Facilitation of heartbeat self-perception in a discrimination task with individual adjustment of the S+ delay values

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Received 17 April 2002; accepted 30 April 2003

Abstract

Thirty-two subjects (16 women, 16 men) performed two tasks that were the result of adapting the heartbeat perception tasks produced by Whitehead et al. [Biofeedback Self-Regul. 2 (1977) 571] and Katkin et al. [Psychophysiology 19 (1982) 568], respectively. In the Whitehead task, the delay values were the standard 128 ms for the S+ stimulus and 384 ms for the S− stimulus after the R-wave in one case; in the other case, the delay values were individually adjusted according to the median of the distribution of interval choices in an adaptation of the Brener and Khvitsin [Psychophysiology 25 (1988a) 554; Psychophysiology 25 (1988b) 436] task carried out previously. In the Katkin procedure, in one case S+ always occurred at a fixed interval (100 ms), whereas S− occurred at uniformly increasing intervals in relation to the R-wave. In the other case, the S+ and S− intervals were also individually modified according to the performance in the Brener and Khvitsin task. The results indicate that when the S+ values are individually adjusted, the sensitivity of subjects, as reflected in the 2 arcsin(p(+/2)) values, significantly improves in the Whitehead task. Additionally, it was seen that the performance deteriorated from the first to the last 50 trials, especially when the S+ values were adjusted.

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Keywords: Heartbeat self-perception; Discrimination task
1. Introduction

In the context of the psychophysiological tradition, numerous researchers have held that emotional states require activation of the autonomic nervous system (James, 1884; Schachter and Singer, 1962; Mandler, 1984). Over the last 50 years, many authors influenced by this position have studied or are currently studying autonomic activity associated with different emotions (Levenson, 1992). From a clinical perspective, the perception of physiological arousal and the interpretation of those perceptions by patients is considered to be a key aspect in some disorders such as anxiety to speak in public or panic (Clark and Fairburn, 1997). A fundamental explanatory mechanism in biofeedback techniques could be visceral perception. Several authors (i.e. Brener, 1982) have argued that self-control over a physiological response is possible only if the subject can discriminate its sensory consequences. To some extent, these ideas have influenced the development of the best psychophysical procedures to measure the perception of physiological responses (Jones, 1994).

Despite the importance of autonomic self-perception in emotion and self-regulation, it has always been a challenge to obtain reliable and valid data on autonomic perception (Jones, 1994). There are several simple questionnaires (Mandler et al., 1958; Pennebaker, 1982; Shields and Stern, 1979), but their intercorrelations and validity have been disappointing (Gannon, 1977). Additionally, researchers have produced a variety of objective tasks, which usually focus on heartbeat activity. Whitehead et al. (1977) designed one of the most frequently used procedures. In each trial, a series of exteroceptive stimuli (lights, sounds, vibrations, etc.) is presented either simultaneously (S+) or not (S−) with heartbeats. Typically, each of the ten stimuli in an S+ series appears 128 ms after the production of the R-wave of the electrocardiogram, whereas each stimulus in the S− series follows the R-wave with a delay of 384 ms. Subjects indicate whether the external stimuli have been immediate or delayed after each trial.

The procedure designed by Whitehead et al. has been criticized for being too difficult to solve. Only about 25% of subjects feature discrimination above chance (Katkin, 1985). To make the task easier, Katkin et al. (1982) modified the delay intervals between the R-wave and the exteroceptive stimuli. In the S− condition, the N+ 100Bi formula was used to determine the S− tone spacing. N is a random number between 1 and 200 and Bi is the ith heartbeat in the train of ten beats. N is fixed for any given trial. If, for example, N = 100, after the first heartbeat, the tone is delayed 130 ms; after the second heartbeat, the tone is delayed 160 ms; after the third heartbeat, it is delayed 190 ms; and after the tenth heartbeat, it is delayed 400 ms. Thus, in the procedure of Katkin et al. subjects discriminate between fixed and variable delays between R-waves and exteroceptive stimuli.

