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Attentional and physiological characteristics of patients with dental anxiety

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Abstract

Twenty patients with dental anxiety were investigated while seated in a dental chair in a dental clinic. Heart rate (HR), heart rate variability (HRV), and skin conductance level (SCL) were recorded while the patients were exposed to scenes of dental treatment as well as a Stroop attentional task. Results showed an attentional bias with longer manual reaction times (RT's) to the incongruent compared to the congruent color words as well as the threat compared to the neutral words. Longer RT's to the incongruent and the threat words were found in the low HRV patients compared to the high HRV patients. Furthermore, all patients showed an increase in HR during exposure and the Stroop task compared to baseline. The HRV showed a decrease during the exposure and the Stroop task compared to baseline. HR and HRV did not differ between exposure and the Stroop task. Moreover, HR and HRV did not return to baseline levels during the recovery period. The SCL showed an increase from baseline to exposure, from exposure to the Stroop task and a decrease in the recovery phase. Results showed the importance of vagal cardiac control in attentional, emotional, and physiological processes in patients suffering from dental fear.

Keywords: Dental anxiety; Heart rate variability; Attentional bias

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1. Introduction

Dental anxiety is a common disorder in Western societies. In a randomly selected sample of 1420 Canadian subjects 16.4% suffered from dental anxiety (Locker, Liddell, & Shapiro, 1999). In a Norwegian study using the same questionnaire 19% of 18-year-olds reported high levels of dental anxiety (Skaret, Raadal, Berg, & Kvale, 1998). These individuals have been reported to have greater avoidance of dental treatment, greater tendency to somatization, and greater sensitivity to dental stimuli compared to an average dental population (Kaufman, Bauman, Lichtenstein, Adi, et al., 1991). These individuals are also at higher risk for poor oral health including tooth decay and poorer oral function (Hagglin, Berggren, Hakeberg, & Ahlqwist, 1996). Moreover, patients with dental anxiety even report elevated scores on a wide range of psychological complaints as measured by the Symptom Checklist 90-Revised (Aartman, de Jongh, & van der Meulen, 1997). Thus dental phobia is an anxiety disorder that has important health implications.

Understanding of the complex mix of cognitive, emotional, and physiological factors associated with anxiety disorders is aided by a comprehensive approach. A model linking vagal regulation of heart rate (HR) to organism adaptability has recently been suggested by Thayer and Lane (2000). These researchers propose that vagally-mediated HRV is an index of the central-peripheral feedback capacity of the organism. This capacity will affect the subject's ability to allocate psychophysiological resources to meet environmental demands (see also Thayer & Lane, in press). Vagally-mediated HRV has been associated with information processing (Porges, 1992), affective processing (Thayer & Lane, 2000), and physiological regulation (Levy, 1990). Thus, vagal activity might be of importance in the excessive fear associated with dental anxiety.

The most common way of interpreting the physiological symptoms described by patients has been as activation of the sympathetic branch of the autonomic nervous system (ANS). For example, increased HR has often been interpreted as an indication of sympathetic activation. However, recent studies have put more emphasis on parasympathetic processes, and this is especially true for cardiovascular responses. Increased HR associated with stress and anxiety has been shown to be related to decreased parasympathetic tone in numerous situations (Friedman & Thayer, 1998). Importantly, persons with persistent anxiety have been found to have low tonic HRV (Friedman & Thayer, 1998; Thayer, Friedman, & Borkovec, 1996). Moreover, decreased HRV has been associated with attentional dysregulation and increased symptoms in some populations (Friedman, Thayer, & Borkovec, 1993; Thayer, Friedman, Borkovec, Johnsen, & Molina, 2000).

