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Habituation of the orienting reaction: Method study and comparison of measures among borderline hypertensives and controls

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Abstract

The strength of the orienting reaction and the habituation of the OR to repeated stimulation have rarely been investigated in psychophysiological research on the etiology of hypertension. However, such biobehavioral measures may supplement conventional investigations that employ laboratory tasks, for example, mental arithmetic, in assessing individual differences in responsiveness.

In a multi-parameter investigation, 56 male student subjects with normotensive blood pressure (122/73 mmHg), 31 subjects with mildly elevated BP (133/78 mmHg), and 48 moderately elevated BP (146/83 mmHg) were presented 10 medium intensity stimuli (85 dB, 1000 Hz). The response measures included a number of cardiovascular variables, electrodermal activity, and two EMG recordings. The investigation comprised two parts. First, a method study was conducted to select appropriate measures of habituation. A screening of response measures was made based on 80 of the subjects and the findings were cross-validated referring to the remaining 55 subjects. Thus eight measures of habituation were found whereby electrodermal responses were more sensitive than cardiovascular measures in depicting the course of habituation. Secondly, blood pressure groups were compared with regard to this set of measures. Neither the amplitude measures of the first OR nor the habituation of the OR differed between groups.

Keywords: Borderline Hypertension, Electrodermal activity; Habituation, Orienting reaction

Introduction

Psychophysiological research relating to the etiology of hypertension has been basically concerned with cardiovascular reactivity. Among the essential theoretical concepts in this domain were the hyperreactivity of the sympathetic nervous system, the notion of vagal withdrawal from the heart, and concepts relating to sensitivity and modulation of the baroreceptor reflex. Most investigators employed more or less standardized laboratory tasks, for example, mental arithmetic and the Cold Pressor Test, to assess individual differences in cardiovascular responsiveness. Furthermore, repetition of such tasks, repeated exposure to novel experimental settings, and series of daily experiments were employed to investigate response adaptation in cardiovascular and neuroendocrine measures (cf. al'Absi & Lovallo, 1993; Frankish & Linden, 1991; Zbrozyna & Westwood, 1988). It may be rewarding to evaluate other paradigms and, possibly, supplement the research methodology accordingly.

The strength of the orienting reaction and the course of habituation of the OR to repeated sensory stimulation have been used in many fields, for example, anxiety research, to assess individual differences in arousal (Boucsein, 1992; Baltissen & Sartory, 1998; O'Gorman, 1977). Although stimilus intensity and risetime affect the response patterning (Turpin, Schaefer & Boucsein, 1999) and response fractionation may be obvious when multi-channel recordings are made (e.g., Barry, 1982; Turpin, 1986), the measurement of OR and the decrement of ORs in habituating to repeated stimulation still appear to be a valuable tool in psychophysiological research.

The research question is whether borderline hypertensives and hypertensives compared to normotensive controls are characterized by a stronger orienting reaction and a slowed habituation. Only a few studies were conducted to test this hypothesis although the notion of enhanced cardiovascular reactivity also appears to imply the notion of diminished adaptation to repeated stimulation. Brod (1982) has argued that orienting reaction and defense reaction constitute a continuum of hemodynamically similar response patterns. Several investigators have underscored that frequently occurring alarm reactions and hyperexcitability may have a significance in the etiology of hypertension (e.g., Folkow, 1982; Zbrozyna, 1982). Obviously, this is also a relevant issue in research on noise stress and the development of hypertension (e.g., Carter & Beh, 1989; Sawada, 1993).

A habituation paradigm was employed by Collins, Baer and Bourianoff (1981). In this study 26 children (age between 8 and 13 years) of hypertensive fathers were compared to a control group of children with normotensive fathers (N= 27). Subjects were presented six tones at 1450 Hz, 71 dB. It was found that children with hypertensive fathers showed a delayed habituation of the OR. This was evident from cardiovascular measures and, likewise, from electrodermal activity. Fredrikson, Edman, Levander, Schalling, Svensson and Tuomisto (1990) compared 19 borderline hypertensive males to 15 normotensives and 12 hypotensives aged 18 concerning the habituation of the OR. Here, 16 non-signal tones (1000 Hz, 90 dB) were presented. The analysis, which also took into account various definitions of response, showed a significant faster habituation among hypotensives. The borderline hypertensives, however, showed only a marginal trend towards a slowed habituation. Fredrikson (1985; 1989) compared 25 mild hypertensive patients with 24 matched normotensive controls. In the first part of the investigation, i.e. the habituation trial, 10 tones at 1000 Hz, 78 dB, with non-signal character were used. It was found that hypertensives, compared to controls, showed a faster habituation of the electrodermal response, but differences in the systolic and diastolic blood pressure reactions did not exist. In the second trial the tones announced a reaction time task (Fredrikson, 1985). Here the hypertensives exhibited an increased reactivity of blood pressure, while no differences were seen in the EDA.

