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International Journal of Psychophysiology 56 (2005) 261–269

INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY

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The influence of anxiety on electrodermal responses to distractors

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Received 19 April 2004; received in revised form 3 November 2004; accepted 21 December 2004
Available online 28 January 2005

Abstract

Contrary to classical expectation, anxiety has been repeatedly observed to be associated with reduced electrodermal activity. This could be the result of successful coping. In line with this interpretation, high-trait anxious individuals performing moderately arousing tasks were expected to manifest a reduced responding to distractors, since this is an adaptive outcome. High- and low-trait anxious participants had to perform a visual search task in a low-stress context. Unrelated neutral and emotional auditory words served as distractors. As a control, neutral and emotional words were also delivered in a no task condition. Skin conductance responses (SCRs) were greater during the task than during the control phase, but in the high anxious group, this increase in SCRs was smaller following emotional distractors than following neutral ones. Moreover, SCRs to both types of words habituated, but the results suggested that only the low-trait anxious participants presented the classical slowing of SCRs habituation when performing the task. All these data are interpreted as an illustration of a resource-based electrodermal inhibition in the high-trait anxious participants. It sustains the idea that mild to moderate anxiety may increase the mastery of situations.

Keywords: Electrodermal activity; Anxiety; Distractibility; Inhibition

1. Introduction

While anxiety is classically thought to be associated with autonomic sympathetic activation (Lindsley, 1951; Claridge, 1967), negative findings with electrodermal activity (EDA), a sympathetic measure, are numerous. Furthermore, at first glance there are apparently paradoxical results. Both tonic and phasic EDA have been observed repeatedly to be reduced in high-trait anxious individuals (e.g. Wilson and Dykman, 1960; Naveteur and Freixa i Bague, 1987; Naveteur and Roy, 1990; Wilken et al., 2000). Even pathologically anxious patients sometimes have initially smaller electrodermal responses than controls, although this is often combined with a subsequent slower habituation in patients (e.g. Lader and Wing,

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doi:10.1016/j.ijpsycho.2004.12.006

1964; Hoehm-Saric et al., 1989, 1991, 1995; Hermann et al., 2002).

Coping abilities underpin several explanations for these findings. On the one hand Hoehn-Saric and McLeod (2000) related reduced sympathetic involvement to coping disorganisation or defensiveness. However, there is no a priori reason to consider reduced autonomic activation as the outcome of maladaptive coping, for surely the ability to lessen reactivity would appear to be an enviable skill for most anxious people. Accordingly reduced EDA could indicate successful coping. In fact Gilbert and Gilbert (1991) related chaotic and ineffective active coping to heightened rather than reduced sympathetic nervous activation, the latter they related instead to passive coping. Although passive coping is often described as maladaptive, some forms such as psychological and behavioural disengagement from a situation, can sometimes be a successful strategy.

Many tasks requiring sustained attention can be performed better if reactivity to distractors is inhibited. This is particularly relevant when distractors can potentially induce an emotional reaction. Habituation of the orienting response (OR) is thought to signify avoidance of attention to environmental stimuli (Waters et al., 1977), and active task engagement usually slows habituation of electrodermal responses (EDR) to irrelevant stimuli (Frith and Allen, 1983; Kroese and Siddle, 1983). Furthermore Kroese and Siddle (1983) convincingly argued, following information processing models of OR habituation (Öhman, 1979), that an internal representation of the eliciting stimuli is necessary for OR habituation, and this requires processing resources. Accordingly habituation to task-irrelevant stimuli may be delayed because resources are mainly allocated to the task rather than to the irrelevant stimuli. For the above reasons reduced electrodermal responding to distractors may reflect successful active coping.

Here high- and low-trait anxious participants were invited to perform a rather easy visual search task which nonetheless required continuous attentional monitoring. Auditory neutral and emotional words acted as distractors during the task. Particular care was given to reduce the situational stress. Indeed, due to their sensitivity to failure or loss of self-esteem (Spielberger, 1972), anxious individuals could use disorganised coping if they detected such a kind of threat. It was anticipated that compared with low anxious participants the high anxious participants would present smaller skin conductance responses (SCRs) to the distractors, or at least faster habituation. The reactivity to the emotional distractors, which are potentially deleterious for task performance, was expected to be specifically reduced in the high-trait anxious participants. To ensure that the involvement in the task was responsible for the differences between high- and low-trait anxious participants, both groups were compared not only during the task but also in a control condition (words delivered alone, no task to perform). Therefore, the expected effects were interactions involving at least, trait anxiety and conditions (task vs control).

