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RESEARCH ARTICLE

EFFECT OF FORMALDEHYDE EXPOSURE ON VISUAL AND AUDITORY CHOICE REACTION TIME

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ABSTRACT

Reaction time study has been evaluated in many health and disease conditions. It reflects the alertness, calmness, concentration and cognitive abilities of an individual. Further study of choice reaction time for individual's response of visual reaction time for red and green and auditory reaction time for low and high frequency sound helps in microanalysis of perception of central nervous system to wide variety of stimulus and response pattern in each of the exposed stimuli. Neurotoxic side effects such as mood fluctuations, impaired concentration abilities, memory deficit and cognitive dysfunction resulting from chronic exposure to formaldehyde fumes are well known. Our earlier study observation revealed increased auditory and visual reaction time. The above fact gave us an impetus to investigate the choice reaction time tasks for auditory and visual stimuli in those exposed to formaldehyde for duration of three to five years period. The Visual reaction time for red color was shortest and delayed for green color in the study and control groups. Similarly, the study group and control reacted faster for high frequency than low frequency sound. The student's t test was employed to evaluate statistical significance. P value ≤ 0.05 was considered to be significant. Both visual and auditory choice reaction time was found to be delayed in study group as compared to control but this was not found to be statistically significant. Protective measures to prevent ill effects of formaldehyde exposure on human health are recommended.

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INTRODUCTION

Reaction time is the time interval between presentation of stimulus and appearance of appropriate voluntary response. Reaction time compromises of exposure to stimuli, sensory relay to the central nervous system, central processing of information in central nervous system and command for appropriate motor response. The study of choice reaction time has been carried in various studies and it gives better insight of neuro-physiological perception, functioning and responses of visual reaction time for red and green light and auditory reaction time for low and high frequency sound (Der and Deary, 2006; Madan *et al*., 1984; Baayen and Milin,2010). Visual reaction time depends on luminance, chromaticity, time taken for stimulus categorization and duration of time required for selecting response option. The color vision responses to varied colors are generated in the cone cells. There are red, blue and green absorbing fundamental cone cells. The other colors seen in the visible spectrum are mixture of three primary colors red, green and blue.

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The red, blue and green cone cells have different protein bound to 11 cis-retinal and characteristic absorption spectrum pattern. The red, blue and green cone cells absorb maximally at a characteristic range of wavelength. Blue show peak absorbance response at wavelength of 440-490 nm, read at 625-740 nm and yellow at 570-580 nm. The appearance of the red, green and yellow color will be best interpreted and recognized if wave length of the emitted light falls within the peak absorbance wave length limit. Response to auditory sound stimuli also depends on the physiological functioning level of the central processing unit, ear and sensory motor apparatus. Thus individual's perception in response identification may vary depending on his health status and is delayed in disease conditions; mood disorders and emotional imbalance (Madan *et al*., 1984; Baayen and Milin, 2010). Formaldehyde is commonly used as a preservative in anatomy, histology and histopathology laboratories. The major toxic effects caused by acute formaldehyde exposure are eye, nose, throat irritation, coughing, wheezing, chest pains and bronchitis. Chronic exposure to formaldehyde is associated with neuronal toxicity, neuronal degeneration and demyelination, increased risk of nasopharyngeal, oropharyngeal and lung cancer in humans

(Kilburn *et al*., 1985; Songur *et al*., 2010; Kilburn *et al*., 1987; Kilburn, 1994). There have been no study reported till date regarding investigating choice auditory and visual reaction time in individuals having prolonged exposure to formaldehyde. Thus the above fact gave us an impetus to investigate the choice reaction time tasks for visual stimuli of red and green light and auditory stimuli of low and high frequency sound in twenty five technicians and attendant staff working in anatomy dissection lab, histology lab and histopathology lab with exposure history of formaldehyde of mean duration between three to five years, six to eight hours per day/ six days a week and compared the results with age matched non formaldehyde exposed control subjects.

MATERIALS AND METHODS

The study was carried out in the Department of Physiology, IGMC and RI Puducherry in age group of 25-35 years in twenty five technicians and attendant staff working in anatomy dissection lab, histology lab and histopathology lab and twenty five age matched health controls. The exposure history to formaldehyde was for six to eight hours per day / week since three to five year. The study was approved by the institutional ethical committee and informed consent was obtained from the participant's cases and controls. All case and control selected for study were non-smokers, non-alcoholic, having normal vision and hearing and had no clinical evidence of any illness neither they were on any medication or therapy. The auditory and visual reaction time was recorded using response analyzer (RTM-608, Medicaid Systems, Chandigarh) with display accuracy of 0.001 sec ±1 digit, and two different lights red and green light and two different sounds high and low frequency sound were used as stimuli (Madan *et al*., 1984; Baayen and Milin, 2010; McKeefry *et al*., 2003; Henry, 1960). The study and control group participants were familiarized with the instrument and after several times of practice, three readings for each parameter were noted. The participants kept the index finger of the dominant hand on the response switch and pressed it after seeing the red and green stimuli or after hearing low or high frequency auditory sounds. The average of the three readings was taken as the value for reaction time task and was noted in the subject record profile. The reaction time was noted in milliseconds. The statistical significance was evaluated using student t test. SSPS software was used to measure P value. Test was considered significant if P value was less than 0.05