It is concluded that at least partial support is given to the notion that basic mechanisms of orienting behavior and its habituation are altered in subjects with elevated blood pressure or mild hypertension. However, the inconsistencies which are evident here may be partly due to differences in sampling and methodology. The subject samples were rather small and differed with respect to distribution of gender, age, and health condition, i.e. patient versus non-patient status. Further methodological issues are the scoring of electrodermal responses (cf. Barry, 1990; Boucsein, 1992) and the derivation of a suitable index of habituation (e.g., Vossel & Zimmer, 1988). Besides electrodermal responses it may be appropriate to include cardiovascular and even somatomotor measures of the OR. Such multi-channel recordings might assess whether the assumed heightened SNS-activity is specific to the electrodermal system or part of a generalized responsiveness. Concerning the etiology of hypertension, cardiovascular parameters of the orienting reaction appear to be particularly relevant. Such multi-channel studies, however, have to account for rapidly habituating or more slowly habituating response systems and, as well, short- and long-latency components within a specific response system.

The present investigation had two intentions. First, to evaluate a number of physiological measures of the OR derived from multi-channel recordings and to select appropriate indices of habituation accordingly. Second, to compare groups of subjects who differ in blood pressure level but are rather homogeneous concerning age, gender, education, and health.

The method study was an essential first step in this research since a comprehensive evaluation of multiple OR-measurements during the course of habituation was not available from the literature. A set of physiological measures that have been used in many psychophysiological studies were employed here to assess the orienting reaction. If a response decrement with repeated stimulation was evident for a specific physiological measure this measure should be included as a suitable measure of habituation. However, such response decrement may coincide with an overall trend in the recording, for example, due to the subject's adaptation to the experimental setting. This method study was designed to include a cross-validation to ensure the reliability of the evaluation.

In the second part of the present study the findings from the method study were applied in testing the assumption that subjects with elevated blood pressure are characterized by enhanced amplitude of the first OR and by slower habituation over repeated stimulation. When searching for valid psychophysiological differences between blood pressure groups, it appears appropriate to have comparatively young subjects with elevated blood pressure instead of chronic hypertensives who may be affected by their labeling, increased health concern, and treatment.

The present study is part of a research project on psychophysiological and psychological aspects of elevated blood pressure in male university students. Further results were published elsewhere (Fahrenberg & Foerster, 1996; Fahrenberg, Foerster & Wilmers, 1995).

The current investigation may have a negative outcome regarding the supposed differences in OR habituation between blood pressure groups since previous studies were rather inconsistent and the habituation paradigms can differ in many methodological aspects. However, the method study may, at least, make a positive contribution to the choice of measures of habituation. Besides the electrodermal measures, which physiological measures emerge especially when subjects with cardiovascular symptoms, namely elevated blood pressure, are studied.

Method

Subjects

In this study 135 male university students (none from psychology courses) served as paid voluntary participants. They ranged in age from 19 to 30 years, with a mean age of 23.9 (S.D. = 2.5), and all reported being in good health. The subjects were informed that the experiment would investigate individual differences in cardiovascular functions and consent was obtained.

The blood pressure groups were determined by taking blood pressure six times. Two of these measures were obtained on a pre-experimental day and four measures during the experiment, each after five minutes of supine rest by the auscultatory method using a mercury manometer (Erkamed). Three blood pressure groups were included: (1) the moderately elevated blood pressure group (N = 48), with a mean blood pressure of at least 140 mmHg systolic and/or 90 mmHg diastolic (M = 145.9/83.3 mmHg), (2) the mildly elevated blood pressure group (N = 31) with at least one blood pressure reading greater than 140 mmHg systolic and/or 90 mmHg diastolic (M = 132.9 / 78.3 mmHg), and (3) the normotensive group (N = 56; M = 122.6 / 72.9 mmHg). The three blood pressure groups differed slightly concerning age (24.6; 23.6; 23.4 years) and weight (76.0; 74.4; 71.6 kg).