Usually, 100–200 trials are presented in these tasks, and the performance can be analyzed by using signal detection theory (Swets, 1964). Whitehead et al. (1977) used the delay values of 128 and 384 ms because it is argued that at 128 ms after the R-wave, numerous sensory events of the heartbeat are present, whereas they have already disappeared at 384 ms. In the Katkin procedure, the idea is very similar. Since the R-wave precedes ventricular contraction by about 50–100 ms, the S+ stimulus is approximately contiguous to left ventricular contraction. Nevertheless, this assumption has recently been questioned (Clemens,
an alternative idea has emerged according to which sensations continue to occur throughout the cardiac cycle in various bodily zones and not exclusively in the heart. According to this idea, it is believed that some sensations may be found in the ventricular zones and have a very short latency, while others may be located in areas as peripheral as the fingers and take longer to be available. A consequence of this would be the impossibility of establishing unequivocal proof of the temporal values of $S_+\text{ and } S_-$ stimuli, and the need to accept a great variability in the times at which each person detects heartbeat/exteroceptive stimuli simultaneity.

Brener and Kluvitse (1988a,b) adopted this more flexible approach to the timing of cardiac sensations. In their task, they made no a priori specific judgments on the optimal spacing of $S_+$ and $S_-$ delays and instead let subjects find their own optimum point. Subjects perform 30 trials in each of which the $S_+$ auditory delay in relation to the R-wave may fluctuate from 0 to 500 ms in steps of 100 ms. The task of subjects is to sample the six intervals until they locate one that yields tones that are simultaneous with heartbeat sensations. No limitations are placed on the number of examinations of each interval or the number of stimuli presentations of each inspection. Performance is analyzed in terms of the distribution of choice judgments across the delays, so that the heartbeat detectors can be identified regardless of whether they are detecting beats close to or distant from the heart.

These studies (Brener and Kluvitse, 1988a,b; Ring and Brener, 1992) have yielded a higher proportion of individuals who are able to detect their heartbeats—approximately 60%—and have suggested somewhat longer delay values, compared with the tasks produced by Whitehead et al. (1977) and Katkin et al. (1982). In general, it has been found that the temporal delays of 100, 200 and 300 ms between the R-wave of the EKG and the external stimuli result in a higher frequency of perception of simultaneity than delays of 0, 400 or 500 ms. From a flexible stance which assumes the existence of mechanoreceptors in the entire body, it can be argued that in the time that elapses between 100 and 300 ms after the myocardial contraction, heartbeat events with equivalent saliency are available.

The purpose of this study was to test whether the sensitivity of heartbeat perception obtained in the adaptations of the tasks of Whitehead et al. (1977) and Katkin et al. (1982), using the standard $S_+\text{ and } S_-$ values, could be improved when both delays are individually adjusted for each subject based on the median of his/her distribution of choices in an adaptation of the Brener and Kluvitse (1988a,b) task carried out previously. We postulated that if an improvement were found, it would lend support to the supposition that great variability exists in the timing of heartbeat sensations. Additionally, we also studied the development of heartbeat detection across the tasks.

2. Methods

2.1. Subjects

The participants were 32 undergraduates of the Department of Psychology of the University of Granada in Spain. The sample consisted of 50% males and 50% females. Age
range was 18–37 years (mean = 22 years). Weight range was 48–80 kg (mean = 58 and 69 kg for women and men, respectively) and height range was 157–183 cm (mean = 164 and 174 cm, respectively). Participation was on a voluntary basis with academic points given to better the participant’s grades in their university courses.