RESULTS

Data expressed are mean ± SD. Analysis was done by Student's unpaired t test. VRT-R: Visual reaction time – Red, VRT-G: Visual reaction time – Green, ART-Low: Auditory reaction time for low pitched sound, ART- high: Auditory reaction time for high pitched sound.

Table 1. Visual and Auditory Reaction Time in the Study Group and Control group

Parameters	Study grup	Control group	P value
VRT-R (milli seconds)	294 ± 16.32	290 ± 24.46	0.4997
VRT-G (milli seconds)	300 ± 17.64	294 ± 12.26	0.1690
ART-Low (milli seconds)	204 ± 22.24	199 ± 20.20	0.4095
ART- High (milli seconds)	198 ± 12.62	194 ± 26.48	0.4986

DISCUSSION

The visual and auditory choice reaction time has been found to be delayed in study group as compared to control but a similar pattern of shortest reaction time for red light and longest for green and early response for the auditory high frequency sound than low frequency sound was noted in both the groups. Both the visual reaction time for red and green and auditory reaction time for low and high frequency sound is delayed in the study group exposed to formaldehyde for duration between three to five years though these values were not statistically significant. The normal auditory mean reaction time is 140 milliseconds and mean visual reaction time is 180 milliseconds (Madan *et al*., 1984; Baayen, 2010; Henry and Rogers, 1960). The memory drum theory states that the complex responses like choice reaction time have to assess more stored information and due to which the reaction time is longer (Henry and Rogers, 1960). Our assessment of choice reaction time was targeted in a study group who are exposed to formaldehyde for exposure period between three to five years; six to eight hours per day / week. Formaldehyde has neurotoxic effects on neuronal morphology and thereby affects human behavioral pattern and responses.

The decreased auditory and visual reaction time in our study group of medical staff personnel technician and attendant exposed to formaldehyde is attributed to the fact that apart from principle of memory drum theory, there is neurobehavioral impairment associated with number of hours of exposure history to formaldehyde per day and moreover chronic exposure leading to epoxide formation near axons which leads to neuronal degeneration and demyelination. Exploring the literature we found that the histology technicians exposed to formaldehyde and solvents were having more complaints of memory, mood, equilibrium, sleep, and headache disturbances than matched controls unexposed to formaldehyde and solvents.[4,5,6,7] Hence neurobehavioral and neuro-morphological changes associated with long term exposure of formaldehyde may be the factors involved in delayed reaction time in our subjects.

Choice Reaction Time

Variation in visual reaction time and fastest reaction time response for red and slowest for green reflects the time required for stimulus categorization, intercortical interpretations, response command and the response proper. The peak absorbance for green and red light by respective cones occurs due to matching wave length band of these colors; and it might be also similar in case of the color light source emitted by the response analyzer machine; contributing to peak absorbance and earlier response to red than green. Also the decreased latency of neuronal response and enhanced neuronal gamma band synchronization for stimulus categorization are factors responsible for faster visuomotor integration and motor response. The gamma band synchronization is more profound for red than green and hence the control and the study group reacted fastest for red than to green (McKeefry *et al*., 2003; Henry, 1960; Venkatesh *et al*., 2002). The faster response to high frequency sound is attributed to the fact that the auditory high frequency sound elicit a faster response than low

frequency sound as tone and pitch of high frequency sound stimulate the hair cells more profoundly generating an action potential in auditory nerve for appropriate stimulation of the auditory cortex for hearing response and thereby speeding inter cortical interactions for perception, evaluation and response command for timely performance of finger tapping task eliciting the motor response. The results of our study of increased reaction time for low frequency sound both in control and study group is in concurrence with other studies which have opined that the increased audio frequency sounds does not affect reaction time or muscular activity relative to audio tones of smaller frequencies (Bliss *et al*., 1995; Haas and Edworthy, 1996). Thus the delayed reaction time in those exposed to formaldehyde may further detiorate neuronal functions and prolonged duration of exposure produce neuropathy apart from respiratory morbidities, lung cancer, contact dermatitis and allergic manifestations. Hence, we recommend better control exhaust system in the gross anatomy, histology and histopathology labs, use of effective ventilation system and personal protective equipments and regular monitoring of formaldehyde levels in these labs to minimize and prevent health ill effects of formaldehyde exposure.

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