Procedure

The subjects were invited to the laboratory on a pre-experiment day to facilitate adaptation to the experimental setting and to check for possible effects of apprehensive anticipation and test anxiety. Specific attempts at familiarization of subjects were made also by demonstration of the equipment, by conducting blood pressure measurements and taking an ECG recording.

For the experiment subjects were seated in a semi-reclining padded chair in a sound-dampened and air-conditioned room (temperature 25 ± degree Celsius; moisture 55 ± 5 per cent). After electrodes and transducers were fastened and checked, which took about 30 minutes, general instructions were given concerning the initial rest phase. After this initial rest phase the habituation paradigm was the first of several tasks (cf. Fahrenberg & Foerster, 1996). The test was announced on the computer screen as follows: "In a few moments, you will hear a series of tones. Please pay attention to these tones." After 15 seconds ten tones at 1000 Hz, 85 db, 2 s duration, rise time 0.4 s, were presented at randomly varying interstimulus intervals at 20, 25 or 30 s.

The laboratory equipment used were a 16-channel polygraph (Hellige, Freiburg i.Br.), a calibrated automatic blood pressure measurement device (Infraton-Tensiomat FIB 4/6, Boucke, Tübingen), impedance cardiograph (model 400, Instruments for Medicine Inc.) that was replaced after subject 81 by another device (Meddata, Stuttgart), a Hewlett Packard computer 1000/65 and an Amiga 1000 PC for presentation of instructions.

Multiple recordings of cardiovascular, electrodermal and other physiological functions were made on 16 channels. The software system BIO developed by Foerster were employed for parameterization (Fahrenberg & Foerster, 1991).

The electrocardiogram (ECG) was recorded from standard lead II. Parameters derived from the ECG included heart rate, amplitude of P-, R- and T-wave, P-Q and Q-T interval. The actual heart rate was corrected for respiration by means of the model from Clynes (1960) for analyzing respiratory sinus arrhythmia. The hypothetical heart rate curve estimated by this model from the spiro-tachogram or pneumogram during the pre-stimulus period (and applied to the whole period) is partialled out from the actually recorded heart rate curve (see Foerster, 1978; 1984, p. 89 and 106-110).

The parameterization of the impedance cardiogram (ICG) and phonocardiogram led to amplitude measures (A-, E-, and X-wave amplitude), the R-Z interval and left ventricular ejection time, the Heather-Index, and indices of stroke volume according to Kubicek's formula.

The carotid pulse was obtained by an Infraton transducer (Boucke, Tübingen, Germany) attached with a special bandage over the left carotid. The ear densitogram was recorded by means of a Hewlett-Packard HP 780-16 transducer attached to the upper part of the right ear. The radialis pulse was registered by means of an optoelectronic transducer (Klenk, München) of 16 mm diameter attached by an adhesive collar over the right radialis artery. The finger plethysmogram was obtained by employing a pneumatic system consisting of a plastic cylinder sealed with foam rubber material. A Boucke Infraton pressure transducer was used to convert air volume changes to an electric signal. The amplitude of pulse volume, PVA, in each recording was measured in arbitrary units. The R-wave of the ECG and the 20 per cent amplitude point of the peripheral pulse wave were used as reference points throughout for computation of pulse transit time, PTT. The finger temperature was measured using a Platinum Pt 100 film thermoresistor (Hellige) attached at the third finger of the right hand.

Respiration was recorded using an air-bellows thorax belt, positioned a few cm below the fourth ICG electrode. Electrodermal activity (Skin conductance level, ln μS) was recorded with a constant voltage of 0.5 V in conjunction with Unibase electrode jelly from thenarhypothenar sites of the right hand. The surface electromyogram was recorded from forearm (extensor digitorum) and from sites above and below the eye employing the contour following method to measure tonic and phasic activity of the orbicularis oculi.

Method Study

Derivation of parameters

In total, 40 physiological measures were included in the initial screening. For each measure the continuous recordings (tone 1 to tone 9, i.e. 290 s = 2900 data points; the tenth tone was ignored) were averaged across 80 subjects. All the variables were then graphically displayed in such a way that habituation could be equally well 'eye-balled'. A response decrement, i.e. a systematic change that might be caused by habituation to repeated stimulation, was evident in 16 measures. This exploratory analysis showed that besides slower habituation (tone 1 to tone 9) a fast habituation (tone 1 to tone 2) had to be accounted for. The screening yielded thus 16 physiological measures that were apparently suited for more precise statistical evaluation.