2.2. Apparatus

During the task, subjects sat comfortably in chairs in front of a computer (Amstrad 386SX) in the experimental area of the laboratory. The computer presented the instructions, sounds and acquired responses of the task through its keyboard. The computer was connected through its serial port to another one (Inves 486SX), located in the instrumentation area, which received and sent the bioelectrical signals to the screen. The electrodes (Grass E5SH) were placed on the subjects using standard lead II configuration for the electrocardiogram recording. The electrodes were connected to a pre-amplifier Grass model 7P3B. The output channel of the polygraph (Grass Model 7) was digitized by use of a Data Translation model 2801-A A/D card. The tasks were programmed using locally developed software.

2.3. Procedure

Subjects completed an adaptation of the alternative preferred choice task (Brener and Kluvitse, 1988a,b) on one occasion, and an adaptation of the Whitehead discrimination task (Whitehead et al., 1977) and the Katkin discrimination task (Katkin et al., 1982) on two occasions, once using the standard S+ and S− delays, and once using the individually adjusted S+ and S− delays. These tasks were carried out in three sessions over a period ranging from 5 to 69 days (average duration was 18 days). In the first session, the subjects performed the Brener and Kluvitse task; in the remaining sessions, the participants completed two discrimination tasks. The order of the Whitehead and Katkin tasks as well as the use of the standard or adjusted S+ and S− delays was simultaneously counterbalanced over sessions two and three.

2.3.1. Adaptation of the Brener–Kluvitse task

There were 30 choice trials similar to those produced by Brener and Kluvitse (1988a,b), but with a much narrower range of delay values. Subjects compared five R-wave-to-tone intervals, which corresponded to 150, 200, 250, 300 and 350 ms delays. Their task was to choose the interval in which the heartbeat sensation and the sounds appeared to be more simultaneous. The sounds were 800 Hz, had a 50 ms duration, and were presented by means

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1 These four experimental conditions (Whitehead task with standard delays, Whitehead task with adjusted delays, Katkin task with standard delays, and Katkin task with adjusted delays) were counterbalanced according to four sequences: (1) Whitehead standard, Whitehead adjusted, Katkin adjusted, and Katkin standard; (2) Whitehead adjusted, Katkin standard, Katkin adjusted, and Whitehead standard; (3) Katkin standard, Katkin adjusted, Whitehead standard, and Whitehead adjusted; and (4) Katkin adjusted, Whitehead standard, Whitehead adjusted, and Katkin standard. The first two tasks of each sequence were administered in the second session, and the last two were presented in the third session. Each sequence was administered to eight participants (four women and four men).
of a computer speaker located in the experimental area. At the beginning of every trial, each of five temporal intervals was randomly assigned to one numeric key on the keyboard. Participants examined the intervals in any order and for as long as and as many times as they desired, with the constraint that each one was examined at least once. When the stimuli presented at the current interval were judged to be simultaneous, subjects pressed the designated response key to register the selection and end the trial. After the tenth and twentieth trials, subjects were given a break. Session length ranged from 60 to 90 min.

Typically, researchers (Brener and Kluvitse, 1988a,b; Brener et al., 1993) have used delay values of 0, 100, 200, 300, 400 and 500 ms as \( S^+ \) stimuli. However, we used more closely spaced values, and covered a smaller time range. We did this precisely in order to specify the optimal delay time for each subject, given our goal of using the chosen time for \( S^+ \) stimuli in the Katkin and Whitehead tasks.

### 2.3.2. Adaptation of the Whitehead task

Each subject performed the Whitehead task on two occasions. Once, the delay value was 128 ms in the \( S^+ \) trials and 384 ms in the \( S^- \) trials, that is, the same values as used by Whitehead et al. (1977). On another occasion, the values were adjusted individually for each subject in accordance with his/her performance in the Brener and Kluvitse task. The delay in the \( S^+ \) trials corresponded to the median of the distribution of the choice trials of this task. Consistent with recent variations in the Whitehead task (Okifuji et al., 1988; Clemens et al., 1988; Eichler and Katkin, 1994) the \( S^- \) delay was set to \( S^+ \) plus 300 ms.