The cardiovascular system can also be used to index information processing of stimuli that differ in emotional content. It has been shown that presenting nonthreat and threat words to patients suffering from generalized anxiety disorder (GAD) resulted in different phasic HR responses compared to nonanxious controls (Thayer et al., 2000). An attentional deficit occurred in GAD in that such individuals were not able to habituate to nonthreat words. That is, they showed a phasic HR-deceleration to both the first and last presentation of a neutral word. HR deceleration is associated with the orienting response and has been related to tuning of sensory organs and information uptake from the environment (Lacey, 1967). In addition, GAD patients showed a change from an HR deceleration (orienting response; OR) to the first threat word to an HR acceleration to the last threat word whereas the nonanxious controls showed an OR throughout. HR-acceleration is associated with the defense reaction because it is related to increased sensory thresholds and in that sense rejection of information from the environment (Lacey, 1967). Furthermore, less tonic HRV was found in GAD patients compared to normal controls. Importantly, tonic HRV was correlated with the attention-related phasic HR responses in that study.

Thayer et al. (2000) concluded that the cardiovascular system was sensitive to information processing of threat and nonthreat stimuli and that GAD patients showed an attentional deficiency manifested in their inability to ignore neutral stimuli. Attentional bias has also been found for threat stimuli in other clinical samples (Cooper, Anastasiades, & Fairburn, 1992; Mathews & MacLeod, 1986). Johnsen, Laberg, Cox, Vaksdal, and Hugdahl (1994), using a modified version of the Stroop (1935) test, found that alcoholics had longer verbal reaction time (RT) in color naming alcohol related words than neutral words of equal length. This was interpreted as an attentional bias for alcoholics to automatically and involuntarily draw their attention to alcohol related stimuli. The same effect occurred in smokers for smoking related words (Johnsen, Thayer, Laberg, & Asbjørnsen, 1997). Active smokers performed more poorly on the color naming task than abstinent smokers and nonsmokers. Since smoking is associated with decreased HRV (Hayano et al., 1990; Nabors-Oberg, Thayer, Niaura, & Sollers, 2002) it was speculated that the effect could be caused by lowered vagal tone in the active smokers compared to the other groups. Low HRV represents a low degree of neurovisceral integration in the organism and decreased ability to organize resources to meet demands such as in an attentional task (Porges, 1992; Thayer & Lane, 2000). Importantly, such attentional bias may serve to perpetuate the fear associated with the threat stimuli and lead to the disorder being resistant to treatment as well as to an increased risk of relapse (Johnsen et al., 1997). Thus, decreased attentional regulation and decreased HRV may be linked to maladaptive behavior.

Therefore, it was hypothesized that if patients with dental anxiety have an attentional bias towards threatening stimuli in their surroundings, we would not only expect longer RT's to incongruent color words compared to congruent color words, but also longer RT's to threat words compared to neutral words. If vagal tone is related to attentional processes, patients with low HRV would show longer RT's in the attentional task compared to patients with high HRV.

Ecological validity remains a concern in anxiety research. One problem with most clinical studies is the use of artificial laboratory settings. It would be advantageous to conduct well-controlled experiments in the natural setting where the phenomena of interest occur. The present study aimed to further investigate the relationship between attentional, emotional and physiological aspects of maladaptive behavior in subjects with dental anxiety during in vitro exposure to dental treatment as well as during an attentional task while seated in a dental chair in a dental clinic. Measuring reactions in a natural setting may give us more valid information and lead to greater generalizability of the findings than laboratory settings or mere self-report of reactions.

Since previous research has shown that HR increases and HRV decreases in anxious persons exposed to threat stimuli and these responses do not recover to baseline levels after the stimuli are removed (Lyonfields, Borkovec, & Thayer, 1995), the same pattern was expected in the present study. Thus the following predictions were made:

1. Longer manual RT to Stroop and threat words compared to neutral words.
2. Longer manual RT on Stroop and threat words in the low HRV compared to the high HRV group.
3. An increase in HR from baseline to exposure and attentional task.
4. If vagal influences caused the change in observed HR, it was hypothesized that HRV would decrease during both exposure and the attentional task compared to baseline and not return to baseline levels during recovery.
5. If sympathetic arousal caused the HR changes, then a corresponding pattern to HR changes would be observed in specific sympathetic measures like skin conductance level (SCL).

2. Method

2.1. Subjects

Fourteen males and six female patients, self-referred to a dental clinic specializing in the treatment of patients with dental fear participated in the study. The subjects had avoided dental treatment for an average of 8.5 years (range 0–26). The patients had a mean age of 36.3 years (range 22–66). One subject was excluded from the analyses because of color blindness, and one subject did only participate in the Stroop task.