2. Method

2.1. Participants

Thirty-three females between the ages of 17 and 21 participated. There were 17 high-trait anxious participants, and 16 low-trait anxious participants. They were selected from a pool of Biology and Sociology students from the University of Lille I based on their trait-anxiety scores as assessed by the self-analysis form of Cattell (1957). Low trait anxiety was defined as a decile score lower than 3. High trait anxiety was defined as a decile score higher than 7. Two additional participants were eliminated after the experiment was run: one high-trait anxious participant who elicited no EDR, and one low-trait anxious participant whose state-anxiety score proved to be atypical with respect to the group's score [participant's score=40, group's mean score=17.00, upper confidence limit=32.70); $P<.001$]. Thirty participants described themselves as right-handers, the remaining three were of mixed handedness.

2.2. Apparatus

EDA was recorded in conductance units (μS) on the left hand. Ag/AgCl Coulbourn electrodes (8 mm diameter of active area) were secured on the medial phalanx of the index and middle finger by means of double-stick collars. Electrodes were filled with a 0.05-M NaCl electrolyte following recommendations by Fowles et al. (1981). EDA was recorded with constant voltage by means of a Coulbourn Instrument coupler. This apparatus was connected to a micro-computer whose homemade software ensures visualisation, storage and analysis of the EDA. Two additional channels detected and recorded traces of auditory and visual stimuli which were under control of a second computer. Auditory stimuli were delivered through binaural headphones. Visual stimuli were presented on a computer screen (17-in., 85-Hz monitor). Left hand temperature was recorded (precision 0.1 °C) with a thermometer Einor 100pt. The thermal sonde resistance "Sketon Rdf 100" was fixed to a copper plate and attached to the second phalanx of the ring finger of the left hand by means of surgical tape.

2.3. Material

2.3.1. Auditory stimuli

The auditory stimuli were 12 one- or two-syllable French words delivered with a sound level ranging from 60 to 65 dB. Six words had a negative emotional value: *cadavre*—corpse, *cancer*—cancer, *inceste*—incest, *meurtre*—murder, *morgue*—mortuary, *suicide*—suicide. Six other words were neutral: *armoire*—wardrobe, *cahier*—notebook, *carton*—cardboard, *chaise*—chair, *porte*—door, *table*—table. All were selected from among a pool of French words whose emotional valence was assessed by Messina et al. (1989) and Silvert et al. (2004). The latter study provided an evaluation in terms of both valence and arousal (see Lang et al., 1990) with the paper-and-pencil version of the Self-Assessment Manikin (SAM; Bradley and Lang, 1994) rating system. The 9-point scales ranged from *unpleasant* to *pleasant* for the valence dimension and from *calm* to *excited* for the arousal dimension. Silvert et al. (2004) also collected ratings of frequency at which these words were used or encountered on a 9-point visual analogue scale. The mean ratings of the 6 emotional and 6 neutral words used were, respectively, 1.32 (SD=0.09) and 4.98 (SD=0.12) on the valence scale, 7.91 (SD=0.21) and 4.82 (SD=0.15) on the arousal scale, and 5.77 (SD=0.81) and 6.00 (SD=0.39) on the frequency scale. The difference was significant for valence [$t(10)=61.42$; $P<.001$] and arousal [$t(10)=29.37$; $P<.001$] but not for frequency [$t(10)=0.61$; *NS*].

2.3.2. Visual stimuli

There were 9 visual stimuli. Each stimulus was composed of 45 black items arranged on a 5 line×9 column display on a grey background. The items consisted in d or p lower case letters written in Times New Roman. One or two commas were added on the top or/and on the bottom of each letter. Each item (letter + commas) was 3° high and 0.7° wide at a distance of 0.7 m. These stimuli have been inspired by the d2 test (Neubauer et al., 1992).