On each occasion in which this task was performed, 100 trials were administered, in each of which subjects had to decide whether the series of sounds was simultaneous or not with the their heartbeat. Depending on the subject’s selection, he/she pressed one designated numeric key on the keyboard. Half of the trials involved \( S^+ \) stimuli and the other half involved \( S^- \) stimuli, and in each block of ten trials, half of each type were randomly presented. Ten heartbeats, and thus ten sounds, were included in each trial. The entire set of 100 trials required about 25 min to complete. As in the adaptation of the Brener and Kluvitse task, the sounds were 800 Hz pure tones and had a duration of 50 ms. All remaining aspects of the Whitehead task were similar to the Brener and Kluvitse procedure.

### 2.3.3. Adaptation of the Katkin task

The procedure here was parallel to that of Katkin et al. (1982). Each subject also carried out this task on two occasions. The length of the trials was defined as ten beats. Once, as in the task by Katkin et al. (1982), the delay was 100 ms in the \( S^+ \) trials. In the \( S^- \) condition, the R-wave-to-tone interval was determined by means of the \( (N+30Bi) \) formula. \( N \) was a random number between 0 and 200 and \( Bi \) was the \( i \)th heartbeat in the series of ten beats. Once this number was chosen before any trial, 30 ms were added to the delay, beginning with the first heartbeat and continuing for each of the ten beats on the trial (30 \( Bi \)). That is, for \( N = 50 \), for instance, the \( S^- \) delay would be 80, 110, 140, 170, 200, 230, 260, 290, 320 and 350 ms throughout the series. Obviously, depending on the \( N \) value, these delays could differ in another trial. On the other occasion, the values were adjusted individually for each subject according to his/her performance in the Brener and Kluvitse task.
delay in the $S^+$ trials corresponded to the median of the distribution of choices of this task (therefore, on this occasion, the $S^+$ delay was identical to that in the adjusted Whitehead task). $S^-$ values were again ($N+30\%$) ms, but this time $N$ was a random number between 0 and the median of the distribution of the choice trials of the Brener and Kluitse task. That is to say, the range of $N$ values was also adjusted individually in this case. In each trial, the subjects had to decide whether the series of sounds were presented at either a fixed or variable time interval after the heartbeat. In all remaining features, the adapted Katkin task was identical to the adapted Whitehead task.

2.4. Data analysis

In the Brener and Kluitse task, a distribution of the judgments as a function of the delay intervals was obtained for each participant and these direct values were transformed into percentages. In order to obtain information about the subject’s interval preferences, an ANOVA was performed on the percentages of interval judgments, transformed into square roots, including the temporal delay (150, 200, 250, 300 and 350 ms) as a repeated measures factor. Also, each subject’s median was computed from the frequency distribution of delay choices. According to with the suggestions made by Ring and Brener (1992) and Brener et al. (1993), the use of the median interval to index when the heartbeat sensation is detected allows a finer specification of the temporal localization than the modal interval.

For the data produced by the Whitehead and Katkin tasks, the decisions made by each subject (simultaneous or not; fixed or variable time) in every trial were calculated as a function of whether the trial was indeed simultaneous or not, and fixed or variable, respectively. Participants were classified as heartbeat detectors if the number of correct responses [(hits + correct rejections) / $N$] deviated significantly from chance according to the binomial expansion ($> 58.5$ correct responses out of 100 trials). Additionally, for each subject’s data, the $2(\arcsin(p(A)^{1/2}))$ values were obtained, where $p(A) = 0.5 + (0.5(\text{hits}) - 0.5(\text{false alarms}))$, as recommended by Green and Swets (1966). The classification of the participants as detectors versus non-detectors was later used to calculate the proportion of detectors as a function of the different $S^+$ and $S^-$ delays. In addition, the analyzes also considered whether the performance changed between trial blocks in the first and the second half of the trials.