Since the response systems of the OR obviously differ in latency, response direction, i.e. increase or decrease, and monophasic or biphasic response, a computerized scoring system was set up. For each response measure specific parameters of the OR could be defined referring to a distinct window: mean, range, absolute (and relative) maximum (or minimum), relative maximum then relative minimum or vice versa, latencies from tone offset to absolute (and relative) maximum (or minimum) and latencies from tone offset to the 10 per cent upstroke of the absolute (and relative) maximum (or minimum). The latency window for each response channel was determined by visual inspection of the averaged record. For each of the 16 primary response measures, between one and five scores were derived so that the total number of variables at this stage was 66. However the findings will be reported only for response scores that passed the cross-validation. It should be noted that the evaluation included one or two latency windows, specific for each channel, to assess phasic components of the OR and, moreover, a window to assess tonic changes that might reflect overall trends, especially the adaptation to the experimental setting. This window had to be very short, i.e. uniformly the first second after stimulus offset, to avoid overlap with the initiation of the OR.

The OR was measured directly, i.e. concerning specific latency windows after stimulus offset, instead of computing differences that refer to pre-stimulus baselines. This method to derive response measures appeared to have advantages because difficulties in selecting baseline periods of adequate length and initial value dependencies (Fahrenberg et al., 1995) were avoided.

The selection of 66 variables was then evaluated statistically. Variance components were estimated in a mixed model ANOVA with tones as fixed factor and subjects as random factor.

Only linear and quadratic trends were looked at. The repeated measurement effect (tone 1 to tone 9) was significant ($p < .05$) in 14 variables. The rapid change (tone 1 to tone 2) was evaluated likewise, whereby 15 variables out of 66 were retained.

Cross-validation

The findings obtained from the first analysis were cross-validated employing 55 subjects. Due to the smaller sample size a replication of results was assumed if a significance level of $p < .10$ was reached.

Table 1 depicts 8 variables out of 66 that may be considered as valid OR habituation parameters in the present study according to the findings presented in Table 2. Four measures apparently indicated habituation across tone 1 to tone 9 and four measures were suited to indicate rapid habituation across tone 1 to tone 2. The amplitude of the electrodermal reaction and the EMG recorded from the orbicularis oculi were present in both categories. The F-value "Tones" indicated that the SCR amplitude surpassed by far the remaining variables as indicator of habituation. The second was the EMG eye and the third was the vasomotor response that was evident in two measures, a biphasic response in pulse transit time obtained by the ear densitogram and, as a rapid change, the amplitude of the finger pulse volume. The acceleration of the heart rate, corrected for respiratory effects, appeared to be valid as indicator of rapid habituation only. Interestingly the heart rate response emerged as a valid parameter while none of the scores that accounted for biphasic changes did. Practically none of the ECG and ICG measures showed a reliable habituation effect.

Table 1 Physiological measures depicting a significant, cross-validated trend, increase or decrease, under repeated stimulation

Variable		Units	Score	Window[a] (Seconds)	Direction
OR parameter indicating habituation across tone 1 to tone 9					
EDA-AMP	Electrodermal activity	µS	relative maximum	1 - 8	linear decrease
EDA-LAT	Electrodermal activity	s	latency of relative maximum	1 - 8	linear increase
EMG-EYE	EMG orbicularis oculi	µV	relative minimum then relative maximum	0.1 - 1.2 (1.2 - 2.5)	decrease
PTT-EAR	Pulse transit time, ear	ms	relative minimum then relative maximum	1 - 5 (5 - 10)	linear decrease
OR parameter indicating rapid habituation across tone 1 to tone 2					
EDA-AMP	Electrodermal activity	µS	relative maximum	1 - 8	linear decrease
EMG-EYE	EMG orbicularis oculi	µV	relative minimum then relative maximum	0.1 - 1.2 (1.2 - 2.5)	decrease
PVA-FING	Pulse volume amplitude, finger	units	minimum	1 - 12	decrease
HR corr	Heart rate, corrected for respiratory effects	(bpm)	maximum	1 - 2.5	decrease
Measures indicating adaptation to the experimental setting					
PVA-FING	Pulse volume amplitude, finger	units	mean	0 - 1	linear increase
PVA-EAR	Pulse volume amplitude, ear	units	mean	0 - 1	linear increase
PTT-CAR	Pulse transit time, carotid	ms	mean	0 - 1	quadratic decrease/ increase

Notes: [a] In case of biphasic changes, two latency windows were employed. EDA-AMP and EMG-EYE were suited as measures of rapid and slow

Table 2: Analyses of variance for testing habituation and adaptation. F- and p-values of MANOVA-Flatness-Test for factor "Tones" based on Part 1 (N=80) and Part 2 (cross-validation, N=55).

