Sophisticated evaluation of possible effect of distinct auditory stimulation during REM sleep on dream content

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Summary. Studies have revealed significant impacts of different external stimuli during sleep on dream content and have reported various incorporation rates. The present study was performed to evaluate possible effect of auditory stimulation with sophisticated method. For this purpose, fifteen healthy male volunteers, who were tested for having normal auditory sensation, slept for two consecutive nights on sleep laboratory and monitored by polysomnography device. Subjects were not informed about content and time in which the sound was played. Traffic ambience sound (40-60 decibel for 1 minute) played during second Rapid eye movement (REM) sleep of experimental (second) night and self-written dream report has collected after second and fourth REM sleep of both nights. Dream reports were coded by two independent coders according the Hall and de castle coding rules. Dreaming something related to traffic sound (according to coding rules) was reported significantly more in dream reports of second REM of experimental night (in which sound was played) in comparison to dream reports of second REM of control night (p=0.033). Direct incorporation of traffic sound was reported in 78% subjects. Our finding revealed that information processing of auditory stimuli continues during sleep and can affect dream content, much more than previously estimated. The evaluation of possible correlated EEG changes when dream has been affected by external auditory stimuli is needed in future studies.

Keywords: Dream content, REM sleep, auditory stimulation, traffic sound

1. Introduction

Although the reactivity to external stimuli is reduced during sleep, cortical responses are not completely absent(Campbell & Muller-Gass, 2011). The ability of auditory stimuli perception during sleep in all ages of human being and other primates is generally agreed upon (Campbell & Muller-Gass, 2011; Issa & Wang, 2011; Suppiej et al., 2010). However, the specificity of this discriminatory ability has never been fully apprehended. Studies have revealed not only the dreams can be affected by waking-life experiences, called continuity hypothesis (Schredl & Knoth, 2012), but also that external stimuli sometimes change dream content (i.e. heating and cooling stimulation) (Candas, Libert, & Muzet, 1982; Hoelscher, Klinger, & Barta, 1981; Schredl et al., 2009; Zung & Wilson, 1961). The effect of various stimuli on dream content result different rates in studies; ranging from 87% reported by pressure cuff on the leg (Nielsen, 1993) to 5% by sinus tone (Dement & Wolpert, 1958). Tactile stimuli, e. g. spray of water and pressure stimuli, have shown the highest incorporation rates in previous studies that can be suggested "close" stimuli will be processed in a different way since it is conceivable from a phylogenetic aspect that such stimuli are more dangerous for the sleeping organism than "distant" stimuli (Schredl et al., 2009).

The effect of external auditory stimuli on dream content was first investigated by Weygandt, published in 1893

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(Schredl, 2010) and continued more scientifically by follower researchers, like Dement, who applied sinus tone to sleeping person in 1953 (Dement & Wolpert, 1958). Although, a fair amount of studies have been focused on sleep and auditory stimuli, but employing pure tone voice in lots of studies(Czisch et al., 2009; Sallinen, Kaartinen, & Lyytinen, 1996) has prevented to shape specific dream content (only 5% of the dreams were affected). Quite a few studies have been focused at effect of meaningful acoustic stimuli on dream content. For example, Berger demonstrated spoken personal names which were randomly presented during the rapid eye movement periods of dreaming were incorporated into the dream content (Berger, 1963). He performed his study on eight subjects by presenting 4 personal names (two emotional and two neutral, according to each subject) and reported up to 41.9 percent incorporation rate, but no difference between emotional and neutral personal name were seen. On the other hand, Hoelscher suggested responsiveness to auditory stimuli during sleep is largely dependent on the personal significance of the stimulus to the sleeper (Hoelscher et al., 1981). They evaluated this by presenting concern- and nonconcern-related verbal stimuli to 7 male during sleep Stages 2 and REM. Study results revealed that concern stimuli were incorporated significantly more often than nonconcern stimuli in REM, although low dream recall rates prevented evaluation of whether this relationship also existed in Stage 2. They revealed incorporation rate of 23% and 6% for REM and stage 2 dream reports, respectively. In another study, Strauch & Meier presented jet fighter or weepy sound to subject during REM sleep and collected their dream(Strauch & Meier, 1996). They reported stimuli were incorporated in one third of subject's dreams. In a recent research, using novel technology in dream domain called Dreamthrower, Kamal et al (Kamal, Al Hajri, & Fels, 2012) tried to evaluate effect of administrating jungle sounds and light stimuli together on REM sleep, but did not found significant influence on subject dreams.