2.2. Apparatus, stimuli, and questionnaires

Physiological responses were recorded using an ambulatory monitoring system (AMS) V. 3.6 (Klaver, de Geus, & de Vries, 1994). HR was measured using interbeat intervals, and averaged over each task performed. HRV was measured as the root mean of the squared successive differences (MSSD), and also averaged over task periods. MSSD is an index of vagally-mediated cardiac control that correlates highly (about .90) with spectrally-derived measures of vagally-mediated HRV (Thayer et al., 2000). In addition, this measure acts as a high pass filter and thus removes the slower, blood pressure mediated variability from the signal. ECG electrodes were disposable 8 mm Ag/AgCl. One was placed over the jugular notch of the sternum, between the collarbones, another was placed 4 cm under the left breast between the ribs, and the third electrode was placed at the right lateral side between the two lower ribs.

SCL was measured with .5 V constant voltage method. Sample rate was set to 500 ms. The SCL was averaged over time on task. Beckman 8 mm AgCl electrodes were placed on the middle phalanx of the second and third fingers of the nondominant hand and filled with .05 M conductive gel. In addition, movement was recorded using an accelerometer housed in the AMS device. These data were used to exclude those epochs with excessive movement. None was excluded.

Patients were exposed to the video scenes of dental treatment on a 28 in. Panasonic TV monitor by means of a Panasonic CD-ROM player.

The Stroop task (color naming) was presented by means of the Micro Experimental Laboratory (second version; MEL; Schneider, 1988) software installed on a Fujitsu Lifebook with a 10 in. × 7.5 in. screen. The size of the letters was 12 mm × 6 mm and presented in the colors red, blue, green, and yellow on a black background. Manual RT for valid trials only was recorded in milliseconds from stimulus onset until a manual reaction was performed on the keyboard.

Four categories of words were used as stimuli. The first category consisted of four color words written in conflicting colors (incongruent category). Because of the limited number of color words the incongruent color words were presented twice. The next category (congruent category) was color words presented in corresponding colors. These were also presented twice. The third category consisted of 10 dental related words (threat condition) written in the same colors as noted above. These words were selected by experts on dental phobia as typical threat words for odontophobic patients. The last category was 10 neutral words (neutral category). To eliminate an effect of word length on RT, the stimuli in the threat and neutral conditions were matched for word length.

The patients completed four different anxiety questionnaires. The Dental Fear Scale (DFS; Kleinknecht, Klepac, & Alexander, 1973) is a 20-item (scored 1–5) questionnaire recording subjective experience of physiological, cognitive, and behavioral aspects of dental fear. Another aspect of dental fear was recorded by the Dental Belief Scale (DBS; Smith, Getz, Milgrom, & Weinstein, 1987). This scale contains 15 items (scored 1–5) and measures the patient's perception of the dental treatment and the dentist's behavior. Phobic anxiety was measured by a shortened form of the original Geer Fear Scale (GFS; Geer, 1965). The present scale contained 18 items (scored 1–7). The above instruments have a documented reliability and validity in Scandinavian samples and are widely used (Skaret, 2000). In addition to this, the Dental Anxiety Scale (DAS; Corah, Gale, & Illig, 1978) was administered. This scale consists of 4 items (scored 1–5) and measures overall dental anxiety.

2.3. Procedure

The subjects met at the clinic for a 1 h interview by a psychologist. The interview is a standard procedure for all patients who apply for treatment at the clinic. The purpose of the interview was to screen patients and to outline an exposure treatment package for them. Thus, no dental treatment was expected at this point in time. This was in line with standard procedure at the clinic. The subjects presented a written consent to participate in the study and were told that they could withdraw from the experiment at any time.