Researchers have used different statistical indices of heartbeat detection accuracy. In the case of experiments employing variants of the Whitehead procedure, percent correct, $2(\arcsin(p(A)^{1/2}))$, $P(H)$, $d’$, $A’$, and various other indices have all been used. Yet, criteria to identify whether subjects actually discriminate heartbeat sensations have not been clearly articulated (Brener et al., 1993). In the present study, we used the binomial criterion to estimate the proportion of heartbeat detectors, since the Whitehead and Katkin procedures are two choice tasks. We used the $2(\arcsin(p(A)^{1/2}))$ values as an index of sensitivity because the number of trials administered was small, the base rate probability of $S^+$ and $S^-$ trials was 0.5, and because the index can be submitted to general parametric analysis (Jones, 1994). Both types of data—the proportion of detectors and sensitivity—are useful to compare our results with those obtained in other studies and to test our hypothesis.
Table 1
Percentage of detectors as a function of the discrimination task and the trial block

<table>
<thead>
<tr>
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<th>Whitehead task</th>
<th>Katkin task</th>
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<tbody>
<tr>
<td></td>
<td>Standard delay</td>
<td>Brener–Kluvitse</td>
</tr>
<tr>
<td>First half</td>
<td>22</td>
<td>47</td>
</tr>
<tr>
<td>Second half</td>
<td>16</td>
<td>34</td>
</tr>
<tr>
<td>Total performance</td>
<td>25</td>
<td>44</td>
</tr>
</tbody>
</table>

3. Results

3.1. Choices in each of the delay intervals

The ANOVA of the percentage of choices for each subject, transformed into square roots, as a function of the temporal delay, showed a significant effect ($F(4,124) = 6.788, P < 0.01$, Greenhouse and Geisser, 1959 correction applied). The Newman–Keuls test indicated that subjects judged heartbeat sensations to be more simultaneous with tones delivered 150 ms after the onset of ventricular contraction than with tones presented at either 200, 250, 300 or 350 ms delays ($P < 0.05$). The 200 ms interval tended to be preferred more often than the 300 ms ($P < 0.07$) and 350 ms intervals ($P < 0.07$).

3.2. Individually-adjusted versus standard $S^+$ criteria

3.2.1. Percentage of heartbeat detectors

Table 1 shows the percentage of detectors as a function of the discrimination task and the trial block. In the standard version of the Whitehead task, the proportion of detectors was lower than in the adjusted version ($\chi^2 = 7.95, P < 0.01$). Only seven subjects qualified as detectors in both versions of the task. Seventeen subjects remained as non-dectors in both performances. In the standard version there were nine reverse discriminators, whereas in the adjusted version only five subjects were reverse discriminators.

In both versions of the Katkin task, an identical percentage of participants were detectors, but there were more detectors in the first half than in the second ($\chi^2 = 5.79, P < 0.01$, and $\chi^2 = 19.94, P < 0.01$, for standard and adjusted, respectively). Only eight subjects qualified as detectors in both versions of the task. Ten subjects remained as non-dectors in both performances. Six participants in the standard version and ten in the adjusted one were reverse discriminators.

3.2.2. Heartbeat sensitivity

Table 2 shows means for the $2(\arcsin(p(A^{1/2)}))$ index as a function of the discrimination task, and $S^+$ delay, for each trial block and entire set of 100 trials. In the adaptation of

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Table 2  
Means (S.D.) for the $2\cdot\arcsin(p(A^{1/2}))$ index as a function of the discrimination task and $S +$ delay for each trial block and entire set of 100 trials.

