amplitudes which were higher in the case of low prestimulus EEG activity.

The present study extends this concept of selective averaging from an a posteriori to an a priori approach. The major aim was to evaluate EPs as a function of the spontaneous EEG. In contrast to the conventional method of simply averaging single epochs over a defined period of time, the algorithm restricts stimuli to periods of low spontaneous EEG activity. The recorded averaged EPs show a marked increase of about 40% in amplitude in comparison to conventional methods.

METHODS AND MATERIALS

Experimental Design and Procedure

In our earlier studies it could be shown that spontaneous oscillations with smaller magnitudes can be enhanced more efficiently by stimulation signals than spontaneous oscillations with larger magnitudes (Başar et al., 1989). Accordingly, we designed experiments in which stimulation occurred selectively during epochs of low voltage EEG (Figure 1). To achieve stimulation contingent upon the rms values of the spontaneous oscillations, a computer control system was recently developed in our laboratories. Spontaneous EEG activity was fed into an averager able to quantify the rms values of four different frequency bands (Figure 2). The device was programmed to release trigger pulses for acoustical stimulation at fixed rates of 3 s. Before triggering, a comparison of the actual rms values to a predefined level was performed: crossing of the level resulted in stimulus suppression. The level was set according to individual EEG parameters so that about 30 out of 100 comparisons resulted in auditory stimulation. The mean interstimulus interval was 9 s with a variability from 3 s to 30 s. Each experimental session consisted of seven parts—three "selective stimulations" and four (1–4) control experiments—with short resting periods in between. In each part, blocks of 32 tones (2000 Hz, 80 dB, 1-s duration) were binaurally delivered through earphones. The selective stimulation paradigm was used in three varieties: stimulus application was conditional on prestimulus a) alpha band activity (8–14 Hz), b) theta band activity (4–8 Hz), and c) the activity in both combined frequency bands (4–14 Hz). In the control condition tones were presented irrespectively of the spontaneous EEG activity with interstimulus intervals (ISI) randomly varying between 3–4 s.

To test the influence of the different ISIs inherent in this paradigm, a second series using the same stimuli and ISIs as in the control and test condition was performed on eight subjects. In two trials, tones were presented as in the control condition. In two further trials, tones were presented using the same mean ISI of 9 s (varying between 3 s and 30 s) as in the selective stimulation condition.

Data Collection

Subjects were ten normal volunteers (4 female, 6 male) aged between 25 and 35 years, without history of neurological diseases and without use of any drug known
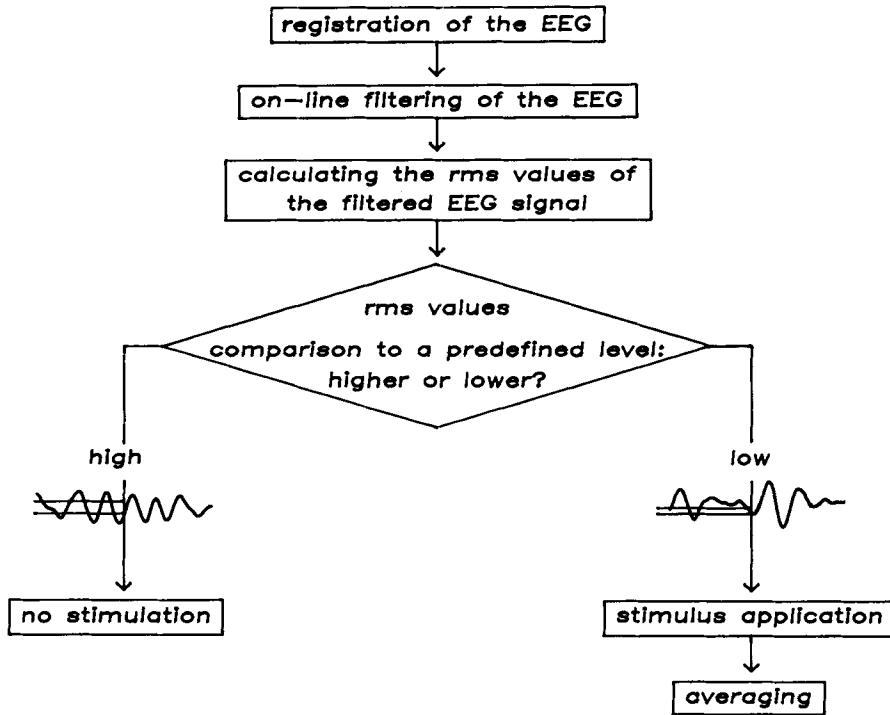
FIGURE 1 Concept of selective stimulation: auditory stimulation is triggered only during absence of highly synchronized alpha or theta EEG activity. Selective stimulation in a defined frequency band is supposed to result in a reduction of the number of stimuli required to produce a clearly recognizable, measurable EP.

