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Guided Effect of Visual, Auditory, Tactile and Olfactory Stimuli on Heart Rate Variability and Psychological Health

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ABSTRACT

Background: The human interactions with nature is used for physical and mental relaxation since long. The various ways of these interactions are like listening bird's chirpings, forest excursion trips, sun-bath, beach-walking. Even in simulated aesthetically designed house in natural surroundings, such as fragrant roses, plantations, accompanied by music therapy relaxation is seeked. The heart rate variability (HRV) is impacted by stress; and neurobiological evidences prove its utility for evaluation of psychological health. **Methods:** The status of sympatho-vagal balance by heart rate variability recording and analysis was conducted in thirty healthy persons (of age group of 20-40 years)on exposure to the visualisation of forest imagery, auditory stimuli of soft piano sound scape, tactile stimuli with touching of oak wood and olfactory stimuli of fragrant rose perfume as part of pilot study. The frequency domain recording of HRV was conducted on Power Lab (AD Instruments) as a Power Spectral Density analysis. The mean values of heart rate variability parameters LF, HF, LF/HF ratio and Total Power over the 90 seconds stimulation were analysed and compared using ANOVA followed by post-hoc analysis for comparison of autonomic response of HRV frequency domain indices among the various stimuli. **Results:** Parasympathetic responses were observed in all our subjects for visual, auditory, tactile and olfactory stimuli. Moreover, parasympathetic response was more pronounced for visual and tactile stimuli than auditory and olfactory stimuli. **Conclusion:** The interaction with guided forest imagery, and suitable auditory, olfactory and tactile stimuli facilitates parasympathetic response favouring emotional stability and mental relaxation.

Keywords: Visual Imagery, Auditory, Olfactory: Tactile, Psychological Health, Heart Rate Variability (HRV)

INTRODUCTION

In a complex world full of stress and ever increasing pace of life, people are constantly looking for ways of releasing their tension. The highly competitive life style is leading to increase incidence of anxiety and depression in society.[1,2] The popular stress relaxation techniques include lifestyle modification therapeutic programs involving interaction with nature such as regular forest excursion trips, listening to musical notes, orienting the home surrounding and room with plants, roses and decorative objects, aesthetic decoration using wood and velvet carpeting etc. as especially all these measures have soothing stress relaxation effect on human mind and body.[2] Recent trends of research protocol are exploring the role of nature in health promotion and have observed that there is a positive acquaintance between natural stimuli and human health. Walking through forest during excursion, forest bathing or even visualization of forest scenery videos, and moreover forest therapy has been observed to improve the immune system, and produces physical and mental relaxation.[2]

In this busy life style it is difficult to find adequate time for practicing these stress relaxation techniques. Moreover recent development in image LED computer technology gives opportunity for visualizing videos of forests and streams at home at leisure. The studies with forest imagery were found to be beneficial with increase vagal drive as compared to visualization of video of urbanization. Mental imagery can be an effective tool in exercising mental control over own bodily states (heart rate, blood pressure, vasomotor activity and so on).[1,2] Another research study opined that the autonomic cardiac modulation for different acoustic stimuli was predominantly parasympathetic. Among the acoustic stimuli used in that study, the mostly influenced autonomic modulation were harmonic and disharmonic, and these were the complex stimuli.[3-5] Similar findings were observed in

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reference to tactile stimuli by Harumi Ikei et al. who in their study conducted on eighteen female university students investigated the physiological effects of touching wood with the palm. There finding revealed that touching wood with the palm calms prefrontal cortex activity and induces parasympathetic nervous activity more than any other objects or materials, thereby inducing physiological relaxation.[6] A parasympathetic response was also observed on pleasantness of odour influencing central autonomic nervous system.[7]

These studies have provided new insights into the interplay between the central and autonomic nervous systems.[8-10] These interactions with nature, acoustic, olfactory and tactile stimuli bring over relaxation of mind and it also aids in allaying stress. As per the Neuro-visceral Integration Model proposition; the heart rate variability mediatesthrough vagal activity and influence the functioning of the prefrontal cortex that gets integrated with the brainstem nuclei and it eventually influences emotion, mental state of mind and cognition.[10-12] The heart rate variability (HRV) is impacted by stress; and neurobiological studies have recommended its use for the objective assessment and evaluation of psychological health and stress.[12,14,15] The paucity of data of impact of all sensory stimuli in single person on autonomic functions and need to ascertaining of best sensory modality influencing parasympathetic drive and beneficial effect if any of compound stimuli on autonomic functions effect gave us an impetus to investigate status of sympatho-vagal balance by Heart Rate Variability recording and analysis in thirty individuals for the effects of visualisation of forest imagery, auditory stimuli of soft piano sound scape, tactile sensation of touching oak wood and olfactory stimuli by sense of fragrant rose perfume as part of pilot study. .

