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A novel or rare stimulus, which is unexpected by a subject and often surprises him evokes a marked cortical potential. It was called P300, which was a late positive component occurring at a latency ranging from 200 to 500 msec. after its presentation (Ritter, Vaughan and Costa, 1968; Roth, 1973; Roth and Kopell, 1973). Another stimulus which is expected to deliver a key information for performing a task, evokes also P300 (Sutton, Tueting, Zubin and John, 1967; Ritter and Vaughan, 1969). If it was presented infrequently, it evoked a large P300 (Sutton, Braren, Zubin and John, 1965; Tueting, Sutton and Zubin, 1971; Friedman, Hakerem, Sutton and Fleiss, 1973; Squires, Squires and Hillyard, 1975; Duncan-Johnson and Donchin, 1977; Squires, Donchin, Herning and McCarthy, 1977). Moreover, event related potentials (ERP) show a stimulus-sequential effect. It was found that P300 of ERPs for the event which had been preceded by an identical event was smaller than when preceded by a different event, when binary stimuli were presented in a random order (Donchin, Kubovy, Kutas, Johnson and Herning, 1973; Squires, Wickens, Squires and Donchin, 1976; Duncan-Johnson and Donchin, 1977; Squi -res, Petuchowski, Wickens and Donchin, 1977; Shimokochi, Miyamoto and Nageishi, 1979).

To account for these phenomena, Squires et al. (1976) proposed the expectancy model which was already suggested in the choice reaction time (CRT) studies where short reaction time (RT) resulted from a trial preceded by an identical (stimulus and response) trial (Hyman, 1953; Bertelson, 1961; Remington, 1969; Falmagne, Cohen and Dwivedi, 1975). In fact, many aspects of P300 resulted from ERP studies seem to be explained by this model. However, as will be described in the followings, we may more rationally interpreted them by the general learning theory proposed by Wagner (Pfautz and Wagner, 1976; Wagner, 1976).

Kamin (1969) originally noticed from his blocking experiments that only an unexpected or surprising "US (unconditioned stimulus) provoke the animal into a 'backward scanning' of its memory store of recent stimulus input:only as a result of such a scan can an association between CS (conditioned stimulus) and US be formed." (Kamin, 1969, p. 60). For instance, supposing a classical conditioning situation, if a pair of well-trained CS and US is presented to the animal, the US is fully predicted by the CS and then further association is not acquired from this trial beyond the level CS had previously acquired. Kamin's notion is consistent with the expectancy model in some features, since Squires's model also stressed that a surprising or unexpected event evoked P300 and "P300 reflects the activity of a general purpose processor which is involved on demand by a host of data processing requirements" (Donchin et al., 1973, p. 322). These two propositions (Kamin, 1969 and Squires et al., 1976) mean that the more a presented stimulus is an expected one, the less the subject is involved in information processing for it. Therefore they can account for the effect of subject's guessing of the ERP studies, where an incorrectly guessed stimulus evoked a larger P 300 than a correct one (Sutton et al., 1965) and a high-risk guessing stimulus evoked the largest (Tueting et al., 1971; Friedman et al., 19 73). Also noted was the manipulation of a priori probability of stimulus presentations where a frequent stimulus evoked a smaller P300 than a rare one, because it seemed that a subject usually expected a more frequent stimulus and then he must be involved much more in the unexpected information processing(Sutton et al., 1965; Tueting et al., 1971; Friedman et al., 1973; Squires et al., 1975; Duncan-Johnson and Donchin, 1977; Squires et al., 1977a).

Squires et al. (1976; 1977b) interpreted the sequential effect on P300 by the expectancy model. They stated "a model accounting for the waveform data should estimate the expectancy the subjects has for an event as a function of the preceding sequence of stimuli" and "the effect of stimulus on the expectancy for succeeding stimuli is a decaying function of sequential position (or time)" (Squires et al., 1976, p. 1144). They assumed that the same stimulus evoked a small P300 because for the following presentation of stimulus a subject was apt to expect the same stimulus in the succeeding trial, just as was better represented in short-term memory (STM) at the time. If so, it might be reasonable that not only the same stimulus as has been presented immediately before (the sequential effect) or shortly before for a few preceding times (the higher-order sequential effect) evokes a small P300, but also in the experiments manipulating a priori stimulus probability, a frequent stimulus evokes a small P300.

At any rate, Squires et al. (1976) assumed that the sequential effect on ERP and CRT was dependent on the subjective expectancy, because an expected stimulus resulted in a small P300 (Sutton et al., 1965) and short RT (Williams, 1966; Hale, 1967a; Keele, 1969). However, there is a substantial discrepancy about the sequential effect of CRT experiments, while on ERP experiments there is entirely consistency (Donchin et al., 1973; Squires et al., 1976; Duncan-Johnson and Donchin, 1977; Squires et al., 1977b; Shimokochi et al., 1979). In most CRT studies (Hyman, 1953; Bertelson, 1961, 1963, 1965; Hale, 1967a; Smith, 1968; Remington, 1969; Falmagne et al., 1975) they described the sequential effect which resulted in shorter RT in response to a repetitive stimulus rather than to an alternative one. However, some CRT experiments (Welford, 1959; Shaffer, 1965; Williams, 1966; Hale, 1967a, 1967b; Schvaneveldt and Chase, 1969) referred the opposite effect as a change effect, which resulted in a longer RT in response to a repetitive one. Cantor and Fenson (1968) also reported this change effect, with children as subjects. Hale (1967a) and Cantor (1969) stressed that it could be attributed to the subject's tendency to predict alternative stimulus from a preceding trial rather than a repetitive one (Jarvik, 1951; Hale, 1967a). If this tendency is true under the ERP experiments, the sequential effect on ERP was not understood by the expectancy model. The reason of these discrepancy has not yet been resolved within the CRT studies (Kornblum, 1973).