to affect EEG. They were instructed to keep eyes open and passively to listen to the tones. The data were derived with an Ag-AgCl disc electrode placed on the vertex (Cz) recording site of the international 10–20 system against a left earlobe reference. The EOG was also registered to mark eye movement artifacts. The electrode imped-ance was kept below 10 KOhm. A Schwarzer EEG machine (UF136) was used to record continously the EEG activity. The ink recording served to monitor artifacts and also to mark the timing of stimuli. The filter of the EEG amplifier bandpass was set to .5–70 Hz. EEG data were sampled at a rate of 1 KHz using an analog-to-digital converter card plugged into a Hewlett Packard A600 computer and then stored on hard disc for off-line analysis.

Data Analysis

Our methodology to evaluate EPs, amplitude frequency characteristics and digitally filtered data was previously described in detail (e.g., Başar, 1980). The essential steps are as follows:

Recording of EEG-EP epochs With every stimulus presented a segment of EEG activity preceding and the EP following the stimulus are digitized and stored on computer disc memory.
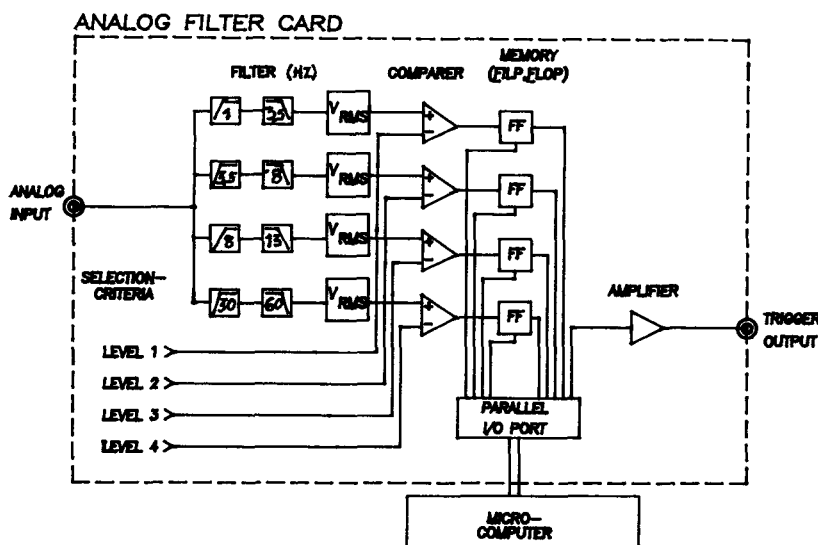
FIGURE 2   Block diagram of the system used for selective stimulation. Detailed illustration of the analog filter card, comparator and memory.

Selective averaging of EPs   The stored raw single EEG-EP epochs are selected with specified criteria after the recording session: EEG segments showing movement artifacts, sleep spindles or slow waves are eliminated.

Computation of amplitude frequency characteristics   The selectively averaged EPs are transformed to the frequency domain with the Fast Fourier transform:

$$G(j\omega) = \int_0^\infty \frac{d\{c(t)\}}{dt} \exp(-j\omega t) \, dt$$

$c(t)$ is the step response of the system, here, the sensory EP ("transient response frequency characteristics method," Başar, 1980).

Digital filtering   EP frequency components are computed using digital filters without phase shift (Başar & Ungan, 1973). The limits of the passband filters used are not arbitrarily chosen. Filters are applied only for selectivity channels, or tuning frequencies indicated by clear peakings in the amplitude frequency characteristics.