Aims and Objectives

- To record and analyze the effect of visual, auditory, olfactory and tactile stimuli on Heart Rate Variability.
- To compare the effect of visual, auditory, olfactory and tactile stimuli on Heart Rate Variability for ascertaining the best sensory mediated autonomic response.
- To observed the effects of compound stimuli (visual, auditory, olfactory and tactile stimuli) in single settings

MATERIALS AND METHODS

The present study was conducted in department of Physiology, Dr Ram Manohar Lohia Institute of Medical Sciences, Lucknow after obtaining the permission of Institutional Research Committee and Institutional Ethical Committee. The sample size in our study included thirty healthy individuals aged between 20 to 40 years. All the individuals selected for studies were healthy, non-smoker, non-alcoholic, having no clinical evidence of any illness, nor or on any drug or therapy. The participants were informed about the aims and procedures of the study. After explaining them a description of the protocol, they gave written consent to participate in the study. The study was conducted in accordance with guidelines of the Declaration of Helsinki. The visual imagery selected for visualization was a three minutes video, the auditory stimuli was background play of soft piano sound scape for three minutes duration, pleasant olfactory stimuli of fragrant rose flower perfume and tactile sensation of smoothed oak wood surface. The auditory, olfactory and tactile stimuli which were employed in our study were in line with other research study for autonomic function assessment.[4-7]

Procedure Protocol for Recording Observation: The participant after being explained the procedures were taken to the autonomic lab. The participants were comfortably seated in relaxed position in the autonomic lab of the department. The room was maintained at 24 degree Celsius and 50 lux illumination. The participants were made to relax for 10 (ten) minutes and thereafter HRV was recorded. The HRV was conducted on Power Lab (AD Instruments) as a Power Spectral Density (PSD) analysis using SA-3000P Software following the standard guidelines as recommended by the European Society of Cardiology and The North American Society of Pacing and Electrophysiology (1996).[16] The HRV was a continuous recording for about five minutes duration for every stimuli followed by thirty minutes break for recording for another stimuli and protocol was conducted as below:

A. The individual was asked to remain relaxed for 60 second (resting HRV) and thereafter resting state HRV was recorded for a minute as part of five minutes HRV recording. This was followed by HRV recording on exposure of individual to forest visual Imagery for 90 seconds, further followed by again resting state HRV recording with closed eyes for 60 seconds. The imagery visual stimulation was displayed using a liquid crystal display computer screen of 24 inches and it had 3840 x 2160 pixel resolutions (Lenovo Company Computer).[2]
B. The individual was asked to report after 30 minutes. And the 30 minute interval was maintained for exposure to all stimuli. Following the same protocol HRV was recorded for exposure to background play of soft piano sound scape, touch of oak wood and exposure to olfactory stimuli of fragrant rose flower perfume

The Frequency domain recording of Heart Rate Variability was conducted on Power Lab (AD Instruments). The change (variation) of heart rate during short term (5 minutes) was analyzed with the method of frequency domain to provide the degree

of balance and activity of autonomic nervous system. The Power Lab (AD Instruments) which was having SA-3000P Software was employed for recording and interpretation of bio-signal processing algorithms.[16] The HRV analysis was assessed by noting the cardiac autonomic modulation which was quantified using frequency domain analysis.[16]

HRV analysis and Statistical analysis

The HRV analysis in the frequency domain were conducted for low frequency (LF: 0.04–0.15 Hz) and high frequency (HF: 0.15–0.40 Hz) spectral components and measurements were reported in ms^2. The spectral analysis was calculated using the Fast Fourier Transform algorithm. The changes in values of LF, HF and LF / HF ratio every 30 s were noted during 90s of stimulation to respective stimuli and Total Power were calculated. All data were calculated from differences from average of 30 sec rest period. The mean values of heart rate variability parameters over the 90 second stimulation were analysed using ANOVA for comparison among the various stimuli followed by post-hoc analysis for comparison of autonomic response of HRV frequency domain indices among the various stimuli.[2,11]