Now, we may be able to comment in some points on the concept of the subjective expectancy in the ERP experiments, since most experimental tasks in the ERP studies required the subjects to count only one of the two tones (Donchin et al., 1973; Squires et al., 1976; Duncan-Johnson and Donchin, 1977; Squires et al., 1977b). It would be unlikely that the predictions of the next stimulus were useful or essential for the subjects to perform these tasks, although in the CRT experiments they could be rewarded for a shorter RT by their prediction. Moreover, the studies for the relationship between RTs and P300 for imperative stimuli demonstrated that the stimuli resulting in shorter RT evoked a larger P300 than in longer RT (Ritter, Simon and Vaughan, 1972; Kutas, McCarthy and Donchin, 1977; Roth, Ford and Kopell, 1978). Kutas et al. (1977) concluded from their trial-by-trial analyses that P300 indexed the stimulus evaluation process, but RT indexed a stimulus, a response selection and an execution process. At any rate, for the sequential effect of ERP, we should consider some other different underlying mechanisms from the subjective expectancy of the next stimulus in the CRT experiments.

After Kamin's notion (Kamin, 1969), Wagner (Pfautz and Wagner, 1976; Wagner, 1976) proposed a new learning theory. From the notion that a surprising or unexpected US might be processed differently from an unsurprising or expected US (Kamin, 1969; Wagner, 1969), or that only an unexpected or surprising US might be processed (Kamin, 1969; Rescorla, 1969), Wagner assumed that only a surprising or unexpected US was primed into STM or active memory, and then by the activity of post trial rehearsal it would be associated with the information simultaneously contained in STM at that time, which is often referred to as CS on a classical conditioning paradigm. An unsurprising or expected US, however, was not primed into STM or active memory and then it would not be associated with the preexistent information. In the latter case, expecting the US means that the US information is already represented in the STM at the time, for the pre-associated CS has retrieved it from long-term memory(LTM). Transmission of the information of the US to STM is interfered by the presence of the information of the US in the STM. When a stimulus is presented to an subject, it will be less likely to be primed into STM if it is already represented in STM, and it will be likely to be primed into STM if it is not represented in STM. After Atkinson and Shiffrin's information processing model (Atkinson and Shiffrin, 1968), Wagner assumed that its transmission into STM could be controlled by the function of a comparator system interposed between the sensory register and STM. He also mentioned, "the comparator is assumed faithfully to examine the contents of the sensory register and the limited-capacity STM, and to act to transmit to STM only that information in the sensory register which is discrepant from that already in STM" (Pfautz and Wagner, 1976, p. 110).

Since a stimulus can be represented in STM through the comparator by the presentation of it and then its representation can be retained in it for a short time, the same stimulus as that preceding it will be poorly primed into STM. Whitlow(1975) confirmed this prediction in the experiment of the defensive reaction of rabbits. He demonstrated that when two intense tones were presented in a random sequence, a tone different from the preceding one elicited a larger vasomotor contraction than the same tone. After Wagner's model, he discussed that the same tone was poorly primed into STM, and then it elicited the small response, while the different tone was well primed, and then it elicited the large response. He also demonstrated that this sequential effect had a time decaying function.

Returning to the ERP studies, it is more likely to consider that the sequential effect may be also attributed to the function of the comparator, since it seems that an event, which had been presented shortly before and whose information is then still retained in STM, will be poorly transmitted into STM, while an event, which has not been presented shortly before and is not yet represented in STM at the time, will be well primed into STM. We may consider that P300 reflects a brain activity transmitting the stimulus information to STM or processing in STM, because the same stimulus as the preceding one evokes a small P300 and a different one evokes a large P300. Short-term habituation of P300 and evoked potential (EP), which is the most prominent phenomenon of these experiments (e.g. Ritter, et al., 1968; Fruhstorfer, Soveri and Järvilehto, 1970), can be also explained by Wagner's model. The first stimulus of a train is well primed into STM because it is not represented in STM at the time, but the second stimulus and the followings are poorly primed because they are already represented. Finally, we can assumed that according to Wagner's model the sequential effect on P300 is attributed to the short-term habituation-like-effect rather than the effect of the subjective expectancy. EP has such a sequential effect as P300, whic hmay be regarded as a stimulus-specific effect of short-term habituation (Hay and Davis, 1971; Davis, Osterhammel, Wier and Gjerdingen, 1972; Schneider and Davis, 1974). Moreover, Sutton et al. (1965) and Friedman et al. (1973) reported the effect on ERP of a priori stimulus probability in their "certain" conditions, where the experimenter told the subjects what the following stimulus would be every time. Because they could make sure of the experimenter's offerings in the early trials, and because we can believe their expectancy depended on these, this finding rather contradicts the expectancy model. On the constrast, it may be attributed to the function of the comparator, for the frequent stimulus is presented more often in the preceding trials than the rare stimulus and then it is more prerepresented in STM at the time of the succeeding presentation. To examine the idea that the sequential effect on ERP is not dependent on the subjective expectancy, we employ a situation where a subject predicts the next type of stimulation as little as possible (i: relatively small number of stimulus presentations, ii: instruction of random presentation to the subjects, and iii: an identical task to the two stimuli etc.). Since Wagner's model assumed that the function of the comparator was dependent on the time decaying function of STM, we try to demonstrate time decay of the sequential effect on ERP, employing both short and relatively long inter stimulus intervals (refer to Smith, 1968; Peterson and Peterson, 1959).