2.4. Procedure

Each participant was tested individually in a light-attenuated room. The ambient temperature varied from 20.5 to 23 °C. The experimenter was female, introduced herself as a high-grade student and behaved cordially. The participant was seated in front of a monitor and a computer keyboard, wearing headphones. She was separated from the experimenter by a three-panel board. The experiment began after a 5-min rest period. EDA was recorded during two phases (control and task) in a counterbalanced order within each group and separated by a short rest. During each recording phase, three neutral and three emotionally negative words were auditorily delivered. Each word of neutral and emotional value was randomly assigned to the control and task phases. This alignment and presentation order was different for each participant within the same group. The participant was invited to keep calm and to avoid unnecessary movements during the two recording phases.

During the control phase, the participant was informed that she would hear words through the headphone and that she would have nothing particular to do during this recording. The three neutral and three emotional words were delivered in a pseudo-randomised order, the three words of the same category being never consecutively presented. The inter-stimulus interval was kept between 25 and 30 s.

During the task phase, the participant was required to fulfil a visual search task. On each display, she had to count all the d letters with two commas. The nine displays were successively presented. The number of targets by display varied from 14–21, with an average of 17. The exposure duration of each display was 25 s. This duration was carefully chosen for the screening of the items to be completed without time pressure. Afterwards the participant had to type out with the right hand the number of targets she had counted. Then she set off the following trial by a pressure on the Enter key. During three trials an emotional word was delivered through the headphones around the middle of the exposure time of the display. During three other trials the word was neutral. The three remaining trials were not disrupted by any word. These three types of trials (disrupted by an emotional word, disrupted by a neutral word and non disrupted) were in a pseudo-randomised order, and three trials of a same type were never in succession. The participant was warned about the probable occurrence of words and was instructed not to pay attention to them and to keep counting the targets. This counting did not require complex reasoning. Instructions did not emphasise the importance of good or bad performance and feedback was never provided regarding performance. All in all participants screened the displays during a maximum of 3 min 45 s, an overall duration which was short enough to minimise boredom.

Once the two recording phases were completed, the participant was invited to recall all the words she heard during the experiment. She was also asked to rate the difficulty of the counting task on a 5-point scale. The level of state anxiety was then retrospectively assessed: using a 7-point scale, the participant rated whether 10 anxiety-laden adjectives (taken from the Q-sort of Bonis de and Lebeau, 1975) matched her overall emotional experience during the experiment. The whole experiment lasted approximately half an hour.

2.5. Data quantification and analysis

SCR refers to the first response $\geq$0.02 μS which occurred in an interval of 1–3 s after the onset of a word stimulus. Skin conductance level (SCL) corresponds to the conductance value computed at the onset of a word stimulus. Left hand temperature was measured three times during the experiment: before the first recording, between the two recordings and after the second recording. The state-anxiety score of each participant consisted in the sum of ratings of the ten anxiety-laden adjectives. The performance at the visual search task was computed in terms of both omissions and false alarms. However, given that false alarms were very sparse, only the omission scores were analysed.

Each physiological (SCR, SCL, hand temperature) and psychological (word recall, counting performance, rating of the task difficulty and state anxiety) dependant variable was submitted to an analysis of variance (ANOVA; SPSS-PC). Violations of sphericity assumptions were counteracted using Greenhouse–Geisser adjustment of the degrees of freedom. All the ANOVAs included Trait anxiety (low, high) and Phase order (control-task, task-control) as between-participant factors. The other variables were all within-participant factors and differed as a function of the dependent variable taken into account. The Tukey HSD test was used for post-hoc comparisons.

3. Results

3.1. Psychological data

3.1.1. State-anxiety scores

A 2 (Trait anxiety: low, high)×2 (Phase order: control-task, task-control) ANOVA was performed. Only the main effect of Trait anxiety was significant [$F(1,29)=8.18$; $P<.01$]: the high-trait anxious participants experienced a greater state anxiety (29.53, SD=13.16; maximum possible value: 70) than did the low-trait anxious participants (17.00, SD=3.86).

3.1.2. Rating scores of the visual search task difficulty

A 2 (Trait anxiety: low, high)×2 (Phase order: control-task, task-control) ANOVA was performed. The main effect of Trait anxiety was significant [$F(1,29)=4.56$; $P<.05$]: the high-trait anxious participants considered the task easier (mean difficulty score: 2.23, SD=0.75; maximum possible difficulty score: 5) than the low-trait anxious participants (2.75, SD=0.58).