<table>
<thead>
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<th>Katkin task</th>
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<tbody>
<tr>
<td></td>
<td>Standard delay</td>
<td>Brener–Kluvitse</td>
</tr>
<tr>
<td>First half</td>
<td>1.691 (0.295)</td>
<td>1.795 (0.303)</td>
</tr>
<tr>
<td>Second half</td>
<td>1.675 (0.222)</td>
<td>1.742 (0.261)</td>
</tr>
<tr>
<td>Total performance</td>
<td>1.683 (0.240)</td>
<td>1.769 (0.263)</td>
</tr>
</tbody>
</table>

the Whitehead task, it can be seen that the greatest sensitivity resulted when the delay that defined $S +$ corresponded to the median of the choice distribution in the Brener and Kluvitse task. Also, high sensitivity can be observed in the first half of the tasks, especially when the delay values are individually adjusted.

The $2\cdot\arcsin(p(A^{1/2}))$ values were entered into a discrimination task × delay value × trial block ANOVA for repeated measures on all three factors. This analysis resulted in a significant effect due to trial block ($F(1,31)=5.73, P<0.03$). In the first half (mean = 1.733), sensitivity was higher than the second half (mean = 1.692). The interaction between discrimination task and delay value was very close to the generally accepted levels of significance ($F(1,31)=4.00, P<0.06$). The same thing happened with the delay values × trial block interaction ($F(1,31)=3.73, P<0.07$). No other main or interaction effect was significant or close to the generally accepted significance levels.

Since the main questions involved the effect of delay value adjustment on the two tasks, rather than the differences between the tasks in the effect of such an adjustment, we analyzed the simple main effects of delay values × discrimination task interaction. We found that in the adaptation of the Whitehead task, the adjusted delays according to the median of the distribution of choices in the Brener and Kluvitse task facilitated higher sensitivity scores (mean = 1.769) than the standard delay (mean = 1.683) ($F(1,31)=6.57, P<0.02$). In the adaptation of the Katkin task, such differences were not significant ($F(1,31)<1$).

As regards the delay values × trial block interaction trend, performance was higher at the beginning of the session than at the end. This effect was primarily due to an especially high performance in the first 50 trials when the delay values were individually adjusted.

3.3. Reliability of sensitivity across the session

Since performance deteriorated during the second half of the task, and one goal of the study was to determine whether the number of trials could be reduced, the Pearson correlations were computed between sensitivity scores based on the first and second halves of the sessions in each presentation of the tasks. In the Whitehead task, the between-half correlations were 0.73 and 0.74 for the standard and adjusted criteria, respectively. The corresponding correlations of the Katkin task were 0.13 and 0.47.

3.4. Median of the distribution of choices as a function of detection ability in the Whitehead task

One important feature of the procedure used in this study is the individually adjusted delay in the discrimination tasks. The results of the Whitehead task indicate that when
S+ and S− delays are individually adjusted according to the distribution of choices in the Brener and Kluvitse task, sensitivity is higher than when standard delay values are used. We believe that the increase in sensitivity is related to the fact that, in all subjects, the medians are greater than 128 ms—the delay used as S+ in the standard Whitehead task—an indirect way to obtain additional information about this is to compare the values of the median as a function of detection ability.

The data from the median of the distribution of choices in the Brener and Kluvitse task were analyzed in two independent one-factor ANOVAs, one for the standard condition, and the other one for the adjusted condition. In the standard version of the Whitehead task, there were significant differences in the median of the distribution of choices ($F(1,30) = 6.18$, $P < 0.02$). Detectors featured lower values (mean = 214 ms) than non-detectors (mean = 242 ms). In the adjusted version, there were no significant differences (224 and 234 ms for detectors and non-detectors, respectively). Therefore, these results suggest that the participants who were able to perform the Whitehead task without adjustment were the ones whose individually-determined delays were closer to the standard delay value (128 ms). Detection ability does not seem to have been generally related to shorter individual delays.