Wagner's model (Pfautz and Wagner, 1976; Wagner, 1976) assumed two different means of priming into STM. The first is the so-called self-generated priming (SGP), in which the information of a presented stimulus is primed into STM through the comparator, as mentioned before. The second is the so-called retrieval-generated priming (RGP), in which the stimulus information is primed into STM from LTM by the retrieval action of the stimulus already associated with it. In the case of RGP, we will also predict that P300 for an incorrectly guessed stimulus is larger than for a correctly guessed stimulus. The compatible result was already confirmed by Sutton et al. (1965) and Tueting et al. (1971).

The ERP studies manipulating a priori stimulus probability can be also interpreted from Wagner's model. We may consider that when frequent stimuli were presented, they were already represented in STM by the two means. The one was the representation by the stimulus presented shortly before and the other was by the subject's expectancy depending on a priori stimulus probability. For those representation, the frequent stimuli would be poorly primed into STM and evoke a small P300. This notion was already confirmed by Duncan-Johnson and Donchin (1977). They demonstrated that the a priori stimulus probability effect and the stimulus sequence effect on P300 were rather independent. This independency preferes Wagner's model to the expectancy model because Squires et al. (1976) assumed both effects were mediated by the same concept of the subjective expectancy. Therefore, in an attempt to examine the validity of the applying Wagner's model to ERP studies, ERP for a stimulus in the case of SGP is compared with that of RGP. Using the same subjects and stimuli for the sequential effect, we measure P300 for the same and different stimuli with regard to the subjects' guesses in a guessing situation.

METHOD

(1) *SUBJECTS*

10 students of Osaka University served as subjects, each in a 2 hr. testing session. One subject was removed from the analysis, because he reported that he had predicted the next type of stimulus in the SGP phase.

(2) *PROCEDURE*

Binary sequences of monaural clicks (to the right or left ear), which were at a moderate intensity substantially above threshold, were presented through a stereo earphone (Victor STH-2). In the SGP phase, a subject was instructed to count the numbers from the presentations of the right and left clicks, respectively. The right and left clicks were presented equiprobably in a random order, but a short inter stimulus interval (mean: 3 sec.; range: 2.5–4.5 sec.) and a long ISI (15 sec.; 8–25 sec.) were alternated. The subject was also instructed that he should prevent body movement and eyeblinks during the short ISIs but might conduct these during the long ISIs if he felt the need. The authors considered that he might be rather ignorant of the sequence of stimuli themselves, for with this instruction, he probably thought that a pair of clicks was being studied. Four blocks of about 60 stimuli (50–70 stimuli) were conducted. After each block, he was asked the both numbers of the right and left clicks. Only a few errors were reported in a few subjects.

In the RGP phase, guessing trials which consisted of a series of a cueing flash, guessing by a subject and presentation of a right or left click, were succeeded by a 15 sec. inter trial interval (8–25 sec.). If he predicted that a left click would be presented in a given trial, he depressed one of two buttons using his right forefinger for the cueing flash, and if he predicted a right click, depressed the other with his right middlefinger. The interval was 3 sec. (1.5–4.5 sec.) between a cueing flash and a click, and approximately 1 to 3 sec. between a button-press response and a click. Five blocks of 30 tirlas were conducted and the number of correct guesses from each subject ranged from 40–60% of his total guesses.

(3) *RECORDING AND DATA COLLECTION*

The scalp EEG was recorded using SANEI Ag-Agcl electrodes affixed with EEG paste (SANEI Type 700) at Fz and Cz according to the 10–20 system, referred to the linked earlobes and the forehead was grounded. An additional pair of electrodes served to record eyeblink and eye movement potentials. The EEG and EOG were amplified by SANEI 1A52 amplifier (time constant 0.3 sec. and upper half amplitude decay at 60 Hz.) and recorded on magnetic tapes by a FM recorder (TEAC R-260) for subsequent off-line analysis on a signal averager (SANEI 7T07). The record concomitant with EOG potentials over 50 μV within 800 msec. after the stimulus onset were discarded from the EEG analysis. About 20 potentials, which was free from the artifacts and was excluded from the first potentials of the each block, were summed on a 819.2 msec. period (a sample per 1.6 msec.) from the stimulus onset. In the SGP phase, 8 averaged waveforms recorded from Cz or Fz were analyzed for each subject. The waveforms for the right or left clicks were available in two cases (the same click as the immediately preceding one and the different click from the preceding) and at the two kinds of the ISIs (following with the short and long ISIs). In the RGP phase, 4 waveforms from Fz or Cz were analyzed. The waveforms for the right or left clicks were available in the two cases (the same clicks as the subject's indexed clicks and the different clicks from them). The statistical examination was conducted by repeated-measures analyses of variance or related-means t tests.