	Factor "Tones"			
	Part 1		Part 2	
Variable	F	p	F	p
OR parameter indicating habituation across tone 1 to tone 9				
EDA-AMP	9.1	.00	11.7	.00
EDA-LAT	2.7	.03	1.7	.16
EMG-EYE	2.4	.02	2.0	.07
PTT-EAR	2.3	.03	1.8	.10
OR parameter indicating rapid habituation across tone 1 to tone 2				
EDA-AMP	71.9	.00	89.4	.00
EMG-EYE	10.8	.00	9.9	.00
PVA-FING	7.9	.01	7.6	.01
HR corr	7.3	.01	2.3	.10
Measures indicating adaptation to the experimental setting				
PVA-FING	4.1	.00	3.1	.01
PVA-EAR	3.5	.00	1.8	.10
PTT-CAR	2.3	.03	2.5	.02

Notes: Measures were selected according to $p < .05$ in Part 1 and $p \leq .10$ in Part 2 (EDA-LAT is an exception).

Table 1 and 2 also contain three measures that depict the level of tonic activity after stimulus offset, i.e. immediately before an OR could occur. Findings indicate an increase in carotid pulse transit time and in pulse volume amplitude obtained from the ear pulse and finger pulse across the habituation paradigm. These measures of adaptation show an especially large percentage of VC Subjects, which may mean that subjects strongly differ concerning such trends, i.e. whether such trends were present or not.

Further analysis revealed that the intercorrelations among the 11 variables, except for variables derived from the same response system, were negligible. This finding holds for the first OR and for the course of habituation (averaged across tone 2 to 9) as well. An exception was finger temperature that was positively correlated with pulse transit time obtained from the finger plethysmogram.

Comparison between blood pressure groups

The comparison between the three blood pressure groups referred to the cross-validated measures, namely four OR habituation parameters, and four rapid habituation parameters. In addition, an index was set up to assess the habituation of the SCR. The number of the SCRs was added up until two zero responses (< 0.02 microsiemens) occurred (see Vossel & Zimmer, 1988). This habituation index was also included as were four measures indicating tonic changes (see Table 1) that possibly reflect individual differences in adaptation to the experimental setting.

One-way ANOVAs were employed to investigate whether the two groups with moderately and mildly elevated blood pressure differed from the normotensive controls in the amplitude of the OR, i.e. response to the first tone. In order to test whether the three groups differed in the course of habituation, a mixed model analysis of variance was used with the between-subject factor Groups and the repeated measurement factor Tones. Tone two to nine were included in this analysis because the first OR was examined separately. Finally, an one-way ANOVA was computed on the SCR habituation index concerning the three blood pressure groups. A significance level of $p < .05$ was used throughout.

The ANOVA revealed that neither the measures relating to the strength of the first OR nor the eight measures depicting the habituation of the OR across repeated stimulation differed between blood pressure groups. Interaction effects Groups by Tones were also absent. The habituation index for electrodermal responses was the same for all groups. These findings render tables and a detailed presentation of statistical evidence unnecessary.

Further exploratory analyses were conducted to assess the supposed habituation trends by regression methods. For each subject a polynomial regression was computed using SAS program REG (SAS Institute Inc., 1993) and estimates of regression parameters were stored for one-factorial ANOVA of group effects, whereby individual differences in the intercept were accounted for. This analysis was carried out for different numbers of tones, i.e. tone 1 to 4 up to tone 1 to 9, because the adequate number of tones was unknown. A significant group effect was found only for SCR amplitude: tones 1 to 4 (linear trend $F\ (2, 124) = 3.31$, $p < .04$) and tones 1 to 8 (quadratic trend $F\ (2, 123) = 3.49$, $p < .04$). Subjects with elevated blood pressure showed faster habituation which was against the expectation.

