1999년도 한국음향학회 학술발표대회 논문집 제18권 제1(s)호

The influence of habituation on psychophysiological differentiation of automobile horns with different psychoacoustic characteristics

Yoon-Ki Min*, Estate M. Sokhadze*, Imgap Yi*, Moon Jae Jho**, Jin-Hun Sohn*
* Department of Psychology, Chungnam National University, Taejon, Korea
** Acoustic and Vibration Group, KRISS, Taejon, Korea

자극 습관화가 자동차 경적음의 심리음향 특성에 따른 심리생리적 구분에 미치는 영향

민윤기*, Estate M. Sokhadze*, 이임갑*, 조문재**, 손진훈*
* 충남대학교 심리학과, **한국표준과학연구원 음향진동 그룹

e-mail: *jhsohn@hanbat.chungnam.ac.kr*

Abstract

Psychoacoustic characteristics of automobile horns infulence subject's subjective evaluation and psychophysiological reactions on the sounds of car horns. However, differentiation of physiological responses to commercially availablenfluence subject's subjective evaluation and psychophysiological reactions on the s horns is a complicated task due to the small contrast in technical features of horns and the influence of habituation. Using 10 college students, comparative analysis of physiological reactivity was carried out in order to identify the effect of habituation on decrement of psychophysiological responsivity, assess the ability to differentiate subjectively most and least preferred/appropriate horns according to physiological manifestations. EEG and autonomic responses to 7 automobile horns were analyzed during 3 blocks of trials (each block was varied in order for presenting stimuli and acoustic parameters of horns). It was shown that electrodermal and cardiovascular responses had different reactivity patterns to repeated stimulation. Skin conductance variables (SCL, SCR) were habituated as a function of trial. Cardiac reactivity (HR, RSA) showed no signs of habituation. In contrast, sensitization was shown in the vascular component of response (pulse volume). The temporal EEG exhibited marked habituation of fast beta band power, while alpha-blocking effect did not habituate during the course of experiment. Differentiation of physiological responses of most and least preferred/appropriate horns was possible in this study. That is, some cardiovascular reactivity variables (HR, RSA, pulse volume, etc.) were differentiated between the least and the most preferred/appropriate horns during the experiment. However, EEG and electrodermal parameters showed significant differences only during first block of trials and were later affected by habituation.

Introduction

Engel [5] recognized the utility of an automobile horn as a laboratory stressor. Actually, an automobile horn's psychoacoustic characteristics

(intensity, loudness, etc.), its functional significance (signal of danger, alarm, etc.) and subjective aversion are considered the sound of horn as a valuable naturalistic auditory stimulus for psychophysiological research. However, comparison of commercially available car horns is a complicated task for several reasons: 1) relative similarity of technical characteristics of high quality competitive brand-name products makes contrasts between auditory stimuli quite small, and thus it is hard to detect differences of responses, 2) psychophysiological processes such as habituation affect physiological responses when horns are used as acoustic probes in repeated stimulation design, and 3) the amount of psychophysiological reactivity is reduced on physiological and subjective levels with an increased number of exposures. The habituation always occurs with the repeated presentation of the same stimulus or relatively similar stimuli of the same modality [2, 3, 7, 12]. After habituation, however, orienting response (OR) re-installment follows when stimulus intensity, modality, duration, frequency, sequence, complexity and significance change [3, 4]. That is, dishabituation may also be elicited by changes in frequency components of acoustic probe within the same stimulus modality [10, 12]. The role of stimulus significance and novelty has been discussed in detail in psychophysiological literature since for a certain period of time it was a topic of intense debate [1, 2, 6, 8]. Autonomic variables are widely used in research of processes related to OR and habituation. Among physiological indicators of habituation, skin conductance response (SCR) is frequently used, and is was demonstrated that the amplitude decreased over trials. Vasomotor parameters (i.e., pulse volume) are also popular measures along with cardiac variables, as well as alpha and beta power of the EEG [3, 4, 7, 10].