RESULT

ERP waveforms "Grand" averaged waveforms recorded at Fz and Cz, which were computed from the data of all subjects obtained from the right and left clicks, are shown in Fig. 1 for a given experimental condition. It shows some similarities for the waveforms. First, they have a negative peak at a latency of about 100 msec.. Second, a large positive component following the negative peak terminated at about 400 msec. and the lateney of the largest positive peak in it was about 250 msec.. Of particular note is that each component of the waveforms for the first clicks showed approximately the same latency.

In SGP, the positive component was larger for the clicks different from the preceding clicks than for the same clicks regardless they were preceded by short intervals (SGP-S) or long intervals (SGP-L). Although in RGP it showed larger amplitude than in SGP, it was larger for the different clicks from the clicks predicted by the subjects than for the same clicks. Therefore, it could be seen that ERPs for the different clicks had a larger positive component than for the same clicks when ERPs were examined from the point of either the preceding stimuli or the subjects' predictions. In the waveforms, however, we could indicate that the dissimilarities of the waveforms between the same and different cases in SGP were different from the dissimilarities in RGP in the following two features. (1) In SGP, there was an additional small positive peak (at a latency of 190 msec.) at the early part of the large positive component and it showed larger amplitudes in the different cases than in the same cases. In RGP, however, we could not identify it but at the point the positive potentials in the different cases were somewhat smaller than in the same cases. (2) The second negative peak following the positive component showed larger amplitudes in the different cases than in the same cases in SGP, but it was not in RGP.

As the record of Fz was simillar to the record of Cz both in the grand averaged waveforms as shown both in Fig. 1 and the statistical analyses below mentioned, we have discribed the results only at Cz.

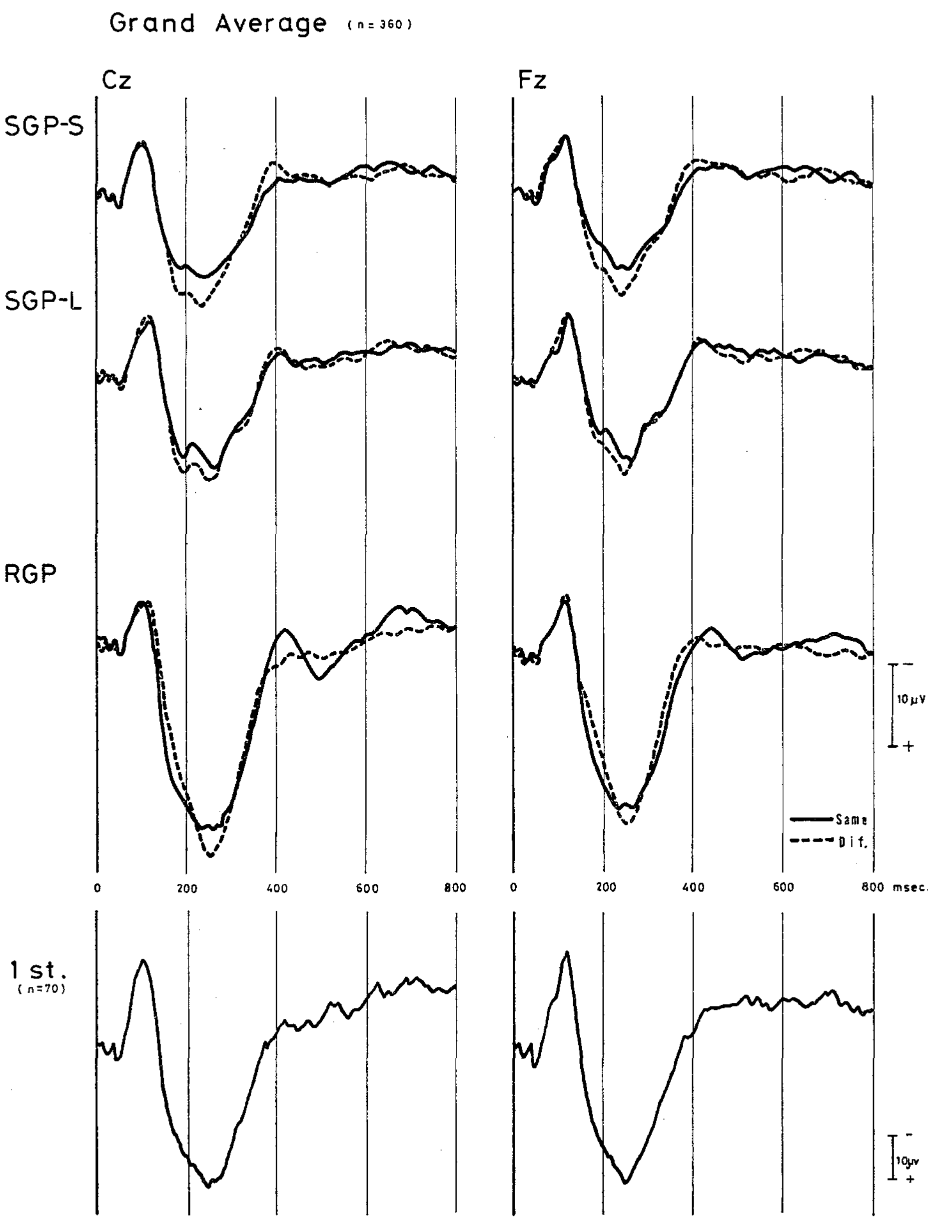

Fig. 1. ERP waveforms recorded at Cz and Fz were averaged from all subjects and for the right and left clicks. The ERPs in the same and different cases are superimposed over SGP-S, SGP-L and RGP. The potentials collected from the 1st stimuli in each block without respect to SGP and RGP are shown at the bottom. SGP-S represented the waveforms for the clicks following with the short ISIs and SGP-L represented clicks following with the long ISIs.