RESULTS

The [Table 1] reflects the HRV indices which include LF (Low frequency), HF (High frequency), LF/ HF ration and TP (Total Power) in ms2. The LF (Low frequency) index is indicator of sympathetic nervous system response and has frequency band of 0.04-0.15Hz whiles the HF (High frequency) indices is indicator of parasympathetic nervous system activity and has frequency band of 0.15- 0.4Hz. LF/ HF ration reflects the sympathovagal balance while TP (Total Power reflects the general activity of autonomic nervous system and includes LF, HF and VLF {Very Low Frequency}). The VLF represents sympathetic activity but in five minute short term analysis it does not carry much meaning as this this band which has frequency range of 0-0.04 HZ in routine reflect meaningless noise signals and it is the LF and HF component which mainly contributes towards total power.[16]

Table 1: HRV frequency domain indices of visual, auditory, olfactory and tactile stimuli

Frequency Domain	No stimuli (Resting)	Visual imagery	Auditory stimuli	Olfactory stimuli	Tactile stimuli
LF (ms^2)	275.67± 197.09	199.51 ± 143.71	227.40 ± 161.70	174.45 ± 131.66	244.64 ± 138.56
LF (nu)	53.67 ± 23.43	50.74 ± 22.84	51.61 ± 21.68	46.60 ± 23.10	52.29 ± 23.91
HF (ms^2)	256.32 ± 195.86	332.19 ± 209.63	292.46 ± 193.15	379.77 ± 200.58	318.39 ± 194.12
HF (nu)	43.48 ± 22.34	46.92 ± 21.25	45.89 ± 21.04	51.48 ± 18.56	46.23 ± 20.71
LH/HF Ratio	1.13 ± 0.41	0.41 ± 0.28	0.73 ± 0.26	0.43 ± 0.19	0.80 ± 0.43
Total power (ms^2)	1019.5 ± 280.53	1264.81 ± 356.75	1549.67 ± 570.49	1139.67 ± 491.63	1630.58 ± 734.41

Table 2: HRV frequency domain indices of visual, auditory, olfactory and tactile stimuli

Frequency Domain	No stimuli (Resting)	Visual imagery	Auditory stimuli	Olfactory stimuli	Tactile stimuli
LF (%)	43.32 ± 12.26	27.52 ± 6.37	33.64 ± 9.61	23.31 ± 6.40	38.26 ± 10.05
HF (%)	30.33 ± 9.60	48.27 ± 16.58	41.69 ± 11.20	51.20 ± 17.28	46.91 ± 15.63

The relative power of high and low frequency band is also expressed in percentage. Fred Schaferr et al.[17] Conventionally, the total power of HRV comprises of about 60% of parasympathetic (reflected by HF indices) and about 40% of sympathetic drive(reflected by LF and VLF indices though VLF in short duration HRV recording as no significance)18. Hence we calculated the percentage of LF and HF for tabular and graphical recording for analysis of frequency domain Heart Rate Variability and is represented in [Table 2 & Figure 1 - Figure 3]. As observed in [Table 2] the LF-Low Frequency (%) is decreased and HF -High frequency (%) is increased on exposure to visual, auditory, olfactory and tactile stimuli [Figure 1]. Moreover the parasympathetic response is more significantly observed with visual and olfactory as compared to auditory and tactile stimuli. The LF/ HF ratio reflects a parasympathetic response on exposure to all four stimuli in comparison to the resting state [Figure 2].

As shown in [Table 3] the intragroup comparison was conducted using ANOVA and Post-hoc analysis was conducted to ascertain which of the stimuli elicited better autonomic response. The results revealed parasympathetic responses in all thirty individuals for visual, auditory, tactile and olfactory stimuli. Moreover the parasympathetic response was more pronounced for visual and tactile stimuli than auditory and olfactory stimuli.

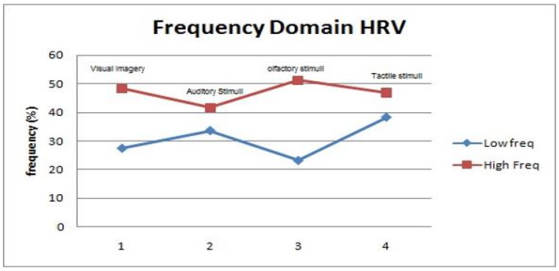

Figure 1: HRV indices LF (Low frequency) and HF (High frequency) in percentage on exposure to visual, auditory, olfactory and tactile stimuli.