Interestingly, group differences were found in measures of tonic activity immediately after the offset of the first tone concerning pulse volume amplitude ear ($F\ (2, 126) = 12.2$, $p <$

.0001), pulse amplitude finger ($F_{(2, 111)} = 4.3$, $p = .016$), and pulse transit time carotid ($F_{(2, 114)} = 8.5$, $p < .001$). Subjects with elevated blood pressure were characterized by a shorter PTT-CAR, i.e. higher pulse wave velocity, a larger PVA-EAR and a smaller PVA-FING. Furthermore for these three cardiovascular measures significant group differences were evident across tone 2 to tone 9. These findings indicate a persistent difference between blood pressure groups independent of the process of habituation to stimulation.

Discussion

The first objective of the present study was to evaluate response measures of the orienting reaction and thereby to search for potential cardiovascular parameters of the OR that show habituation as it is especially evident in electrodermal responses. Then, it was to be tested whether subjects with elevated blood pressure would exhibit a stronger OR in electrodermal, cardiovascular and other physiological measures or a slowed habituation.

The method study was based on multi-channel recordings and included a number of response scores as well as a flexible design of latency windows. A large number of variables were derived for the screening and the statistical evaluation relating to a habituation paradigm that employed medium intensity acoustic stimuli. The comparatively large number of subjects and the cross-validation of findings in the second part of this method study should ensure a high reliability of findings.

The validity of this approach is shown by the distinct habituation of the electrodermal component of the orienting reaction across repeated stimulation - as was to be expected. Furthermore the dominant role of the EDA in the context of OR and habituation was evident. Besides amplitude and latency of the electrodermal response few measures of OR habituation could be found. The statistically significant effects for EMG-EYE and PTT-EAR were actually weak effects. This method study, therefore, also included such measures that indicated a rapid habituation process from the first to the second stimulus. Here, significant but small effects were obtained for two measures, finger pulse volume amplitude and heart rate. None of the many parameters from the electrocardiogram and the impedance cardiogram proved to be a reliable measure of OR habituation.

Objections could be raised against the stimulus intensity employed in the present study. It is possible that substantial orienting reactions and a significant habituation process might become detectable only after a certain stimulus intensity has been reached. However, much higher stimulus intensities are likely to elicit movement artifacts and interactions between response systems that threaten the reliability and validity of OR measurement. A moderate increase in stimulus intensity, say 95 dB, or a habituation paradigm with a series of tones that are not announced beforehand and, furthermore, a signal versus non-signal condition may produce results at variance with the present investigation that employed medium intensity low information tones. A method study is desirable that includes such paradigms and, at the same time, seeks to separate OR habituation and effects of adaptation.

Obviously, the electrodermal response system is most sensible to assessing OR habituation under repeated stimulation by tones of medium intensity. This advantage which, in the present method study, became evident in the rank order of potential response measures, is reflected in the literature. Investigations that evaluated EDA habituation measures outnumber by far such investigations that employed other psychophysiological measures. One may speculate whether the specific nature of the EDA, i.e. the characteristic curve relating stimulus intensity and response amplitude, has a biological significance and how this feature reflects the peculiarity that this physiological response system is only under excitatory sympathetic-cholinergic control without an inhibitory parasympathetic mechanism.

Besides electrodermal response, the measures indicating OR habituation comprised the vasoconstrictive response, increased pulse wave velocity, heart rate acceleration, and a somatomotor response. With the exception of the latter, these components appear to reflect a sympathetic response pattern. However, the negligible intercorrelations between these measures (accounting for slow and fast habituating components) show clearly that a fractionation of the response systems existed – a well-known finding.

The method study, on the other hand, revealed that a number of measures taken immediately after stimulus offset exhibited a significant change from the first to the last stimuli of the habituation paradigm. Such measures were included to assess possible changes in tonic activity, although reservations have to be made concerning the reliability of such very short data periods. Obvious trends in pulse wave amplitude and pulse transit time appear to be indicative of an adaptation process that has to be distinguished from the course of habituation to repeated stimuli. These effects were rather small (according to estimated components of variance) and the between-subjects variance was particularly large; however, the findings were consistent in indicating vasodilatation and increased pulse transit time, i.e. decreased pulse wave velocity.

It can be speculated whether this effect was due to thermoregulation in ongoing adaptation to the air-conditioned room or whether a rather persistent vasoconstrictive response elicited by the pre-experimental procedure disappeared rather slowly. It is noteworthy that his effect, which appears to be limited to the vasomotor system, occurred although special precautions were taken to familiarize the subjects with the experimental setting and although at least 30 minutes of physical rest passed before the recording began. Other data that are available from this investigation do not suggest that a substantial overall trend existed across the whole experiment. For example, blood pressure values taken at the initial rest were lower than in any other part of this experiment including the post-experimental rest condition.