The first negative peak and the large positive component as well as the second negative peak following this could be found in the grand averaged waveforms except for the first stimuli on the blocks. Therefore, in the same or different cases of SGP-S, SGP-L and RGP, we identified the four peaks in each ERP for the right or left clicks in each subject. The latency of the first negative peak (N110) was 106 msec. ± 14 msec. (Mean$\pm$SD), the largest positive peak in the positive component(P250) was 243 ± 35 msec.. The second negative peak (N420) was 421 ± 30 msec., and the positive peak following this (P500) was 495 ± 39 msec.. The latencies of these four peaks and the three peak to peak amplitudes were analyzed statistically. Additionally, the deflections of ERPs at the latencies of 200 msec. and 250 msec. were calculated from the potential levels at 0 msec. and were also analyzed, since we could not consistently identify two positive peaks in the large positive component of all the waveforms.

Latency As shown in Fig. 2, the mean latencies of the four peaks were not different between the ERPs for the right and left clicks ($Fs<1$). Only the latencies of N110 revealed significant difference among SGP-S, SGP-L and RGP ($F=4.72$, $df=2/16$, $P<.05$), but not the latencies of P250, N420 and P500 ($Fs<1$). The latencies of N420 and P500 in the same cases were longer than in the different cases ($F=8.77$, $df=1/8$, $P<.025$ and $F=28.21$, $df=1/8$, $P<.001$, respectively) but N110 and P250 were not ($Fs<1$). Any interaction of the latencies revealed no significant difference by the ANOVAs.

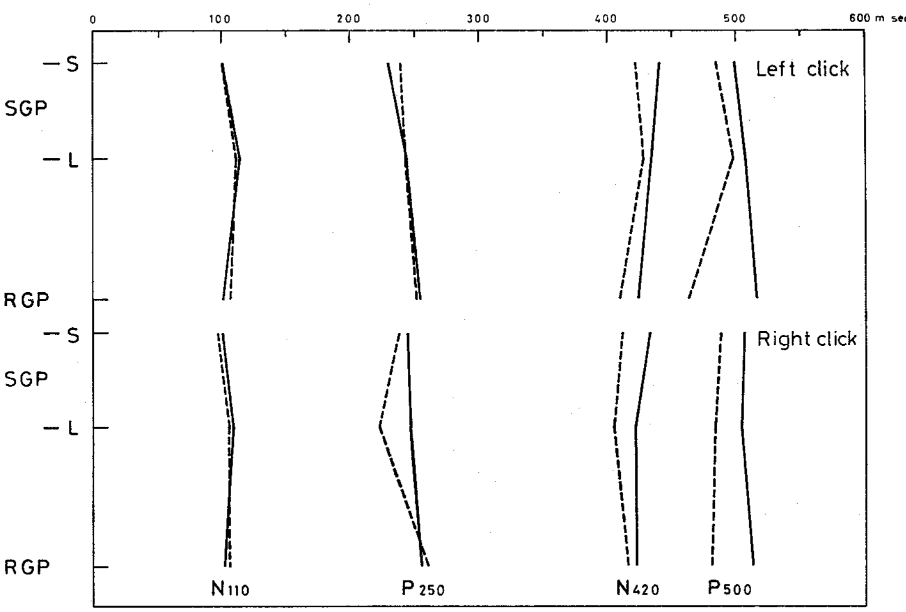

Fig. 2. The mean latencies of N110, P250, N420 and P500 for the right and left clicks of the same and different cases in each experimental condition.