While human behavioral data have indicated selective impairments of sound processing during sleep(Campbell & Muller-Gass, 2011), brain imaging and neurophysiology studies have reported that overall neural activity in auditory cortex during sleep is surprisingly similar to that during wakefulness (Issa & Wang, 2011). Scientists have approved Electroencephalography (EEG) and Event-related potentials (ERPs) as good means of investigating the ability of an asleep person to discriminate auditory stimulation and have revealed most subjects have EEG change in response to stimulation (Davis, Davis, Loomis, Harvey, & Hobart, 1939; Liberson, 1948).

Indeed, stimulation during sleep is one of the oldest method in scientific dream research (Schredl, 2010). While, during previous studies it was suggested that direct pure tone acoustic stimuli could be incorporated into ongoing dreams, our studies tend to find out whether external meaning full acoustic stimuli are incorporated in dream content. But, gender, social and psychological conditions of subject (Domhoff & Schneider, 2008) and sleep environment can affect dreams, so having suitable control group for comparing dreams content changes and preparing restricted environmental situation for all subjects were ones of the most important issue which was neglected in some similar studies (Dement & Wolpert, 1958). The purpose of present study was to evaluate how auditory stimulation can affect dream content with precise methodological procedure.

2. Method

2.1. Participants

Fifteen healthy male, ranging from 22-25 years old, volunteered for this experiment. All participants passed basic auditory testing to establish normal auditory function. Pure tone average test (PTA) was used for this purpose, and volunteer with any auditory abnormalities (like abnormal auditory threshold, aberrant auditory domain and etc.) were dismissed from this study. All volunteered with serious medical diseases, treatment with anticonvulsants, sedatives, psychotropic drugs or medications, history of current or past drug or alcohol abuse, major psychiatric disorder (according to DSM IV TR), any auditory abnormality and any history of sleep disorder were excluded. The subjects lay in a usual sound proof chamber in the sleep laboratory and all experienced the same situation there to prevent any interruption in their dreams.

The subjects were admitted to the sleep laboratory and overnight polysomnography was performed to investigate sleep stages. Device consists of 32 channels EEG, EMG, EOG, ECG and respiratory flowmetry that let us to monitor all aspects of subject's sleep. Sleep stages were scored according to American Academy of Sleep Medicine (Littner et al., 2003).

2.2. Auditory stimulation

The auditory stimulation was collected from street ambience sound. We used traffic sounds, which has been collected in street with almost heavy traffic. Traffic sound was employed for our study, because everyone have experiences of being in street, using car and etc., and this helps us to be sure that the sound is familiar for subjects. Sound was played by mp3 player connected to loudspeakers in the chamber with amplitude of 40-60 db. Stimulus duration was 60s and was presented as crescendo – plateau (for 40s) – decrescendo pattern. The distance of loudspeakers to subject's bed was 1m and changing in body position had little influence on stimulus presentation. Because of sound proof room, no other sound affected the subjects.

2.3. Procedure

The study was accomplished at the sleep laboratory of Ibne-Sina hospital of Mashhad (Iran) and was approved by the local ethics committee.

The participant slept for 2 consecutive nights in the chamber of sleep laboratory. In the first night, they adapted to the setting and atmosphere and procedure was explained to them. Then, they usually slept under observation of polysomnography from 10:30 pm to 6:30 am according to standard procedures (Hori et al., 2001). Investigator woke them up (by calling their name) after the end of 2nd and 4th REM phase (which has been determined according to subjects EEG, ECOG and EMG) and asked them to write their dream down. Sound was not played at first night, but both nights, loudspeakers were near the subject's bed to eliminate oriented thinking and intermediary factors and subjects didn't know which night sound would be played. On the second night, subjects slept again, but 5 min after the beginning of 2nd phase of REM, 40-60 db sound was played for 60s as crescendo – plateau (for 40s) – decrescendo pattern. Investigator woke them up after the end of 2nd and 4th REM