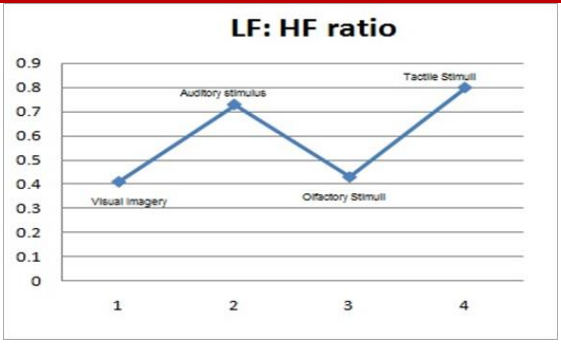

Figure 2: HRV indices LF/ HF ratio for visual, auditory, olfactory and tactile stimuli.

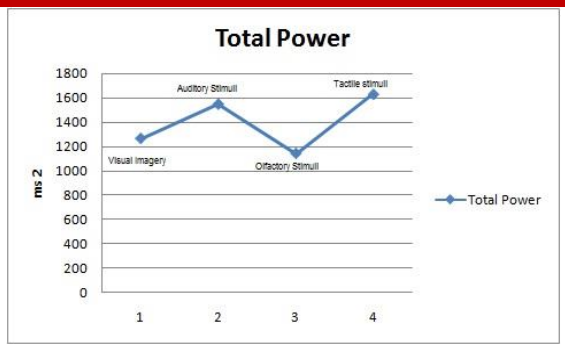

Figure 3: HRV indices TP (Total Power) for visual, auditory, olfactory and tactile stimuli.

Table 3: Comparison of HRV indices between different stimuli (Visual, Auditory, Olfactory and Tactile)

Frequency Domain	Visual imagery	Auditory stimuli	Olfactory stimuli	Tactile stimuli	ANOVA (p =value)	Post- hoc*
Low Frequency(%)	27.52 ± 6.37	33.64 ± 9.61	23.31 ± 6.40	38.26 ± 10.05	0.0098	a,c,d
High frequency(%)	48.27 ± 16.58	41.69 ± 11.20	51.20 ± 17.28	46.91 ± 15.63	0.045	a,c
LH/HF Ratio	0.41 ± 0.28	0.73 ± 0.26	0.43 ± 0.19	0.80 ± 0.43	0.00061	a,c,f
Total power (ms2)	1264.81 ± 356.75	1549.67 ± 570.49	1139.67 ± 491.63	1630.58 ± 734.41	0.049	a,f

*Post hoc analysis (within the group):
a: statistical significant difference between Visual imagery Vs Auditory stimuli
b: statistical significant difference between Visual imagery Vs Olfactory stimuli
c: statistical significant difference between Visual imagery Vs Tactile stimuli
d: statistical significant difference between Auditory stimuli Vs olfactory stimuli
e: statistical significant difference between Auditory stimuli Vs Tactile stimuli
f: statistical significant difference between Olfactory stimuli Vs Tactile stimuli

Thus overall higher HRV (Total Power as show in [Figure 1.3] in our subjects indicates that stress relaxation techniques influences flexible and adaptive emotional responses mediated by parasympathetic affects and this is in concurrence with findings observed by Thayer et al, 2012.[10,12,14] The higher HRV will also facilitate effective behavioural responses and better cognition and cognitive task performance and is associated with the effective functioning of prefrontal-subcortical inhibitory circuits. This flexible and adaptive behaviour response will help to allay anxiety and prevent depressive psychosis.

The value of HRV frequency domain of combined exposure to all stimuli in single setting was TP of 1080 ms^2, LF of 220 ms^2, HF of 660 ms^2, VLF of 300ms^2 and LF/ HF ration of 0.33 exhibiting enhanced parasympathetic drive.

Our results revealed parasympathetic responses in all thirty individuals for visual, auditory, tactile and olfactory stimuli. Moreover, parasympathetic response was more pronounced for visual and olfactory stimuli than auditory and tactile stimuli.