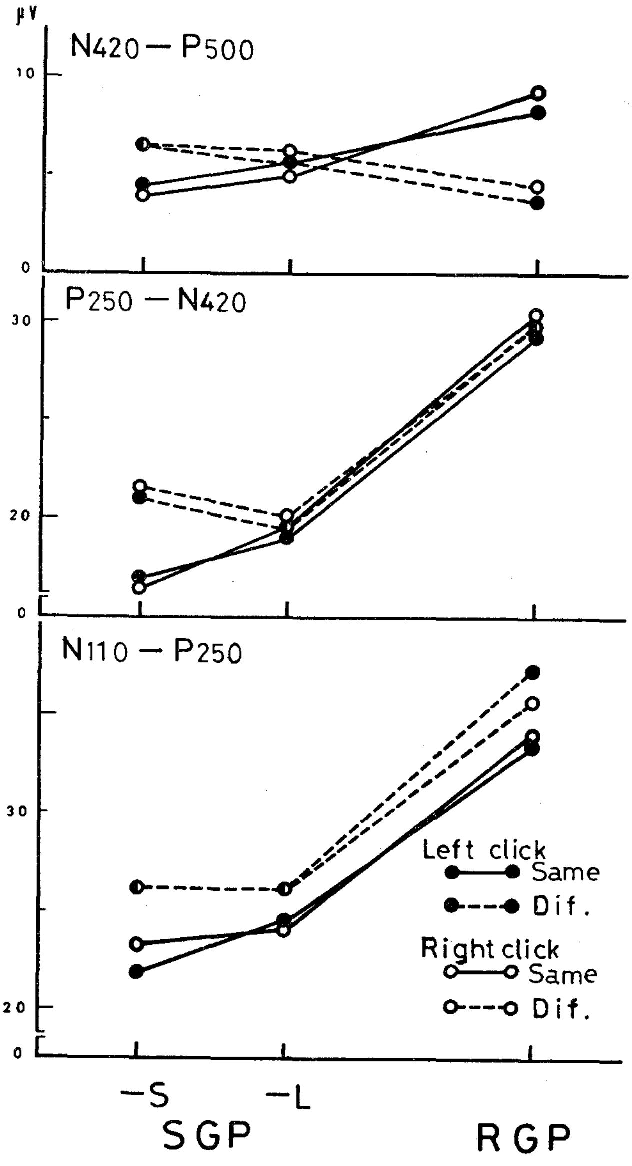

Fig. 3. The means of the 3 peak to peak amplitudes for the right and left clicks of the same and different cases in each experimental condition.

Amplitude As shown in Fig. 3, the three peak to peak amplitudes were not different between the ERPs for the right and left clicks (Fs$<$1). N110–P250 amplitudes of the ERPs computed from the different cases were larger than from the same cases ($F=30.58$, $df=1/8$, $P<.001$) and they were different among SGP-S, SGP-L and RGP ($F=18.26$, $df=2/16$, $P<.001$). P250–N420 amplitudes were also larger in the different cases ($F=42.32$, $df=1/8$, $P<.001$) and there was difference among them ($F=19.55$, $df=2/16$, $P<.001$). Moreover, the same and different cases $\times$ the three conditions interaction revealed a significant difference ($F=4.65$, $df=2/16$, $P<.05$), and only in SGP-S, P250–N420 amplitudes in the different cases revealed significantly different from that in the same cases ($t=4.92$, $df=8$, $P<.001$). As shown at the top of Fig. 3, N420–P500 amplitudes in the different cases were larger than in the same cases in SGP-S and SGP-L, but smaller in RGP. The ANOVA of N420–P500 amplitudes revealed a significant difference of only this interaction ($F=16.55$, $df=2/16$, $P<.001$). The t tests of the amplitudes combined for the right and left clicks confirmed significant differences in SGP-S ($t=3.04$, $df=8$, $P<.02$) and RGP ($t=4.18$, $df=8$, $P<.01$).

The mean potentials at the latencies of 200 and 250 msec. were computed from all waveforms which were summed by the potentials for the right and left clicks together (Fig. 4). The mean potentials in RGP were approximately 10 μV larger than in SGP-S and SGP-L. In SGP-S and -L both potentials of L200 and L250 of the ERPs in the different cases were larger than of the same cases and the t tests confirmed these ($Ps<.05$). In RGP, however, L250 in the different cases was larger

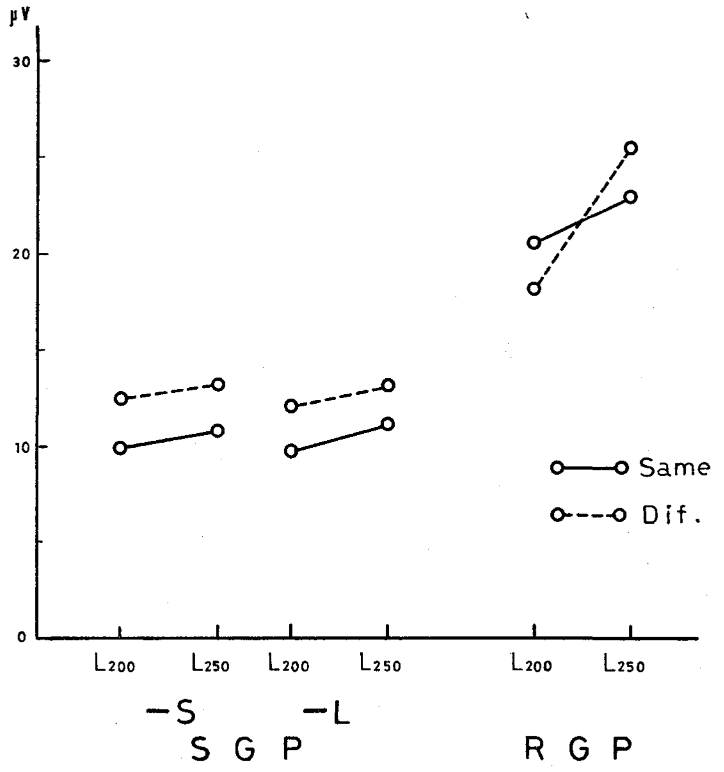

Fig. 4. The mean potentials of the ERPs at the latency of 200 msec. (L200) and 250 msec. (L250) in the same and different cases are represented in the each experimental condition. They were measured from the potential levels at the latency of 0 msec..

than in the same cases ($t=2.32$, $df=8$, $P<.05$), but L200 was reversed ($t=2.28$, $df=8$, $P\approx.05$). Finally we could noted that all these analyses were well consisted with the observation about the large positive component upon the grand averaged waveforms.