3.1.3. Performance scores to the visual task

On average 1.5 (SD=2.45) targets were omitted with an average performance of 90.8% of correct detection. A 2 (Trait anxiety: low, high)×2 (Phase order: control-task, task-control)×3 (Trial type: disrupted by a negative word, disrupted by a neutral word, not disrupted)×3 (Trial: 1–3) ANOVA was performed upon the performance scores. No significant result arose from this analysis.

3.1.4. Word recall

A 2 (Trait anxiety: low, high)×2 (Phase order: control-task, task-control)×2 (Phase: control, task)×2 (Word type: neutral, emotional)×3 (Trial: 1–3) ANOVA was performed on the number of words recalled. This analysis revealed a main effect of the Phase [$F(1,29)=67.02$; $P<.001$]: the words delivered during the control phase were significantly better recalled (mean number of words recalled : 2.17, SD=0.87) than the words delivered during the task (0.79, SD=0.87). The main effect of the Word type was also significant [$F(1,29)=13.76$; $P<.001$]: more emotional words were recalled (1.68, SD=1.01) in comparison to neutral words (1.27, SD=1.17). No other effects reached significance.

3.2. Hand temperature

A 2 (Trait anxiety: low, high)×2 (Phase order: control-task, task-control)×3 (Measure: 1–3) ANOVA was performed on hand temperature. This indicated only a significant effect of Measure [$F(2,58)=10.91$; $P<.001$], reflecting an increase in hand temperature.

3.3. Electrodermal activity

3.3.1. SCL

A 2 (Trait anxiety: low, high)×2 (Phase: control, experimental)×2 (Phase order: control-experimental, experimental-control)×6 (Trial: 1–6) ANOVA was performed upon SCL. The Phase×Order interaction was significant [$F(1,29)=8.12$; $P<.01$]. When the control phase occurred first, SCL was higher during the task phase (9.40 μS, SD=5.28) than during the control phase (8.19 μS, SD=4.89) [$P<.05$]. When the task phase occurred first, SCL did not vary significantly between both phases (task phase: 9.05 μS, SD=5.80; control phase: 9.39, SD=5.72). No other significant result arose: notably no significant difference in SCL between the high- (8.16 μS, SD=3.69) and low-trait anxious participants (9.91μS, SD=6.72) [$F(1,29)=0.79$; *NS*].

3.3.2. SCR magnitude

A 2 (Trait anxiety: low, high)×2 (Phase order: control-task, task-control)×2 (Phase: control, task), ×2 (Word type: neutral, emotional)×3 (Trial: 1–3) ANOVA, was performed on SCR magnitude. The results are shown in Fig. 1 as a function of Word type and in Fig. 2 as a function of Phase and Trial. The ANOVA revealed a main effect of the Phase [$F(1,29)=15.48$; $P<.001$]: SCR magnitude was higher during the task (0.54 μS, SD=0.38) than during the control phase (0.36 μS, SD=0.36; Figs. 1 and 2). The main effect of Trial was also significant [$F(2,58)=15.71$; $P<.001$; Fig. 2], indicating a decrease in SCR magnitude with successive trials. The main effect of Trait anxiety was not significant [$F(1,29)=1.42$; *NS*]. The main effect of Word type was also non significant [$F(1,29)=2.41$; *NS*]. There was a significant Trait anxiety×Phase×Word Type interaction [$F(1,29)=4.48$; $P<.05$; Fig. 1], which was clarified by considering each group separately. Results showed that the Phase×Word type interaction was significant in the high-trait anxious participants [$F(1,15)=8.24$; $P<.05$] but not in the low-

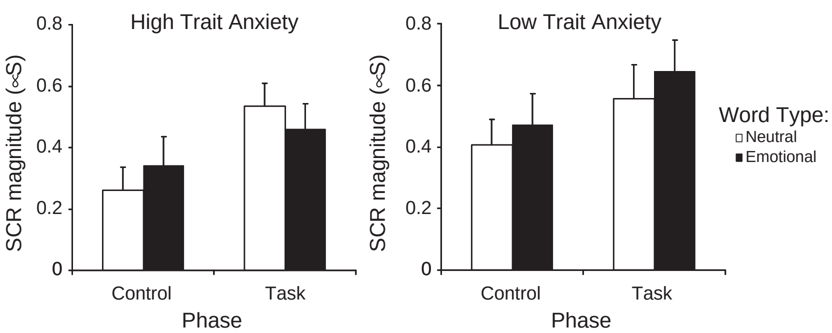

Fig. 1. Mean SCR magnitude and standard error as a function of the word type for the high- and low-trait anxious groups, during the control phase (words presented without any task) and during the task.