DISCUSSION

The heart rate variability recording and analysis on exposure to the visualisation of forest imagery, auditory stimuli of background play of soft piano sound scape, tactile sensation by touching of oak wood and olfactory stimuli by sense of fragrant rose perfume revealed increased vagal drive in all thirty individuals. Our findings for visual imagery of increased parasympathetic drive were concurrent with those of Deschaumes-Molinaro C et all who in their studies found that vagal mediated autonomic nervous system response patterns correlate with mental imagery.[15] The contents of imagery influence autonomic responses, and thereby make it comparable to real activity. Similarly it was observed in study of Song C etc. the visual stimulation with forest imagery induced a significant decrease in oxy-Hb concentrations in the right prefrontal cortex and a significant increase in perceptions of feeling "comfortable," "relaxed," and "natural.“ and there was overall noticeable parasympathetic response on HRV.[2] The parasympathetic response towards auditory stimuli in our study was in concurrence with study of Simone Fiuza Regacone et al. and their study also opined that the autonomic cardiac modulation for different acoustic stimuli was predominantly parasympathetic.[4,19 -21] The piano notes played in our study was in slow speed and at lower tempo. The literature also documents that the audible sound of music when played at slower speeds is known to enhance parasympathetic activity. The sound stimuli having a lower tempo were potentially more effective in enhancing autonomic tone and decreasing heart rate.[22,23]

Similarly the touching of wood with the palm leads to parasympathetic response and response observed in our study and was in concurrence with findings of Harumi Ikei et al. who ascertained the probable reason for enhanced vagal drive to the fact that that touching the wood calms the prefrontal cortex

activity and induces parasympathetic nervous activity more than other materials, thereby inducing physiological relaxation.[6,22] The olfactory stimuli of fragrant perfume of roses also produces parasympathetic effect as observed in our study. The olfactory sense physiological response depends on pleasantness of odour.[23-25] M. Bensafi et al. found strong correlations between pleasantness and heart rate variation and the arousal and intensity dimensions.[7,26-28] Similarly Harumi Ikei also observed that olfactory stimulation by Hinoki cypress leaf oil induced a significant reduction in oxy-Hb concentration in the right prefrontal cortex and increased parasympathetic nervous activity.[27- 29] Moreover the olfactory system has direct connections with hippocampus, thalamus, and frontal cortex and these are involved in emotional expression and odour recognition memory.[30,31]

Thus our study support the neuro-visceral integration model principle which suggests that; the heart rate variability mediates through vagal drive, the activity of the prefrontal cortex and the observed responses are integrated with the brainstem nuclei eventually influencing emotion, mental state of mind and cognition. The neuro-visceral integration facilitates parasympathetic response via prefrontal cortex circuit. Physiologically, the prefrontal cortex recognizes safety clues received from the environment and exerts its inhibitory control over sympatho-excitatory subcortical circuits, especially on the central nucleus of the amygdala. Our proposition is supported by the findings of a meta-analysis studywhich revealed (Thayer et al 2012)[10] that resting HRV is tied to the functioning of prefrontal-subcortical circuits, such that higher resting HRV is associated with the effective functioning of prefrontal-subcortical inhibitory circuits and this circuit exerts a flexible and adaptive responses to environmental signalling. The overall effects of parasympathetic response as observed on combine exposure to all stimuli in single sitting substantiate the fact that interactions with nature with forest guided imagery or in simulated aesthetically designed in house natural surroundings such as fragrant roses, green plantations, pleasant odour of suitable fragrant environment can be accompanied by background play of instrumental music etc. may produce physical and mental relaxation in individuals. Practicing stress relaxation techniques in community may be helpful in management of psychological disorders such as anxiety and depression.

Strength and Weaknesses of Study

The present study had employed exposure to all stimuli (visual, auditory, olfactory and tactile) in a single person as all these special senses affect autonomic responses in comparison to use of any one of these single stimuli in exploring autonomic responses by other researchers. The combine effect of all stimuli employed in single sitting has shown to be predominantly parasympathetic and this may help to design home and work place setting in appropriate aesthetic manner so has it will have positive, and energising effect promoting mood elation and emotional stability as these factors are very important for physical and psychological wellbeing.

The limitation of our study was that it was a pilot study with a smaller sample size. Moreover a future study with larger sample size will be helpful in designing suitable protocol for an effective stress relaxation and management of individuals in health and diseased.

CONCLUSION

Practicing stress relaxation technique is the need of the day in today's competitive world full of stress. The visualization of forest imagery or exposure to hormonic auditory stimuli and pleasant olfactory and tactile stimuli exerts parasympathetic autonomic responses and modulates mental and physical relaxation and thus helps in relieving stress while auditory stimuli and olfactory stimuli may exert a variable response in terms of sympatho-vagal balance depending upon individual temperament, liking and stimuli sensitivity. Our pilot study indicates that the enhanced activity of the parasympathetic system is linked with emotional stability and physical and mental relaxation and thus interaction with nature or guided imagery and other stimuli can be an important media for psychological and mental wellbeing in present era. This will help to prevent increasing evidences of anxiety, depression and other psychological disorders in the community.

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