DISCUSSION

Although the latency of the large positive component was shorter than that of P300 reported in other ERP studies (e.g. Sutton et al., 1965; Duncan-Johnson and Donchin, 1977; Squires et al., 1977a), we could identify it was P300 from the following reasons. As was reported previously, P300 was evoked most certainly to the task relevant events which were infrequently presented in a train under the condition manipulating a priori stimulus-probabilities (Sutton et al., 1965; Squires et al., 1975; Duncan-Johnson and Donchin, 1977). We thought that the two aspects of the infrequent stimuli might be critical to produce P300: i) the stimuli were preceded by the different stimuli and ii) they were not expected by the subjects. In the present experiment, we observed the positive component appeared in the task relevant events (counted or guessed) and it showed larger potential when the stimuli were preceded by the other stimulus (SGP) or the subjects predicted the other stimulus (RGP). The first stimuli in each block also evoked the largest positive component. As those properties with infrequnet task-relevant-events could be seen in the positive component above mentioned, we could identify it as P300.

The ERPs for the same stimuli as the preceding stimuli had a small P300, showing the sequential effect. Since the subjects did not predict the type of next stimulus, this result may be explained by the Wagner's model (Pfautz and Wagner, 1976; Wagner, 1976). The present results, however, did not reveal any difference of the amplitudes of P300 between SGP-S and SGP-L, while Öhman and Lader (1972) reported that the long ISI (10 sec.) condition produced a larger P300 than the short ISI (3 sec.) condition in their attending conditions. This contradictory finding is probably attributed to the subjects' attitude in the present experiment. Namely, they regarded the stimuli following with long ISIs as warning stimuli and following with short ISIs as testing stimuli. Thus, in spite of attending to the stimuli much more in the case of SGP-S than that of SGP-L, the stimuli at SGP-S evoked P300 as large as at SGP-L (e.g. Hilliyard, Hink, Schwent and Picton, 1973).

Although the subjects might be ignorant of the relation of the present stimulus and the next stimulus interposing the long ISIs, P300 for the stimuli of SGP-L showed the sequential effect. So, the sequential effect in SGP-L can not be interpreted by the expectancy model (Squires et al., 1976). Moreover, the comparison of the difference of ERPs between the same and different cases in SGP-S and the difference in SGP-L showed the time decay of the sequential effect (P250–N420 amplitudes). In the present counting task, the subjects are not required to memorize each stimulus until the next presentation of the stimuli. So, we can say that it was retained in STM through each of the long ISIs, because STM was not replaced by other information and/or it could be maintained in STM by rehearsal activity (Peterson and Peterson, 1959; Whitlow, 1975).

The other differences between the same and different cases (N420–P500 amplitudes and the latencies of N420 and P500) may reflect differences of information processing of the stimuli in STM, but we can not explain that for certain now. However, when a stimulus, to which a subject needs task-relevant processing, is presented, what is already represented in STM might not be processed in STM in the simillar way as what is not represented in STM at the time. For instance, in SGP N420–P500 amplitudes in the different cases are larger than of the same cases, but in RGP this relationship is reversed. We may assume that these potentials reflect the activity of further stimulus processing in STM. The different stimuli in SGP are likely to continue to be processed in STM or to be well rehearsed after the presentations. They may evoke a larger potential, because they are represented well in STM. In RGP, the same stimuli as the subject's predictions are good news to him and may be processed positively in STM to solve the task, although they are represented poorly in STM.

When a stimulus is presented under a CRT task, a subject will perform the response bound with it. If it is already represented in STM, it will be poorly primed into STM and may result in a long RT according to Wagner's model. If it is not in STM, it will be well primed and result in a short RT. These are consequences of the change effect. On the contrary, the information about the response or movement as well as that of the stimulus can be prerepresented at the time, if he gave the same response as in the previous trial. If the information about the response associated with the stimulus is already represented in STM, the stimulus will abruptly be able to command to produce this response in STM and then result in a short RT, although it may be poorly primed into STM. If the response is not represented at that moment, it will command the response after retrieving the information from LTM and consequently result in a long RT, although it may be well primed into STM. These are consequences of the sequential effect. These two effects may be alternated by the dominant information contained in STM at the time of the stimulus presentation, whether the information is represented by any of the stimuli or any of the responses. This prediction was partially confirmed in the CRT studies. When the intervals between a response and the onset of the next stimulus were very short, the sequential effect resulted, and when they were relatively long, the sequential effect was not demonstrated (Bertelson, 1961; Bertelson and Renkin, 1966; Hale, 1967a). In addition, if discriminative responses for CRTs were performed by one finger for several buttons, it resulted in the change effect (Williams, 1966; Hannes, 1968; Cantor and Fenson, 1968). This result also supports the present prediction, because we can assume that the alternative finger-responses were composed of the common somatic components in many fragments and then the effect of the memory of the preceding response for the sequential effect was disturbed by the same components of the response. This prediction on CRT from Wagner's model can not solve the discrepant results of the CRT experiments entirely and further experiments are necessary to obtain an appropriate interpretation for such discrepant results.