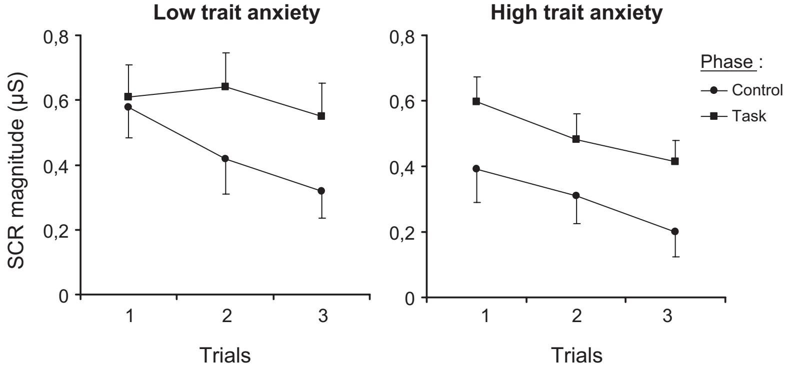

Fig. 2. Mean SCR magnitude and standard error across trials for the high- and low-trait anxious groups, during the control phase (words presented without any task) and during the task.

trait anxious participants. Relevant post-hoc comparisons indicated that in the high-trait anxious participants, the difference between control and task phases was significant for neutral words [P<0.001] but not for emotional words. In contrast this difference was significant for both types of words in the low-trait anxious participants [both Ps<.05]. The between group comparisons showed that during the task, the SCRs induced by the emotional words were significantly smaller in the high-trait anxious participants than in the low-trait anxious participants [P<.01], whereas the two groups did not differ with the neutral words.

The Trait anxiety×Phase×Trial interaction also reached significance [$F(2,58)=3.21$; $P<.05$; Fig. 2]. With one exception SCR magnitude always significantly decreased [low trait anxiety–control phase: $F(2,28)=18.84$; $P< .001$; high trait anxiety–control phase: $F(2,30)=7.17$; $P<.01$; high trait anxiety–task: $F(2,30)=5.20$; $P<.05$]. The exception was during the task in the low-trait anxious participants [$F(2,28)=0.90$; *NS*]. When each group was considered separately, results showed that the Phase×Trial interaction was significant only in the low-trait anxious participants [$F(2,28)=4.55$, $P<.05$]. Differences between phases were always significant within a given trial [all Ps< .05] expect in Trial 1 in the low anxious participants. No other interaction was significant.

4. Discussion

Our results provided evidence in support of reduced electrodermal reactivity in high compared with low anxious individuals. Firstly, through examination of response to emotional vs neutral distractors, overall SCRs were higher during the task than during the control condition. But as shown in Fig. 1, in the high-trait anxious participants the increase in SCR magnitude induced by the task was smaller following emotional distractors than following neutral distractors, such that responses to emotional distractors were smaller than in the low-trait anxious participants. This suggests that a specific inhibitory process subserving active coping may have occurred. Secondly, independent of the emotional value of the distractors, the results on habituation, shown in Fig. 2, also provided evidence of more consistent habituation (inhibitory activity) in high anxious participants. While both anxiety groups habituated similarly in the control condition, during the task condition habituation was sustained in the high anxious group whereas it was retarded in the low anxious group. Thus the persistence of habituation in the high-trait anxious participants could also reflect a task-related inhibitory coping effect.

Before considering an inhibitory coping dynamic further, are there alternative explanations to successful coping? Regarding habituation differences, the possibility cannot be discarded that there is an anomaly on Trial 1 in the low-trait anxious participants. Here a ceiling effect in the task condition could be tentatively proposed. More easily rejected are explanations of both the emotional distractor and habituation effects in relation to differences in sympathetic arousal, since SCLs, thought to be a robust index of sympathetic arousal, did not differ as a function of trait anxiety.