Our criteria to identify the averaged N1/P2-EP components were as follows: N1 was the largest negative peak between 75 and 125 ms, P2 was the largest positive peak after N1 and before 220 ms. Both peaks were easily identified in each data set: their amplitudes and latencies were measured along with the maximal peak to peak amplitude. The preliminary analysis was restricted to one dependent variable, the N1-P2 amplitude. These values were tested for the significance of differences by means of a nonparametric test. For this purpose the Friedman two-way analysis and post-hoc Wilcoxon-Wilcox test (Sachs, 1984) were used.
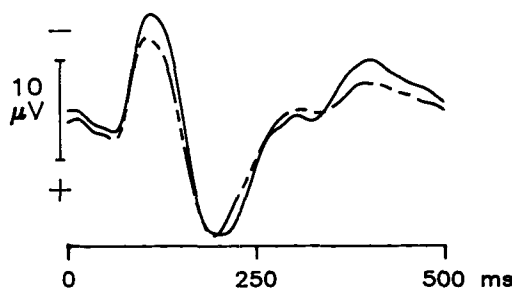
FIGURE 3   Interstimulus interval (ISI) dependence of the vertex AEP (N = 16). Dashed line: ISI of 3–4 s, solid line: mean ISI of 9 s.

RESULTS

Difference between ISI Adequate Controls and Standard Controls

This study aimed to describe a new algorithm for averaging of EPs by taking the prestimulus EEG states into consideration. Therefore, we compared the results obtained with the conventional method. The concept of selective averaging implies that interstimulus intervals diverge from the usually ones in two aspects: (1) they are longer in the mean and (2) the stimuli are triggered in an irregular and unpredictable way. To which degree the results reported here are affected by different ISIs is illustrated in Figure 3 which presents the grand averages of AEPs with short, nearly regular ISI (dashed lines) and AEPs with longer and irregular ISI (solid lines). The latter AEP with irregular and longer ISIs—two different sequences of tones (a) and (b) were used—depict N1–P2 amplitudes 12% higher in comparison to the conventionally obtained averaged evoked potentials (see Table 1).

Comparison between the Selective Stimulation Conditions and Controls: Averaged Data

Figure 4 illustrates the differences between averaged auditory EPs obtained by means of selective stimulation (solid lines) and preceding control EPs (dashed lines) in a

TABLE 1
AEP N1–P2 Amplitudes (μV)

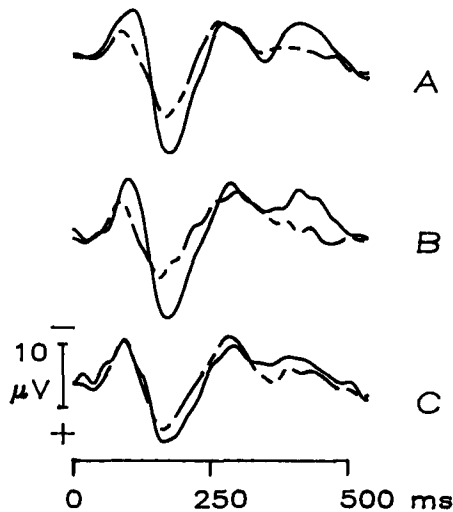| Subject	ISI 9s(a)/ISI 3.5s	Percent Change	ISI 9s(b)/ISI 3.5s	Percent Change
1	15.7/13.8	21%	18.4/15.8	18%
2	23.4/21.7	8%	22.6/19.7	15%
3	28.8/22.0	31%	26.5/24.8	8%
4	13.2/11.8	12%	10.6/14.4	−26%
5	14.1/11.5	23%	17.9/12.5	43%
6	14.6/13.8	5%	11.9/13.0	−10%
7	20.1/17.8	13%	18.6/18.3	2%
8	26.9/29.5	10%	29.7/24.4	22%
m.v.			19.7/17.5	12%
s.d.			6.1/4.9	
$n =$			(16)/(16)	

FIGURE 4 A–C   A comparative illustration of the AEPs of one representative subject obtained by conventional (dashed lines) and selective stimulation (solid lines). Solid lines: stimulation restricted to periods of low rms values in the (A) alpha, (B) theta and (C) alpha/theta frequency range.