In concluding, the method study yielded a number of physiological measures that were appropriate to assess the habituation of the orienting reaction, whereby a rapid and a slower process of habituation had to be accounted for. The dominant role of the electrodermal response system became evident from these findings as compared to the vasomotor response, pulse wave velocity, heart rate, and somatomotor components. None of the many parameters obtained from the ECG and ICG appeared to be likewise suited in depicting OR habituation. There was evidence that besides habituation a process of adaptation to the experimental setting was present, though, restricted to thermoregulation and vasodilatation.

The results concerning the differences between blood pressure groups were negative. Neither electrodermal measures nor other physiological variables revealed significant ANOVA effects in the strength of the orienting reaction and the speed of habituation between subjects with elevated blood pressure and normotensive blood pressure. Findings from exploratory analyses that employed regression methods indicated, moreover, faster habituation in elevated blood pressure groups. The present study, thus, failed to support the theoretical assumption that a higher level and enhanced responsiveness of blood pressure are associated with slowed habituation to repeated stimulation. Two previous investigations (Collins et al., 1981; Fredrikson, 1989) had inconsistent findings and methodological issues were obvious.

The present study was meant to especially include cardiovascular measures in order to examine the supposed differences in habituation referring to such measures. Altered mechanisms of responsiveness in subjects with elevated blood pressure or borderline hypertension should manifest itself first of all in the cardiovascular system. A valid test of this hypothesis was hardly possible due to the fact that very few cardiovascular measures turned out to be appropriate measures of OR habituation. Compared to electrodermal responses as "gold standard" in OR habituation research, such cardiovascular measures showed only small effects. It is possible that the effect strength of the vasomotor response, pulse transit time and heart rate were too small to allow for a reliable testing of group differences although a rather large number of subjects were included in the present investigation.

Further reservations are necessary regarding the range of blood pressure. A comparison between chronic hypertensive patients and normotensive controls would allow for more between-subjects variance. However, such designs are likely to include many unwanted sources of variance, for example, confoundation with effects of labeling, increased health concern, and therapy.

Actually, significant differences between blood pressure groups were found for three cardiovascular measures, namely carotid pulse transit time and two measures of pulse amplitude. These differences existed already in measures of tonic activity after the first stimulus and persisted across the habituation paradigm. Since pulse wave velocity is known to depend on level of blood pressure the enhanced PWV in subjects with higher blood pressure may be expected. The findings concerning pulse volume amplitudes were inconsistent in sign for ear pulse and finger pulse and do not allow a valid statement for the time being.

The general conclusion is that the supposed group difference could not be found. The method study yielded a number of OR habituation measure; however, cardiovascular measures were less sensitive than electrodermal and electromyographic measures. The basic research question concerning differential responsiveness and habituation in subjects with elevated blood pressure is certainly not settled. A more appropriate test of the hypothesis would require continuous (beat-to-beat), non-invasive blood pressure measurement in order to assess OR habituation for the essential response system directly. Since this methodology has become available such an investigation concerning symptom specificity in the process of (non-) habituation appears to be feasible.