The current study focused upon comparative analysis of physiological responses evoked by auditory stimulation with automobile horns. The purposes of the syudy was to identify central and autonomic reactivity to startling acoustic probe capable of eliciting orienting reaction, to investigate the habituation course of EEG, electrodermal and cardiovascular reactivity and to differentiate physiological responses to horn pairs subjectively evaluated as most and least preferred, appropriate, and arousing.

Methods

Ten college students (19-23 years) participated in this study. Physiological signals [EEG, ECG, finger photopletysmogram(PPG), skin conductance] were recorded by BIOPAC, Grass System and Acqknowledge III. The following EEG and autonomic variables were measured for each condition: relative power (RP in percents from total power) of alpha and beta bands in the EEG spectrum (T3), heart rate (HR), respiratory sinus arrhythmia index, pulse transit time (PTT), pulse volume amplitude (PV), skin conductance level (SCL), skin conductance response (SCR) amplitude and SCR rise time. The experimental procedure consisted of adaptation (1 min) and 3 blocks of experimental sessions (8 min 20 s each). For each session that was presented by 7 different horns (with different orders for each session), each horn was presented for 5 s and recording was done for 20 s after 40 s baseline. The first session consisted of "mixed" mode including both high and low frequency bands of horn sound. The second session consisted of "high" mode including high frequency components of horn sound, and the third session consisted of "low" mode including only low frequency bands. After each stimulation trial, subjects were asked to evaluate subjective "appropriatness," "preference" and "arousalabilty" of the delivered horn stimuli for 1 min.

Acoustical characteristics of employed horns are presented in Table 1.

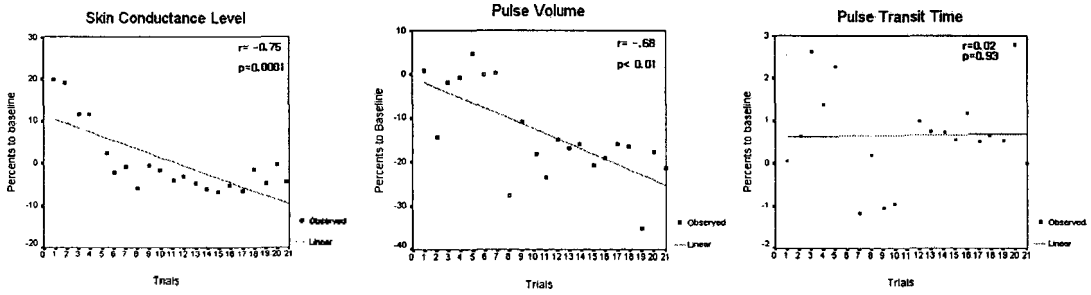
Results

Electrodermal activity was found to be prone to habituate since all skin conductance variables exhibited profound linear decrement trends. SCL decrease was linear with $r=-0.75$ ($p<0.01$), SCR amplitude with $r=-0.45$ ($p<0.05$), as well as SCR rise

Table 1. Technical and psychoacoustic characteristics of automobile horns employed in the study

Products	spectrum (dB)	loudness (sone/Bark)	sharpness (acum)	roughness (asper/Bark)	tonality (tu)
Hella/100phi/ shell/Germany	109.5	205.63	8.77	3.27	0.78
Mixo/100phi/ shell/France	110.00	202.69	8.32	3.33	0.82
Grandeur/100phi/ shell/Korea	101.05	120.24	5.19	2.2	0.84
Hella/100phi/ flatl/Germany	118.25	368.44	22.87	5.91	0.56
Bosch/100phi/ flat/Spain	112.95	250.86	15.08	3.45	0.76
Sonata/100phi/ flat/Korea	103.10	142.91	11.17	0.22	0.88
Knight Horn/ 100phi/flat/Japan	116.9	272.36	15.06	2.23	0.66

a)



b)