single subject. The solid curve in section A corresponds to the EP elicited by stimulation during low amplitude alpha activity. In section B, the criterion for stimulation was low prestimulus theta activity. In both cases a large difference between the responses to selective stimulation and to conventional stimulation can be observed. Section C illustrates the EP when single trials had to meet the two criteria of both low alpha and low theta prestimulus activity. Compared to sections A and B, there is a minor gain in amplitude. This example reflects the global tendency to a clear amplification in amplitude in the prestimulus alpha and theta contingent condition EPs compared to the conventional averaged EPs, and a minor effect if both frequency bands were evaluated at the same time. Superimposed evoked responses of all subjects under study according to the different experimental conditions are shown in Figure 5. For each subject, one control out of four is presented. Amplitude differences between selective and conventional stimulation is also reflected in the grand averages computed from all subjects. Table 2 is a synoptic presentation of the N1 to P2 peak-to-peak amplitude values of the ten subjects under study. The percentage gain in amplitude of the EPs of the selective stimulation experiments is given based on the mean amplitude in the control conditions. A comparison of this gain in the different selective stimulation experiments reveals that EPs with prestimulus amplitude restrictions in a single frequency band—alpha or theta—showed comparable increase in amplitude, 47% and 41%, respectively. The EPs with low prestimulus activity in the broad range from 4–14 Hz did not differ that much—28%—from the control condition. In eight subjects out of ten all selective stimulation AEPs showed higher amplitudes than the conventionally recorded counterparts, varying in gain between about 20% up to 80% or more.

Friedman two-way analysis was performed to test the distributions of the N1–P2 amplitudes for the seven experimental groups (three selective stimulation experiments, four controls) that were found to be significantly different ($p < .0001$). A post-hoc Wilcoxon-Wilcox test revealed that the amplitude distribution of the alpha
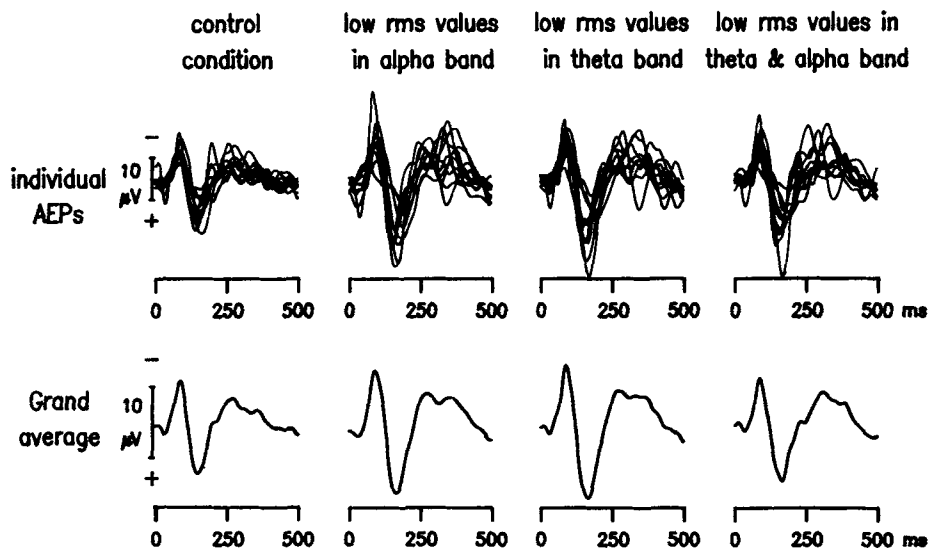
selective stimulation conditions:

FIGURE 5 Superimposed individual AEPs (top) and grand averages (bottom) of all subjects under study (N = 10) obtained during different experimental conditions of conventional or selective stimulation.

TABLE 2
N1–P2 AMPLITUDES (μV)