To support this interpretation, we analyzed the differences in sensitivity between the standard delay and the individually adjusted conditions, in those participants whose median in the distribution of choices in the Brener and Kluvitse task was higher than 1 standard deviation (that is, > 257 ms above the median), lower than 1 standard deviation (that is, < 203 ms below the median), and between +1 and −1 standard deviation. The average of the differences in the $2(\arcsin(p(A)^{1/2}))$ values was 0.12 in favor of the adjusted condition in the high group ($N = 5$); in the intermediate group ($N = 23$), the average was 0.08 in favor of the adjusted condition; in the low group ($N = 4$), the average was 0.002 in favor of the standard condition. Therefore, it seems that the differences between the median of the participants and the S+ delay standard (128 ms) are related to the differences in sensitivity between the standard and the individually adjusted conditions.

3.5. Age, weight, height, and time between sessions as a function of detection ability

To avoid possible alternative explanations of the heartbeat sensitivity results, age, weight, height and time between sessions were entered into various independent one-factor ANOVAs, with detection ability as the between group factor. Significant differences were only found ($F(1,39) = 4.77$, $P < 0.04$) in Height in the Katkin task with standard delays. Non-detectors were taller (mean = 172 cm) than detectors (mean = 167 cm).

4. Discussion

4.1. Sensitivity and individualized adjustments of the delay of the exteroceptive stimuli

4.1.1. Whitehead task

These results corroborate the existence of a great individual variability regarding the moment when heartbeat sensations arise and suggest that the individualized adjustments of the delay bring about better performance. The data clearly indicate that, in the Whitehead
task, when the standard delays of 128 and 384 ms are used for S+ and S− stimuli, respectively, heartbeat self-perception is lower than when both values are individually defined. Additionally, this was reflected in the further observation that 44% of subjects performed significantly better than chance in the adjusted version of this task, whereas only 25% exhibited above chance discrimination in the standard version. It is important to highlight the fact that these results were obtained with manipulations of the time delay using a smaller range and width (150, 200, 250, 300 and 350 ms) than that used by Brener and Klavitse (0, 100, 200, 300, 400 and 500 ms). In addition, these results suggest the usefulness and validity of the Brener and Klavitse task in conjunction with the task designed by Whitehead et al. (1977). When the median of the distribution of choices is used as the S+ delay, performance in the Whitehead task can be improved.

We believe that these results are related to the manipulations that we have introduced, but there are other possible explanations. A first matter that we need to consider is that the individual adjustments included modifications of the values of the standard S− delay. It could be argued, for example, that the improvement of cardiac perception in the adjusted delay condition is due to the fact that the difference between S+ and S− stimuli is 300 ms and not just 256 ms, as happens in the standard delay condition. Moreover, when S+ and S− delays were individually adjusted, the average of S+ values in the group of participants (230 ms) was different from the average of S+ standard values (128 ms). Therefore, the best performance could be attributed as much to the individual adjustment carried out on S+ values as to the average of differences of S+ values with respect to the standard S+ delay.

We believe that the S+−S− differences of both versions of the Whitehead task cannot explain the subject’s performance. Okifuji et al. (1988) found that S+ and S− delays presented 250 and 550 ms after the R-wave, respectively, lead to better performance than do S+ and S− delays presented 100 and 400 ms after the R-wave, although the difference between S+ and S− delays in both conditions is 300 ms. Therefore, discrimination appears to depend on the differences between the S+ values of the two conditions, rather than on the difference between S+ and S− values. We also believe that it is individual adjustment and not the average differences between both delay conditions that has favored the increase in sensitivity. The inverse relationship between median value and sensitivity in the standard Whitehead task supports this interpretation.

When we compared the median values of the choice trials in the Brener and Klavitse task as a function of the detection ability of the participants, we found differences only in the standard condition and not in the adjusted one. Seemingly, in the standard delay condition, the median of the distribution of choices in the Brener and Klavitse task is something important because it explains part of the differences between detectors and non-detectors. Also, since detectors have lower values than non-detectors, presumably what happens is that participants with higher medians have more difficulties performing the standard version of the task.