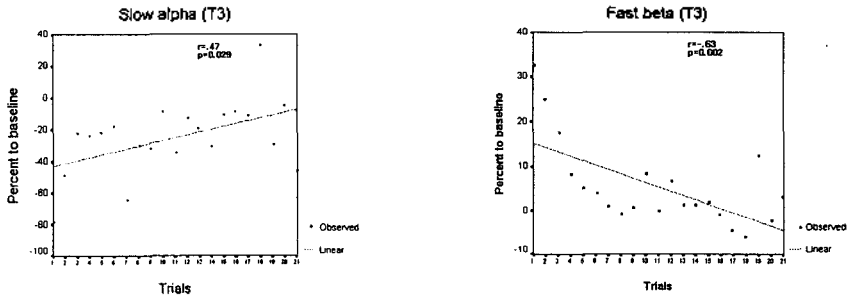


Figure 1. a) Regression analysis of standardized SCL change, finger pulse volume (PV) amplitude and pulse transit time (PTT) over trials of auditory stimulation with automobile horns. SCL endures marked habituation ($r=-0.75$, $p<0.01$), while pulse volume decrease response (vasoconstriction) demonstrates facilitation of reactivity ($r=-0.69$, $p<0.01$). PTT does not habituate, nor sensitize.

b) Regression of standardized slow alpha(T3) and fast beta(T3, T4) RP responses over trials of stimulation with automobile horns. Slow alpha responses demonstrate sensitization, while fast beta shows habituation. Linear regression trends are significant statistically. X axis : number of trials, Y axis : changes from baseline(%). N=10.

time (r=-0.81, p<0.01) and percentage of scorable SCRs to stimulation (r=-0.84, p<0.01) were greatly reduced. In contrast, cardiovascular variables did not manifest decrement of reactivity and remained reactive over trials. Namely, PTT and RSA did not show any drift of reactivity. HR responses tended to be slightly enhanced with an increased number of trials, whereas PV decreased with repeated stimulation (r=-0.68, p<0.01). Thus, no signs of cardiovascular habituation was detected. Furthermore, vascular components of cardiovascular response (e.g., pulse volume) showed a sensitization tendency. Figure 1a shows trends of standardized SCL, PV and PTT over trials. Temporal EEG demonstrated concurrent reactivity trends for relative powers of slow alpha (sensitization) and fast beta (habituation). Reactivity of slow alpha at T3 tends to increase over trials (r=0.47, p<0.05). In contrast, fast beta power reactivity decreased at T3 (r=-0.63, p<0.01). These data are shown in Figure 1b. Analysis of differences among physiological responses with relevance to subjective ratings data showed that in "preference" category the most preferred horn evoked cardiac and electrodermal responses distinct from the least preferred horn. However, electrodermal differentiation was significant (e.g., tonic SCL higher in preferred by 2.54 uS, p< 0.05) or close to significance level (phasic dSCL, p=0.059, SCR amplitude higher in preferred at 1.39 uS, p=0.06) only in the first session ("mixed" horns), while both phasic HR and tonic RSA differentiation were still valid in "high" and "low" sessions (e.g., HR accelerated 3.86 bpm more to Hella than to Knight horn, p<0.05; while RSA was 1.42 bpm lower, p<0.05). Fast beta power (T3) decreased more when reacting to least preferred horn in the "mixed" session. In the most-least preferred pair, phasic RP change difference was -5.10 percent (p<0.05). Differentiation of physiological responses according to subjective "appropriatness" rating was significant only in the "mixed" session for the most and the least "appropriate" horn pairs. In particular, observed phasic SCL increase was higher for the most preferred horn (0.64 uS, p<0.05) with trends toward higher SCR amplitude (p=0.057) and higher basal SCL (p=0.07), while both tonic RSA level and RSA decrease were significantly more reactive to the most "appropriate" horn. Fast beta RP tonic level (T3) was 4.87 (p<0.05) higher to most "appropriate" as compared to the least "appropriate," while slow alpha RP for the most appropriate horn was 2.03 percent lower (p=0.05) in the "mixed" session. Differentiation by "arousalability" rating yielded significantly lower tonic HR only during the "low" session, as compared to the least arousing horn, and less HR acceleration as a result of exposure to most arousing horn in the "high" session. However, fast beta power (T3) was lower for the most "appropriate" horn during the "mixed" session (-3.41 and -3.44 respectively, p<0.05), while slow alpha power (T3) was higher (2.82, p<0.05) in the "high" session. The "low" session did not show any EEG differentiation. Thus, differentiation by "appropriatness" and "preference" rating was effective in "mixed" conditions for both autonomic (SCL, HR, RSA) and EEG variables, while in "high" and "low" conditions only HR, RSA, and slow alpha showed significant of differences in most vs. least preferred, appropriate, or arousing horns. EEG differentiation was significant only for "mixed," while it failed to show any difference of responses during "low" sessions. Some differentiation results are presented in Figure 2 and Figure 3.