After the interview, baseline recordings of psychophysiological data were performed for 5 min in the same room in the dental clinic as the interview was conducted. This was done because the mere exposure to the dental treatment unit could act as an in vivo exposure. Thus, to separate baseline from exposure, baseline recordings were conducted in the interview-room. After baseline recordings the subjects moved to a dental treatment unit in an adjacent room. A fixed sequence of in vitro exposure and Stroop testing followed. The exposure consisted of video clips on a videodisk consisting of 9 scenes of dental treatment. The video followed a sequence of entering the clinic, meeting with the dentist, probing, administering local anesthesia using a syringe, drilling with two types of drills, impression procedure, and drilling viewed from the location of the patient. Each sequence was about 2 min in duration. The subjects were instructed that they were to watch the screen and not turn away. They were informed that if the exposure became too intense the video could be stopped or paused whenever they wanted. No subjects stopped or paused the exposure.

After exposure the subjects performed the Stroop task while seated in the same dental chair. Four keys of the keyboard were masked with red, blue, green, and yellow tape. They were instructed to color name the words as fast as possible without making errors. They were told to press the corresponding color on the keyboard at the same time as they named the color (Johnsen et al., 1994). Both motor and verbal responses were required to increase the difficulty of the task (Nielsen, 1975). The stimuli were randomly presented, and each stimulus was presented from its onset until the subject gave a motor response (or a maximum of 6 s). A new stimulus would be presented upon the offset of the previous stimulus.

The Stroop task was followed by 5 min of recovery. In this phase the subjects were seated in the dental chair relaxing. Physiological recordings were performed throughout the four tasks (baseline, exposure, Stroop, and recovery).

After the study was conducted two groups were formed based upon the subjects average HRV throughout the experiment. The groups were split on the median resulting in seven subjects in the low HRV group and six subjects in the high HRV group.

2.4. Design and statistics

Our analyses consisted of testing a number of preplanned contrasts. Differences on the self-report questionnaires between high and low vagal tone groups were tested using *t*-tests for independent groups.

In order to test differences between high and low vagal tone on attention, separate *t*-tests for independent samples were performed for each category of the Stroop test. Furthermore, to test for attentional bias *t*-tests for dependent samples were performed between categories. In order to investigate differences in psychophysiological responses during the different tasks, *t*-tests for dependent samples were performed for each dependent variable separately for the different tasks. Because of specific directional hypotheses between the means, one-tailed tests were performed on these analyses. Missing data, due to technical problems, caused the variation in degrees of freedom.

3. Results

Subjective ratings of dental and phobic anxiety are described in Table 1. No differences between high and low vagal tone participants was found on any of the questionnaire data.

The results from the Stroop task showed longer RT's to incongruent color words compared to congruent color words, $t(18) = 5.25$, $P < .01$ (see Fig. 1). Furthermore, longer RT's were found to threat words compared to neutral words, $t(18) = 1.89$, $P < .05$ (one-tailed).

Table 1
Means and S.D.'s for DAS, DFS, DBS, and GFS

Variable	Mean	S.D.
DAS	15.75	6.17
DFS	64.33	9.91
DBS	37.73	11.70
GFS	43.92	7.80

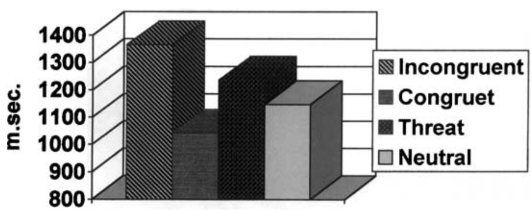

Fig. 1. Mean manual RT measured in milliseconds (ms) to incongruent, congruent, threat, and neutral words.

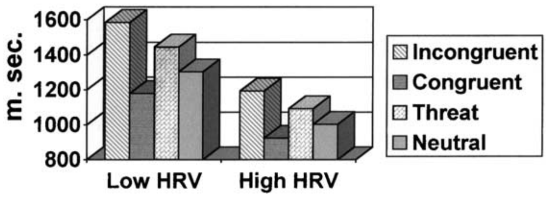

Fig. 2. Mean manual RT measured in milliseconds (ms) to incongruent, congruent, threat, and neutral words separated for subjects showing low HRV and high HRV.