| Subject	Low Alpha/ Control	Percent Change	Low Theta/ Control	Percent Change	Low Theta & Alpha/ Control	Percent Change
1	24.4/13.9	75%	18.7/13.9	34%	18.6/13.9	33%
2	7.3/ 6.9	5%	6.9/ 6.9	0%	5.0/ 6.9	−27%
3	23.7/12.5	89%	26.3/12.5	110%	17.9/12.5	43%
4	18.7/11.8	58%	17.5/11.8	48%	14.2/11.8	20%
5	23.7/20.1	17%	25.3/20.1	25%	23.7/20.1	17%
6	31.0/17.9	73%	30.0/17.9	67%	23.5/17.9	31%
7	20.4/13.4	52%	17.5/13.4	30%	15.8/13.4	17%
8	35.4/21.7	63%	36.9/21.7	70%	36.8/21.7	70%
9	36.9/30.3	21%	26.9/30.3	−11%	31.2/30.3	3%
10	12.7/10.3	23%	17.7/10.3	71%	16.7/10.3	62%
m.v.	23.4/15.8	47%	22.4/15.8	41%	20.3/15.8	28%
s.d.	9.3/6.6		8.4/6.6		8.1/6.6	
n =	(10) (40)		(10) (40)		(10) (40)	
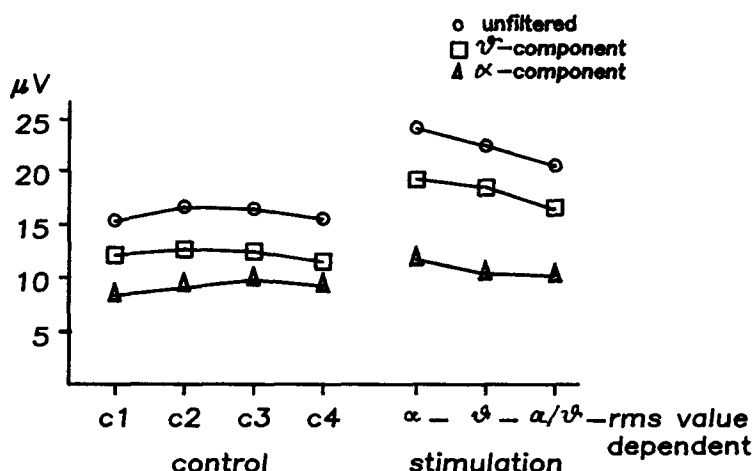
FIGURE 6   Averages of the N1–P2 peak-to-peak values computed from all subjects under study (N = 10) in controls and selective stimulation experiments. Unfiltered curves as well as filtered curves (alpha and theta ranges) were evaluated.

band contingent experiment differs significantly from controls ($p < .01$), whereas the amplitude distribution of the theta band contingent experiment differs significantly from controls 1, 2, 4 ($p < .05$).

The diagram in Figure 6 presents the averages of the maximal peak-to-peak N1–P2 amplitude of all subjects. Control experiments are grouped on the left, selective stimulation experiments on the right side. The three symbols for each run mark the maximal amplitudes of the unfiltered responses, of theta and of alpha components. The amplitude values for the unfiltered data have been computed from Table 2. Similar computations were made for the filtered curves.

As for the unfiltered data, conventionally averaged EPs showed very small differences in amplitude. No tendency of decreasing or increasing amplitudes was observed during the course of controls 1 to 4 (neither for the N1 to P2 amplitude nor for N1 or P2 related to baseline). The mean amplitudes of the EPs obtained by selective stimulation are distinctly higher with the smallest effect in the alpha plus theta condition. As to the filtered data, theta and alpha components are of nearly the same magnitude across control conditions. Then we note the strength of alpha and theta responses, respectively, in the different selective stimulation conditions. When stimulus application was conditional on prestimulus alpha band activity, there was an increase not only in the alpha component, but also in the theta response. Vice versa, an alpha enhancement was observed in the theta band contingent trials. Analyzing these mean amplitudes of filtered data that reflect the results in individual subjects, we observe that both components reveal a strong resonant behavior independent of prestimulus theta or alpha band contingent stimulation.

Comparison between the Selective Stimulation Conditions and Controls: Single Trial Analysis