The stimuli in the same cases of RGP evoked smaller P300 than in the different cases. This is consistent with the predictions from the expectancy model (Squires et al., 1976) as well as from Wagner's model (Pfautz and Wagner, 1976; Wagner, 1976). The fact that ERPs for the same stimuli both in SGP and RGP had a smaller P300 than for the different stimuli is also consistent with the present predictions. The ERPs for the clicks were fairly consistent between SGP and RGP, having the same four peaks of about the same latencies. However, there is some difference in the wave shapes of P300 for the same and different cases between SGP and RGP. According to Wagner's model, the function of the comparator is identical whether the contents of STM have been primed by the stimulus itself (selfgenerated priming) or by retrieval action from LTM of associated cues (retrieval-generated priming). When the same information as that of a presented one is contained in STM at the moment, it will be less primed into STM by the control of the comparator and then it will elicit only a small unconditioned response (Whitlow, 1975) and be processed only by brief rehearsal activity in STM (Terry and Wagner, 1975; Wagner, 1976). We assume that P300 reflects one or more of these information processes. However, since Wagner's model asserted from the finding of overt responses as the subjects' final output (unconditioned responses) or conditioned responses acquired from the trials (Kamin, 1969), we may find the different cortical activity between self-and retrieval-generated priming. If the hypothesis is true, it seems that the early part of P300 (at the latency of about 200 msec.) may be responsible for the different activities of the comparator when the contents of STM have been self- and retrieval-generated.

The present assumption is that an expected stimulus evoked only a small P300 as it is in the expectancy model (Squires et al., 1976). From this point of view, the greatest difficulty in applying the present assumption to the human ERP studies is that task relevant events produce a conspicuous P300. In the present experiment, the stimuli which had to be counted by the subjects or which informed to them whether their guesses were correct or incorrect, evoked P300. The subjects had to prime the stimuli into STM and process the stimuli in STM or active memory to perform these tasks. Therefore, we must consider that a subject can prime information of a stimulus into STM inspite of it being already represented in some features, if he needs it. For instance, Sutton et al. (1967) stated that the stimuli which resolve uncertainty or deliver useful information for a subject evoked P300. It was referred to as the attention effect in many publications (e.g. Hillyard et al., 1973). Although this effect may be in part attributed to the general arousal level (Näätänen, 1975), probably a "positive" function of the other comparator may be assumed. Even when the information about a stimulus (modality, orientation and time of stimulus presentation etc.) is prerepresented in STM, it can be primed into STM, if the subject needs it at the time or if he expects that it can deliver useful information to him. However, we cannot say anything about this positive function now.

In summary, the sequential effect of P300 cannot be fully understood by the subjective expectancy in accordance with the expectancy model (Squires et al., 1976). Wagner (Pfautz and Wagner, 1976; Wagner, 1976) assumed information of a presented stimulus transmitting to STM was interfered with the contents of STM, if they were the same as it. Moreover, it could be primed by stimulus-presentation itself and by retrieval action from LTM of the associated cues. The same stimuli as preceding one and the stimuli which were already expected by a subject evoked a small P300. Therefore, we proposed that P300 may reflect the brain activity which transmits information of a presented stimulus into STM or active memory.

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EVENT RELATED POTENTIALS VARIED WITH THE CONTENTS OF SHORT-TERM MEMORY

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Task relevant stimuli evoke a late positive potential (P300) in human EEG. When they are unexpected by a subject or surprised him, they produce a larger P300 than they are expected or unsurprised. Squires et al. (1976) proposed the expectancy model which was analogized from choice-reaction time experiments. It assumed that the expected stimuli evoked only a small P300 and resulted in short reaction times. They also evoke a small P300 if the same stimuli have been presented precedingly, but evoke a large P300 if different stimuli have been presented. The expectancy model interpreted this sequential effect by the assumption that a subject tended to expect the same as the stimulus presented immediately or shortly before. However, like a short-term habituation, it should be interpreted to mean that when a stimulus was prerepresented in short-term memory at the time of its presentation, did not evoke a large P300. We could believe that the expected stimuli were represented in short-term memory by retrieval from long-term memory and the preceding stimulus was represented in short-term memory by a dacaying function of short-term memory. These notions were originally proposed on the basis of animal learning experiments by Wagner (Pfautz and Wagner, 1976; Wagner, 1976). He assumed that if a stimulus was prerepresented in short-term memory, its information was poorly transmitted to short-term memory, and consequently it was poorly processed and then elicited only small responses. However, if it was not prerepresented in short-term memory, its information was well transmitted and processed and then it elicited large responses. The purpose of the present experiment was to find whether the sequential effect of P300 would be free from the subjective expectancy. Moreover, we would like to confirm that P300 for the stimuli which were already represented in short-term memory at the time was proportionally smaller than that which was not represented, whether they were prerepresented by preceding presentation of themselves or by retrieval action from long-term memory.

The two monaural clicks (to the right or left ear) were presented in random orders. In the SGP condition, the subjects were instructed to count the numbers of the presentations of the right and left clicks, respectively. In the RGP condition, they were instructed to guess the right or left of the following click immediately before the presentation of the clicks in a discrete trial. The EEG was recorded from Fz and

Cz. In the SGP condition, the averaged ERP waveforms for the right and left clicks were collected in the different cases where the clicks were different from the preceding clicks, and in the same cases where the clicks were the same as the precedings. In the RGP condition, they were also collected in the different and same cases with respect to the subjects' predictions.

Results in both conditions showed a larger positive peak at the latency of about 250 msec. in the different cases than in the same cases. The same stimulus as was represented in short-term memory at the time of the presentation evoked small P300, whether it was presented shortly before or retrieved from long-term memory. We would conclude that these results should be interpreted by Wagner's model and the P300 reflected the brain activity of information processing of a presented stimulus priming into short-term memory.