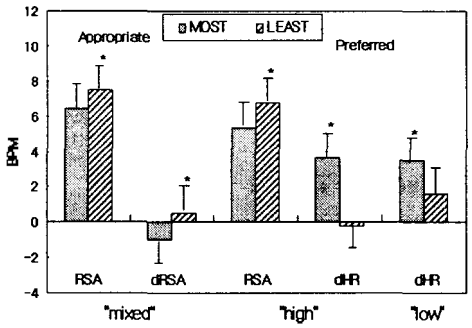


Figure 2. Differentiation of phasic (dHR, dRSA) and tonic (RSA) cardiac responses to the most and the least subjectively appropriate and preferred horns in the first (mixed), the second (high) and the third (low) sessions of auditory stimulation. Mean values are presented with SE (N=10). * p<0.05.

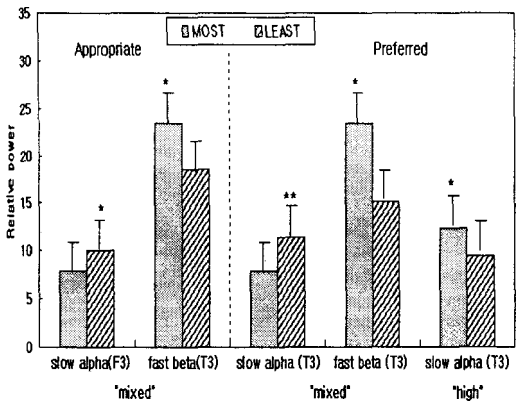


Figure 3. Differentiation of tonic slow alpha and fast beta responses (T3) to most and least subjectively appropriate and preferred horns in the first("mixed") and the second ("high") session of auditory stimulation with horns. Mean with SE (N=10). *p<.05, **p<.01

Discussion

Habituation of phasic SCRs during repeated trials has been described in many studies of electrodermal reactivity to abrupt loud stimuli [2, 4, 9]. In this study, SCL wa also habituated and consistent with the previous studies, whereas the habituation in cardiovascular activities were not shown. Tonic cardiac activity (HR, RSA) and phasic vascular responses (PV) were facilitated, and the results suggest that manifestation of cardiovascular sensitization can be interpreted by dual-process startling auditory stimulation have each their own theory of habituation [8].

The important finding is that ANS responses to unique pattern of changes in response to repetitive stimulation. The concurrence of skin conductance response habituation and tonic HR increase may be understood in the context of the dual-process theory of habituation [8, 11]. In our study only electrodermal activity showed decrement of response and marked habituation, while vascular reactivity was facilitated and overall cardiovascular activity (HR, RSA, PTT) that presumably reflects tonic state failed to show habituation. The distinctive facilitation of cardiac and vascular activity indexes the sensitization process, which is related to induced tonic arousal. It is suggested that repetitive startling stimulation is stressful [9]. Phasic and tonic RP of temporal slow alpha did not show habituation across all sessions. For example, alpha-blocking effect was persistent during whole experiment and this result is in accord with data reported by [3, 11]. The fast beta (T3), on other hand, demonstrated marked habituation. Decrement of beta reactivity indicates a decrease of orienting significance of stimuli with repeated presentation [1], but at the same time is independent from reactivity of the slow alpha band which happened to be more sensitive to variations in the entire stimulus properties. The simultaneous changes in alpha power may indicate fluctuations of arousal level during the experiment and thus reflect the state according to the dual-process theory of habituation(8].