Averaged EPs tended to show almost regular oscillatory waveforms of, for example, 6 or 9 Hz. Single responses tended to form similar patterns of damped oscillations in the same frequency range. Figure 7 illustrates about 15 single EP epochs filtered
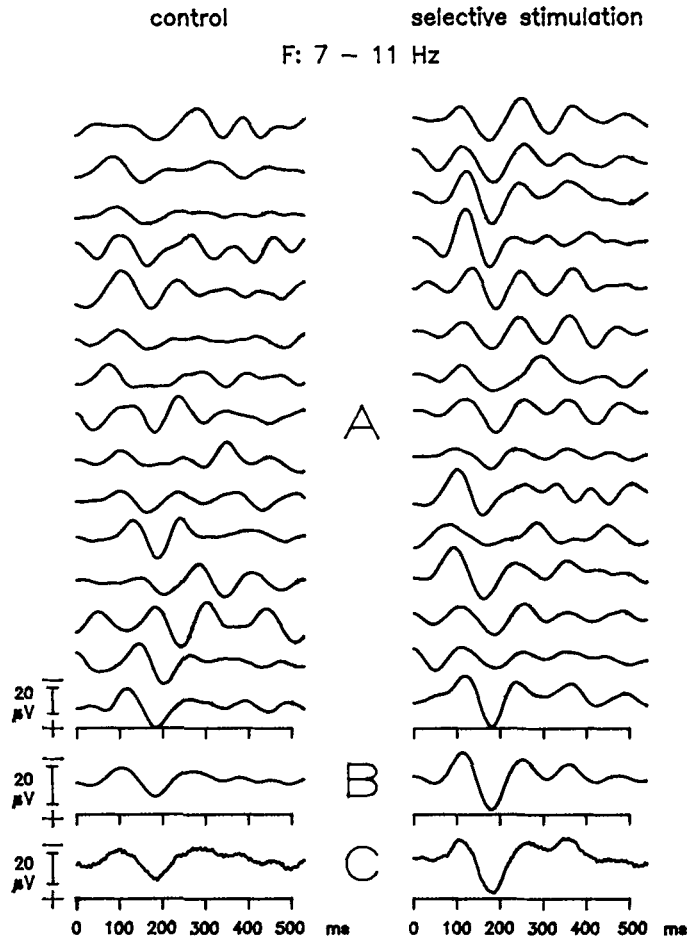
FIGURE 7   Single EP epochs filtered in the 7–11 Hz range (A); averaged EP filtered in the 7–11 Hz range (B); unfiltered averaged EP (C). Left column: control, right column: alpha band contingent selective stimulation. Single responses in the left column show 7–8 Hz oscillations, their waveforms being rather similar to one another.

in the 7–11 Hz range of two successively conducted experiments in the same subject. The left column refers to a control, the right to an alpha band contingent selective stimulation experiment. The first fifteen epochs are presented in both cases. The single responses in the right column showed time-locked, large-amplitude wave packets with a high degree of similarity to one another. Even the averaged EP without filtering showed a rather similar type of 7–8 Hz oscillatory waveform. In the left column, the variability of single responses was higher. Comparative analyses in all subjects confirmed that the responses in the selective stimulation conditions often exhibited replicable patterns in form of damped oscillations similar to the averaged EP, whereas this behavior was observed less often in the control condition. To quantify this observation of single trials with little standard deviation, correlation coefficients between single trials and averaged EPs both filtered in the .5–30 Hz range were evaluated within 300 ms after stimulus onset. Table 3 summarizes mean cor-

TABLE 3
Correlation Coefficients: Single Trial vs. Mean Value

Subject	Control	Selective Stimulation: Prestimulus rms Values Low in the Frequency Range of		
		Alpha	Theta	Alpha/Theta
1	.58	.70	.65	.63
2	.30	.34	.35	.26
3	.46	.66	.70	.58
4	.34	.58	.53	.46
5	.62	.63	.68	.54
6	.60	.73	.73	.59
7	.50	.70	.68	.61
8	.56	.68	.82	.74
9	.44	.53	.54	.58
10	.55	.66	.52	.59

$p < .07$

$p < .05$

relation coefficients of the selective stimulation experiments and the mean of all controls. Standardization of prestimulus EEG conditions by quantification of prestimulus frequency band activities seems to result in a decreasing variability of single trials. Friedman analysis revealed different distributions between experimental groupings ($p < .001$). Significant differences were found between alpha and theta band contingent experiments and the mean of controls ($p < .01$; $p < .05$, post-hoc Wilcoxon-Wilcox test).

DISCUSSION

Inverse Relation between EEG and EP May Lead to a New Standardization in EP Measurements

Analyses of combined epochs of spontaneous activity and evoked potentials in the auditory and visual pathways of the cat brain led us to the concept of the existence of an inverse relationship between EEG and evoked potentials (Başar, 1980). In this study we presented evidence that vertex EPs elicited by auditory stimulation during periods of low amplitude alpha or theta band activity showed about 40% higher amplitudes than conventional AEPs. Distinct interindividual differences were observed, some subjects displayed an increase of 80% and more. The outstanding variability of the vertex potential—across subjects, across trials and across states of the subjects—makes it difficult to define its relation to a single parameter: several additional factors may have contributed to large variations in amplitude changes explained in this study. For example, directing attention toward an auditory stimulus has consistently been reported to enhance the N1/P2 component of the evoked response (for a review, see Näätänen, 1988). In addition, a number of ten subjects under study certainly is too small to draw any definite conclusion or to try to introduce a standardization. But if these findings can be more generally confirmed, then an alternative method of averaging exists that may be more appropriate than the conventional method, also for clinical applications. Although mean interstimulus intervals increase, the recording time does not need to increase also, because a smaller number of single trials is needed to compute clearly recognizable averaged EPs. A