Table 2
Means and S.D.'s for HR measured in beats per minute (BPM), HRV measured in MSSD, and SCL measured in micro Siemens (μS)

	Mean (S.D.)			
	Rest	Exposure	Stroop	Recovery
HR (BPM)	68.71 (11.18)	73.26 (13.99)	74.11 (13.35)	72.46 (12.36)
HRV (MSSD)	51.00 (25.02)	42.70 (17.51)	39.77 (22.99)	39.57 (15.17)
SCL (μS)	3.44 (1.96)	5.01 (2.41)	6.91 (3.24)	6.23 (2.81)

The means and S.D.'s are separated for recordings during baseline (rest), in vitro exposure (exposure), Stroop attentional task (Stroop), and recovery.

With respect to the relationship between HRV and attention, longer RT's were found in the low HRV group compared to the high HRV group on the incongruent and threat categories, $t(11) = 2.47$, $P < .03$ and $t(11) = 2.31$, $P < .04$, respectively (see Fig. 2).

As can be seen in Table 2 an HR increase was found from baseline recordings to in vitro exposure, $t(17) = 2.65$, $P < .01$. Higher HR was also found during Stroop and recovery compared to baseline recordings, $t(16) = 3.88$, $P < .01$, and $t(17) = 4.35$, $P < .01$, respectively. No other changes in HR were found.

Looking at the HRV data a decrease from baseline to in vitro exposure was found, $t(14) = 2.39$, $P < .01$. Lower HRV was also found during Stroop and recovery recordings compared to baseline, $t(13) = 2.30$, $P < .04$, and $t(14) = 2.45$, $P < .02$, respectively. No other differences were found. SCL showed an increase from baseline to exposure, $t(17) = 5.09$, $P < .01$, from exposure to Stroop, $t(16) = 5.77$, $P < .01$, and a decrease in SCL from the Stroop task to the recovery phase, $t(16) = 3.09$, $P < .01$. Furthermore, higher SCL was found during Stroop and recovery recordings compared to baseline recordings, $t(16) = 6.71$, $P < .01$, and $t(17) = 7.41$, $P < .01$, respectively.

4. Discussion

The results showed longer RT's on incongruent compared to congruent words, and threat compared to neutral words. Longer RT was also found in the low compared to the high HRV group for incongruent and threat words. Furthermore, an HR increase was found during in vitro exposure and the Stroop task compared to baseline. An opposite pattern occurred for the HRV, with a decrease in HRV corresponding to the HR increase. Importantly, neither HR nor HRV returned to baseline levels during the recovery period. The SCL showed an increase from baseline to exposure, from exposure to the Stroop task and finally a decrease in the recovery phase.

The present sample showed elevated ratings on all anxiety measures compared to normative ratings. The DFS has been used in several recent studies of clinical and normative Norwegian samples. The mean normative score for DFS among adult dental attendants in Norway was 44.6 (Kvale et al., 1997). The cutoff point representing high dental anxiety is >59 (Skaret et al., 1998). The present study showed a mean score of 64.3, which well exceeds this cutoff point. Although, this cutoff point reflects individual caseness, a mean score that exceeds this indicates high anxiety score in the group. Furthermore, the mean normative score for adult Norwegian dental patients on the DBS was 25.5 (Kvale et al., 1997). The present study showed a mean of 37.7. This was lower than what is recognized as a cutoff point for caseness on the DBS (Skaret, Raadal, Berg, & Kvale, 1999). The sample in the present study also showed a high score on general phobic symptoms. In normative samples Berggren and Carlssom (1984) reported a mean score of 34.6 to 38.5 in Swedish samples, while the present study revealed a mean score of 43.91. Population normative mean scores for the DAS in a Norwegian study revealed scores of 8.28 for the age-group of 25–39, and 7.51 for subjects of 40–59 years of age (Neverlien, 1990). The present study showed a mean score of 15.75. Scores larger than 15 are considered to indicate severe dental anxiety (Berggren & Carlssom, 1984; Corah et al., 1978). Taken together, this indicates that the present sample consisted of a highly anxious group both on behavioral, physiological, and cognitive symptoms.