Thus, auditory stimulation with automobile horns evoked autonomic responses in the form of HR acceleration, respiratory sinus arrhythmia decrease, finger pulse volume decrease, moderate pulse transit time increase, and electrodermal activity expressed in an increase of SCL and SCR of high amplitude, as well as slow-alpha blocking effect and increase of fast beta activity in temporal EEG. As the number of trials increased with repetitive stimulation, habituation of electrodermal responses and fast beta reactivity occurred. Furthermore, vascular responsiveness to stimulation was facilitated. The concurrent course of habituation of electrodermal and cardiovascular activity could be explained by sensitization of vascular responses typical for defensive or orienting reactions elicited by intensive auditory stimulus. In the first session it was possible to differentiate subjectively most and least preferred and appropriate horns by their electrodermal (SCL, SCR amplitude), cardiovascular (RSA, HR) and EEG (slow alpha, fast beta power) parameters. However, in repeated sessions of stimulation with modified frequency components of presented horns, differentiation was possible only in phasic and tonic cardiac activity (HR and RSA) and alpha-blocking responses, due to strong habituation effects on electrodermal reactivity and fast beta responsiveness.

Acknowledgment

This project was supported by MOST grant #17-01-03.

References

1. Barry R.J. "Novelty and significance effects in the fractionation of phasic OR measures: A synthesis with traditional OR theory", *Psychophysiology*, Vol. 19, pp. 28-35, 1982.
2. Barry R.J. and Sokolov E. "Habituation of phasic and tonic components of the orienting reflex", *International Journal of Psychophysiology, Vol.* 15, pp. 39-42, 1993.
3. Bernstein A.S., Taylor K., Starkey P., Juni S., Lubowski J. and Paley H. "Bilateral skin conductance, finger pulse volume, and EEG orienting response to tones of differing intensities in chronic schizophrenics and controls", *Journal of Nervous and Mental Disease*, Vol. 169, pp. 513-528, 1981
4. Boucsein W. *Electrodermal activity*, Plenum Press, N.Y. , 1992.
5. Engel B.T. "Stimulus-response and individual-response specificity", *Archives of General Psychiatry*, Vol. 2, pp. 305-313, 1960.
6. Gati I. and Ben-Shakar G. "Novelty and significance in orienting and habituation: A feature-matching approach", *J. Experimental Psychology: General, Vol.* 119, pp. 251-263, 1990.
7. Graham F.K. "Habituation and dishabituation of responses innervated by the autonomic nervous system". In: H.V. Peeke and M.J.Herz.(Eds) *Habituation: Vol. 1. Behavioral studies.*(pp. 163-218). Academic Press, N.Y., 1973
8. Groves P. and Thompson R.F. " Habituation: A dual-process theory", *Psychological Review*, Vol. 77, pp. 419-450, 1970.
9. Iacono W.G. and Lykken D. " The effects of instructions and an engaging visual task on habituation to loud tones: An evaluation of an alternative to the traditional habituation paradigm", *Physiological Psychology, Vol.* 12, pp. 23-29, 1984.
10. Magliero A., Gatchel R.J. and Loewski D. "Skin conductance responses to stimulus energy decreases following habituation", *Psychophysiology, Vol.* 18, pp. 549-558, 1981.
11. Ornitz E., Russell A., Yuan H. and Liu M. " Autonomic, electroencephalographic, and myogenic activity accompanying startle and its habituation during mid-childhood", *Psychophysiology*, Vol. 33, pp. 507-513, 1996.
12. Siddle D. *Orienting and habituation: Perspective in human research.* Wiley & Sons, N.Y., 1983.