A similar result can be observed in the study carried out by Brener et al. (1993). We analyzed their data about the Whitehead task considering judgments of simultaneity as correct hits when the stimuli were presented at R + 128 ms. We found that, for the participants, the Pearson correlation between the 2(arcsin(p(A)(1/2))) scores and the median values of the distribution of choices in the Brener and Klavitse task were −0.45, P < 0.01. In this study
as well, the higher the value of the median, the lower the discrimination of the participants in the standard version of the Whitehead task.

If discrimination in the standard version of the task is inversely related to the median, it is reasonable to think that the higher level of discrimination reached in the adjusted version is due to the individualized use of S+ values. It is likely that if we had used an S+ value that coincided with the average of our adjusted condition (230 ms), for example, discrimination would also have improved, but perhaps not to the same degree. An additional fact that supports this idea comes from the observation that the improvement in sensitivity observed in the adjusted delay condition seems to differ in participants depending on the similarity of the median and the value of standard S+ delays. Thus, if we had used the same delay value that coincided with the S+ mean in the adjusted condition (230 ms) for all the participants, instead of using individualized adjustments, improvements in sensitivity would have been smaller, especially in those participants who have a higher median. Consequently, the differences between delay standard and adjusted conditions would be reduced.

4.1.2. Katkin task

In the Katkin task, sensitivity scores and the proportion of detectors (47%) were similar when delay values were standard and when delay values were adjusted for each subject. We still cannot offer a clear explanation why individualized adjustment leads to a significant improvement in the Whitehead task and not in that of Katkin. It may be due to the particular features of the latter task. It is possible that discrimination between S+ and S− delays is not as complete in the Katkin task as in the Whitehead task (Jones, 1994). Any S− trial includes some sounds with delays similar to those used in S+ trials. For example, if N = 0, the delays in the S− trial would be 30, 60, 90, 120, 150, 180, 210, 230, 260 and 290 ms. Accordingly, there would be some sounds with delays similar to the one used in the S+ trials (100 ms). Also, even when N = 200, the 300 ms differences between the S+ and S− sounds would involve only one sound. This problem is also present in the adjusted version of the task. These results match the ones obtained by Eichler and Katkin (1994) and support the use of a fixed interval paradigm over a variable S− delay.

4.2. Heartbeat sensitivity throughout the performance halves

The data indicate that, in the first 50 trials, subjects used their self-detection resources or abilities better than in the other trials, especially when the delay values were individually defined. As can be observed in Table 1, it was during the first half, in the delay adjusted conditions, that higher scores of sensitivity were obtained, both in the Whitehead and the Katkin tasks. Something similar is observed regarding the percentage of detectors. The performance of participants clearly did not improve but rather deteriorated when moving from the first to the second half. This shows that these tasks as they are presented (without information about performance in each trial) are not learning tasks. This interpretation is further supported by the fact that sensitivity did not improve when the discrimination tasks were repeated on the four occasions (F(3,93) < 1). Thus, to obtain "pure" data about heartbeat self-perception, the number of trials could possibly be reduced to 50 or 60 in this type of discrimination task.
Besides, in the Whitehead task, the data indicate an appropriate stability with both the standard as well as the adjusted versions. In the Katkin task, the standard version has a very low stability, while the adjusted one reaches more appropriate levels. These stability data should facilitate our decision to shorten the Whitehead task.

To conclude, the present data point to a link between the subject’s performance in the adaptations of the Brener and Kluvitse task and of the procedure by Whitehead et al. (1977). Performance in the latter can be facilitated by individualizing the delay values based on the median of the selection distributions in the first task. At the same time, performance in the adaptation of the Whitehead and the Katkin tasks deteriorated from the first to the second halves of the tasks, especially when adjusted delay values were used.

Acknowledgements

The authors wish to thank Dr Edwin W. Cook III for his valuable comments and suggestions in the review of the original manuscript.

References


James, W., 1884. What is an emotion. Mind 9, 188–205.