Elicitation of coping strategies in high-trait anxious participants could be related to their higher state anxiety, though admittedly levels of reported state anxiety were moderate. Such anxiety could be ascribed mostly to the task because special care was provided in order to dampen the emotional impact of the other components of the experimental situation. State anxiety may have contributed to motivation towards the task with a desire to perform well, which in turn underpinned the experience of less difficulty reported by the high-trait anxious participants. If not such a by product and if the self-reported lower difficulty did not simply reflect a retrospective positive appraisal coupled with a worse initial expectation biased on state anxiety (see Lazarus, 1991), their finding the task less difficult together with their higher state anxiety, may have given rise to the potential for a greater allocation of resources in the high anxious participants. These resources may be available for coping. Several possible types of coping, not mutually exclusive, will be considered in turn—attentional coping, defensiveness and voluntary inhibition.

The model of attention of Easterbrook (1959) postulates that anxiety (drive) provokes a reduction in the range of cue utilisation associated with a narrowing of attention. This was illustrated by Silverman and Blitz (1956). Anxiety did not induce a difference in learning a list of syllables (task relevant stimuli). However, incidental learning, as indexed by memory for distractor numbers presented beside the syllables, was worse in the high anxious group. Similarly Wachtel (1968) reported that when participants were threatened they were slower to react to peripheral stimuli when they were engaged in a continuous tracking task. However, a mere explanation in terms of inattention to peripheral stimuli should apply equally to neutral and emotional distractors (as was not the case) or should preserve the classical finding of greater SCRs to emotional stimuli due to their strong attention grabbing power (White, 1996). Therefore the attentional model we prefer proposes a greater allocation of resources to distractors deemed necessary for an adaptive inhibition of responses (Öhman, 1979). Since there is no between group difference in task performance, it would follow that the high-trait anxious participants devoted a greater amount of resources to the task as a whole, that is including inhibiting the impact of distractors. Here the groups did not differ in memory for the distractors, but a further experiment with higher memory load would provide a better test of the relation between resource allocation processing and memory storage of distractors.

The reduced reactivity of the high anxious group to the emotional words elicited by the involvement in the task may signify a defensiveness which is not specific to this type of context. For instance, Naveteur and Freixa i Baqué (1987) have described smaller reactivity to emotional slides compared with neutral slides during passive viewing. In unselected normal volunteers performing a task of high difficulty level, Ray et al. (1977) also postulated a protector mechanism meant to reduce the disruption due to high levels of activation in order to explain decreased electrodermal reactivity (see also Harley, 1973). These protective effects relate to the fact that the ability to control emotional responses has evolved as an adaptive capacity, as with emotional responses themselves (see Levenson, 1999). Thus, it could be inferred that individuals low in ego strength/high anxiety have strong perceptual defense against threatening stimuli (Roessler, 1973).

A last type of explanation is related to whether the reductions in electrodermal responsiveness were the result of an inhibitory process under voluntary control. Indeed, as participants have received information about EDA which they knew to be recorded, they could have tried to inhibit it directly. Is such skill available? This possibility has been proposed by Iacono and Lykken (1984), although Gruzelier and Eves (1987) failed to find a difference between instruction to passively ignore tones or inhibit responses to them. While evidence of indirect control on overall reactivity including SCLs has been provided through training in biofeedback and relaxation (Klinge, 1972; Ikeda and Hirai, 1976; Critchley et al., 2002; Nagai et al., 2004a,b), evidence of relatively spontaneous self-control on ORs is still sparse (see Lacroix and Roberts, 1978).

In sum, corroborating previous findings the present study evinced reduced electrodermal reactivity in high-trait anxious participants. These effects were considered appropriate to task requirements and consistent with resource-based active adaptive coping. The moderate state-anxiety level presented by the high-trait anxious participant may also have been a motivating factor which facilitated the coping strategy. In this sense, the reduction of electrodermal responses could be seen as a normal inhibitory process whereby mild to moderate anxiety increases mastery of situations and as such represents an issue worthy of further consideration.

Acknowledgements

The authors thank all participants for their cooperation. We are also grateful to V. Annoussamy, A. Bous, Dr H. Bouwalerh, and Pr. H. Sequeira who have all, in different capacities, helped us.

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