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Appendix

Table 3: List of variables

Nr.	Abbreviation	Variable	Unit
		Somato-Motor Variables	
1.	EMG-Ext	EMG extensor digitorum	mV* sec
2.	EMG-LID	EMG frontilis lateralis	mV
		Autonomic Variables	
Cardovascular			
3.	HR	Heart rate	bpm
4.	HRC	Heart rate corrected for respiratory rate	bpm
5.	ECG-PAMP	P-wave amplitude	mV
6.	ECG-Pe-Qs	Pe-Qs-time	ms
7.	ECG-RAMP	P-mave amplitude	ms
8.	ECG-Q-T rel	Relative	ms
9.	ECG-TAMP	T-wave amplitude	mV
10.	ECG-J+80	J-Punkt + 80 ms	ms
11.	ICG-ALZ	A-wave transit time (ECG-R to ICG-NC)	ms
12.	ICG-AAMP	A-wave amplitude	units
13.	ICG-PEP1	Null crossing transit time (ECG-R to ICG-NC)	ms
14.	ICG-PEP2	ICG-feedpoint transit time	ms
15.	ICG-RZ-time	E-wave transit time (ECG-R to ICG-E)	ms
16.	ICG-EAMP	E-wave amplitude	mV
17.	ICG-XLZ	X-wave transit time (ECKG-R to ICG-X)	ms
18.	ICG-XAMP	X-wave amplitude	mV
19.	IKG-FRAMP	F-wave amplitude	ms
20.	LVET1	LVET 1(zero crossing - X-wave transit time)	ms
21.	LVET2	LVET 2(feedpoint - X-wave transit time)	ms
22.	SV1	Stroke volume 1 (LVET1* E-wave amplitude)	(ml)
23.	SV2	Stroke volume 2 (LVET 2 *(E-wave ampl. - feedpoint ampl.)	(ml)
24.	HI1	Heather-Index 1 (E-wave ampl. / E-wave transit time)	units
25.	HI2	Heather-Index 2 ((E-Welle Ampl. - feedpoint ampl.) / E-wave transit time)	units
26.	PTT-CAR	Pulse transit tome, carotis	ms
27.	PVA-CAR	Pulse volume amplitude, carotis	units
28.	BV-CAR	Blood volume variability, carotis (DC signal)	units
29.	PTT-EAR	Pulse transit time, ear	ms
30.	BV-EAR	Blood volume variability, ear (DC signal)	units
31.	PTT-RAD	Pulse transit time, radialis	ms
32.	PVA-AMP	Pulse volume amplitude, radialis	units
33.	BV-RAD	Blood volume variability, radialis	units
34.	PTT-FIN	Pulse transit time, finger	ms
35.	PVA-FIN	Pulse volume amplitude, finger	units
36.	BV-FIN	Blood volume variability, finger	units
Respiration			
37.	RR	Respiratory rate	cycles/10 sec
Electrodermal activity			
38.	SCL	Scin conductance level	microsiemens
Skin temperature			
39.	TEMP-FIN	Scin temperature, finger	°Celsius

Table 4: Types of parameters used for scoring the stimulus contingent changes

Abbreviation	Type of parameter
M	Mean
R	Range
Aa	Absolute maximum
Ai	Absolute minimum
La	Local maximum
Li	Local minimum
Lai	Local maximum, then local minimum
Lia	Local minimum, then local maximum
Lat-Aa	Latency of tone offset to the peak of the absolute or
Lat-La	local maximum
Lat-Ai	Latency of tone offset to the valley of the absolute or
Lat-Li	local minimum
Lat-Aa10	Latency of tone offset to the 10%-upstroke of the absolute or
Lat-La10	or local maximum

Table 5: Analyses of variance for testing habituation and adaptation: Components of variance (percentage) and p-values associated with factor Tones based on Part 1 (N = 80) and Part 2 (cross-validation, N = 55).

	p-values Tones		VC Tones		VC Subjects		VC Error	
Variable	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2	Part 1	Part 2
OR parameter indicating habituation across tone 1 to tone 9								
EDA-AMP	.00[a]	.00[b]	16.3	25.0	46.6	37.8	37.1	37.2
EDA-LAT	.03	.16(.00)	2.7	3.6	15.9	18.8	81.4	85.6
EMG-EYE	.03	.07(.05)	0.8	1.5	39.1	34.2	60.2	64.3
PTT-EAR	.03	.10	0.8	0.9	57.7	43.7	41.5	55.6
OR parameter indicating rapid habituation across tone 1 to tone 2								
EDA-AMP	.00	.00	10.4	24.6	78.0	60.1	21.4	15.3
EMG-EYE	.00	.00	5.6	5.9	49.8	57.7	44.6	36.4
PVA-FING	.00	.01	2.3	3.9	69.7	62.9	28.0	33.2
HR corr	.01	.10	4.5	2.5	33.3	31.7	61.9	66.1
Measures indicating adaptation to the experimental setting								
PVA-EAR	.00	.10(.05)	0.5	0.3	93.3	90.6	6.2	9.1
PVA-FING	.00	.00	1.9	2.5	83.3	68.1	14.8	29.4
PTT-CAR	.03	.02	1.9	2.5	83.3	68.1	14.8	29.4
PTT-FING	.00	.20(.10)	0.1	0.3	88.4	78.0	11.5	21.7
TEMP-FING	.00	.00	0.1	0.5	99.1	89.3	0.8	10.2

Notes: [a] p-values related to Wilk's Lambda, [b] p-values related to the Huyn-Feld's Epsilon corrected F-values. In case of discrepancies, univariate statistics were used. Measures were selected according to $p < .05$ in Part 1 and $p \leq .10$ in Part 2.
For abbreviations see Table 1.