A Stroop effect (Stroop, 1935) occurred in all participants with longer RT's to incongruent color words compared to congruent color words. Furthermore, an attentional bias toward stimuli representing the feared object was found. This was seen in longer RT's to words in the threat compared to the neutral condition. Such attentional bias involves an interference of the attentional system that results in an automatic allocation of processing resources to the stimuli representing the feared object. This is not under voluntary control since the patients were explicitly instructed to ignore the content and only report the color of the words presented to them (Johnsen et al., 1994). This attentional bias could be caused by a lack of ability to modulate attentional processes (Johnsen et al., 1997). Porges (1992) stated that the ability to regulate attentional processes was related to cardiac vagal control and an increased HRV. This view was further supported in the present study by the difference found between patients with high compared to low HRV. The low HRV group showed increased RT's in both conditions that were supposed to create attentional bias, that is the incongruent and threat conditions. This inability to modulate attentional resources may serve to perpetuate avoidance of treatment in this population.

One of the key features of dental fear is physiological symptoms such as increased HR and sweating. These symptoms were also observed in the patients participating in the present study. The increased HR observed in the patients was not attributable to increased sympathetic arousal, but to decreased parasympathetic activation, that is a decrease in vagal tone. This was the case since HRV and HR showed a corresponding but opposite pattern. SCL, which is a measure of eccrine sweat gland activity, and as such a measure of sympathetic arousal, showed a very different pattern. Suppression of vagal tone could cause an HR increase since efferent neural output from the vagus inhibits HR activity (Saul, 1990). Vagal withdrawal would be a state of disinhibition of the sympathetic drive to the heart and by doing so increase HR.

Failure of these indices of cardiac activity to return to baseline levels has been observed in other anxious samples (Lyonfields et al., 1995). The inability of the organism to match its cardiovascular responses to the environmental demands has been thought to reflect a lack of behavioral flexibility and adaptability. Thus, these individuals may be prone to perseverative responses that serve as a positive feedback loop maintaining their maladaptive behavioral patterns. Greater tonic levels of vagally-mediated HRV have been associated with increased cognitive, affective, behavioral, and physiological flexibility as well as with negative feedback mechanisms that serve to interrupt ongoing activity and allow for selection of more appropriate responses (Thayer & Lane, 2000).

Since cardiovascular responses and SCL responses showed a different pattern it could be argued that they reflect different processes. SCL, which reflects sympathetic activity, could be an index of mere arousal in the organism. This could be the case since an increase occurred both to exposure (a passive coping task) and a further increase to the Stroop task (an active coping task). Such an argument was bolstered by the fact that a decrease in SCL occurred in the recovery phase. Recovery resulted in a deactivation of the organism by means of reduced sympathetic arousal. Cardiovascular responses, on the other hand, could be seen as reflecting the motivational aspects of the stimulation. Exposure to threatening stimuli produced a reduction in vagal tone and this response continued after the stimuli were removed. The continued suppression of vagally-mediated cardiovascular activity into the recovery period may reflect ongoing perseverative thinking such as worry. We have previously shown that worry has been associated even in nonanxious persons with decreased vagal tone (Thayer et al., 1996). Since baseline and recovery data were recorded on different locations some caution should be taken in the interpretation of these results.

One open question is if the observed psychophysiological response is different or more excessive than responses that would occur in normal dental patients since most subjects would experience a certain level of discomfort. The present study did not address that question directly since no control group was studied. However, previous research suggests that persons with high dental fear have greater sensitivity to dental stimuli than an average dental population (Kaufman et al., 1991). Moreover, the present participants showed a pattern of response that was similar to other anxiety samples. Given that dental anxious persons also appear to be generally anxious, these results are consistent with the extant literature. Both the decrease in vagal tone and the lack of recovery observed in the present study fits well with psychophysiological characteristics of other anxious populations we have studied (Lyonfields et al., 1995).

Previous research with anxious patients has suggested that psychotherapeutic interventions may be effective in increasing HRV with concomitant decreases in symptoms, (Friedman et al., 1993). We are currently pursuing an exposure based therapeutic intervention with this sample of dental phobics. If shown to be effective, this strategy could be used to decrease the avoidance of dental treatment and thereby increase the oral health of a significant segment of the population.

In summary, the present study has shown the relationship between emotional, attentional and psychophysiological processes occurring in the natural setting for patients suffering from dental anxiety. A profound role for cardiac vagal control was found for physiological, emotional, and attentional processes.

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