reduced number of stimuli would be advantageous especially for children where it is difficult to get a sufficient number of artifact-free sweeps. EP measurements in this group would require prestimulus criteria different from those for adults. For example in children up to 6 years, there is no alpha responsiveness upon auditory stimulation (Başar-Eroglu & Başar, 1990).

Comments on Experimental Aspects, Interindividual and Intertrial Variability

Regardless of if the stimulation criterion was low alpha or low theta band activity—marked enhancements could usually be observed in both frequency bands. Accordingly, amplitude frequency characteristics of both grand average EPs revealed similar resonant maxima in the slow alpha/fast theta range of 7–8 Hz. This lack of differences between conditions may be partly due to the fact that vertex EP is an alpha-theta compound response. According to our working hypothesis, EPs are composed of a number of components in different frequency channels. It seems that the frequency maxima of the vertex response cannot be separated into two distinguished bands, but rather seem to be coupled. In addition, the filter characteristics partly included border frequencies, so that a 7–9 Hz range was evaluated in both conditions.

When stimulation was contingent on alpha plus theta band activity, the amplitude did not differ significantly from controls in contrast to the other conditions. We interpreted this finding that the chosen frequency range was too broad (in this condition like in the other ones, the maximal number of trials was 100. At least 30 of them had to lead to a stimulation). To fulfill this condition, the level may have been set too high to allow sufficient separation between stages of high or low activity. We suppose that the most prominent effect could be reached by adapting the frequency range for rms evaluation to the range of maximal responsiveness of the evoked potential ("prestimulus adaptive filtering"). This approach would extend the adaptive filtering method introduced by Başar (1980) for EPs to the prestimulus EEG segment. The efficiency of the method also depends on the degree of spontaneous fluctuations in the EEG. The more pronounced the waxing and waning, the sharper a separation can be made between stages of low and high activity. Time delay of rms evaluation (activity detection) is in the 200 ms range. Spontaneous activity could appear and interact with the EP. In such instances the effect would probably not be the occurrence of a pseudo EP because this activity is not in phase; on the contrary, a reduced EP could result.

It is a wellknown fact that the auditory vertex response is affected by the interstimulus interval (Davis et al., 1966; Hari et al., 1982). Because the aim of our study was to describe a new algorithm for averaging of EPs by taking the prestimulus EEG states into consideration, we chose as control condition the conventional averaging method. To determine to which degree the ISI incongruence amounted to the amplitude differences, we performed additional controls with the same mean interstimulus interval as in the selective stimulation conditions and concluded that the different ISIs amount to about 12% to the amplitude gain. In other words the new algorithm effects an amplitude gain of at least 30%. Brandt and Jansen (1991) have shown a predictability of EP-amplitude of 40% in the mean. Their study which further demonstrates a nonlinear inverse relation between EEG and EP enhancement shows the importance of analysis of prestimulus EEG for better evaluation of evoked potentials.

Our suggestion is that the selective stimulation procedure effects a higher correlation between single sweeps (Rahn & Başar, 1990). This is in good accordance with

the results of McDonald (1964) who claimed that the main reason for variability in single sweeps were different initial EEG conditions. His data refer to brainstem acoustic evoked responses in cats, the contingent time period being in the range of about 50 ms. The increase in correlation coefficients between individual records and averaged evoked response also matches the work of Sayers et al. (1974) who stated that effective stimuli act by synchronizing the phases of spectral components of the spontaneous EEG activity already present.

Comparison to other Studies on Prestimulus EEG Parameters and the N1–P2 Amplitude of the EP

Brandt et al. (1991) reported that subjects displayed consistent increases in N1–P2 amplitudes as a function of increasing prestimulus relative alpha power; relative delta and theta power were found to be inversely related. As to the delta/theta frequency range, similar observations were reported by Romani et al. (1988) who performed selective averages on the base of a "slow-wave index" (SWI) and described a reverse relationship between the relative delta-theta amplitude of the 1-s prestimulus spectrum and the N1–P2 amplitude (but only for subjects with a high mean SWI). Our results partly seem to correspond to these reports (prestimulus theta), partly they are at odds (prestimulus alpha).

   A direct comparison of our study with the ones mentioned above is possible only to a certain extent because of many methodological differences. Romani et al. (1988) indeed used auditory stimuli and vertex derivations, but stimulation parameters differ, subjects were instructed to silently count the tones and two different channels were used for the data of pre- and poststimulus epochs. The study of Brandt et al. (1991) refers to the visual modality and an electrode site between Pz and Oz. Moreover both studies are related to **relative** prestimulus power computations, whereas we referred to an **absolute** quantity, the prestimulus rms value. Certainly it should be emphasized that all these works support the existence of a relationship between the spontaneous EEG patterns and the evoked responses. The phase angle of alpha band activity at the moment of stimulation also influences the evoked potential: in the visual modality, Rémond and Lesèvre (1967) found different averages depending on whether stimulation occurred in an alpha source or an alpha sink, Jansen and Brandt (1991) confirmed that for certain phase angles alpha reaches a maximum in the N1 latency range. We cannot comment on these results because our experimental setup is different, and we do not believe phase analysis to be indicated when stimulating at low alpha activity stages.

Spontaneous Alpha Activity

The spontaneous alpha EEG, viewed as a series of momentary scalp field maps, was found to show stable map configurations of varying durations (Lehmann, 1990). Lehmann suggested that different EEG segment classes manifest different brain functional states exerting different effects on information processing. Reaction time or the differing configurations in response to identical stimuli might depend on the momentary map-defined microstate at stimulus arrival. This view is supported by our study: Even by using such a coarse-grained scale of states, our findings indicate that brain's momentary functional state as reflected in the spontaneous EEG influences information processing. Rms values within the alpha band is of course only one aspect of the electrical spatiotemporal continuum reflected in the EEG. Walter (1964)

checked the alpha band rhythm with intracerebral electrodes and found a variety of alpha rhythms and concluded that what one sees on the scalp is a spatial average of a large number of components. Keeping this in mind, it becomes clear that a rms value dependent classification cannot be functionally specific; nevertheless, our results suggest common characteristics of the relationship between alpha band activity and auditory evoked potentials over subjects. They may also support the idea that the background EEG is not mere noise but rather may serve a certain purpose with respect to mental processes (Petsche et al., 1986). Event-related desynchronization (ERD)—a synonym for attenuation or blocking of the alpha band during the performance of cognitive or motor tasks—as described by Pfurtscheller (1988) implies that the ERD is dependent on the amplitude of alpha band activity before the event (stimulus): without alpha band activity at all, no ERD can be measured. ERD can also be negative, meaning that alpha band activity can be provoked (synchronization effect). The relation between spontaneous and evoked alpha rhythms were the recently subject of magnetoencephalographic studies: Narici et al. (1990) demonstrated that stimulation using a frequency equal or near the center frequency of the spontaneous activity may produce longlasting oscillations.

Cognitive States in Prestimulus Activity

The findings reported here corroborate the conception that the synchronization of the prestimulus EEG should be considered an active component in evoked responses (Başar, 1980). If external stimuli are applied during phases of highly synchronized activity, further enhancement and frequency stabilization may not be elicited. Our earlier results on the development of "preparation rhythms" (Başar & Stampfer, 1985; Başar et al. 1992) have shown that it is possible to measure almost reproducible EEG patterns in subjects expecting defined sensory stimuli (targets). Evidence was presented that pretarget activity interacts with evoked potentials: Pretarget alpha effected a reduction or sometimes almost disappearing of the response, namely of the N1 component (Başar et al., 1989). This study is somehow supplementary to these results. Accordingly, newly-designed experiments using selective stimulation devices may be of importance in the understanding of cognitive processes. Starting from our preliminary results, we feel encouraged to test further applications. At the present, we have just quantified spontaneous alpha/theta at the vertex position in the time window (dead time) of 1 s. To standardize the method, other time windows and further recording sites will be needed. According to a model of Lopes da Silva et al. (1973) there are several alpha generator networks in several brain areas. The next steps will include recordings from a larger number of cortical electrodes (occipital, frontal and parietal locations) and the use of visual stimulation. A standardization of the present approach might be possible only after the performance of these steps.

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