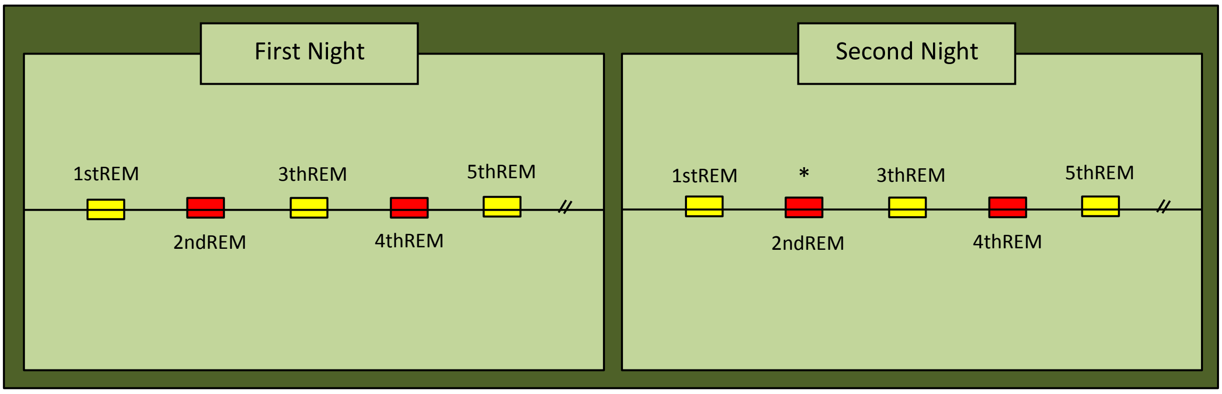

Figure 1. Dream reports are collected just after second and forth REM sleep of both nights (Red boxes). No interaction was done in other stages. Sound was played for 1 minute just in second REM sleep of second (experimental) night (sign *)

phase and asked them to write their dream down. The time interval between end of the auditory stimuli and wakening in the second REM period was commonly 3 minutes. Sound was not played again at 4th REM phase to help us to investigate effect of auditory stimulus on a current REM phase and consequent ones. Therefore, we played the sound once and collected 4 dream papers for each case (fig.1).

Dream reports were collected after awakening the subjects during REM sleep, where dream experiences are usually more frequent, longer and more complex than in NREM sleep (Foulkes & Schmidt, 1983). All words count include in dream length. Dream reports were coded by two blind independent rater using Hall and de castle coding rule (Hall & Van de Castle, 1966). The original Hall/Van de Castle system consists of eight general categories, most of which are divided into two or more subcategories. Because the categories in a nominal coding system can be clearly defined, there is high intercoder reliability in the use of the Hall/Van de Castle system.

Travel (Hall and de castle coding symbol: TR), Streets (Hall and de castle coding symbol: ST) and activity of "hearing" something evaluated in their dreams and compared these elements in second night dream to first night dream of the same subject; this prevents all possible social, emotional and other personal issues to interrupt the study. TR and ST were evaluated in percentage of Objects were seen in dream and hearing activity was defined as "activity of hearing something" according Hall and de castle coding rules.

3. Results

Sleep apnea is detected in one subject, discovered in first night (he did not know about his problem, before participating in our study) and another subject did not remember his second dream of experimental night. Because of study exclusion criteria, these ones were omitted from study and 13 subjects have been evaluated. These ones had no sleep abnormality during two nights. Dream recall is 100%, when they were awake after 2nd and 4th REM sleep of first and experimental night. Length of sleep had a normal distribution between subjects, and no significant change was found between first night and experimental night (P=0.237, Paired sample T test) (Table 1).

The number of word of all dream reports was counted and no significant different has been seen between first and second night dream reports (P>0.05, General Linear Model).

Dream analysis according Hall and Van de Castle coding rules, revealed significant difference between percentage of reporting TR and ST between dream reports from 2nd REM period of the first night and dream reports from 2nd REM period of second night(P=0.033, Wilcoxon Signed Ranks Test) (Table 1 and Fig 2). Mean number of objects in dream reports, according to Hall & Van de Castle definition of Objects, were 3.46 and 3.07 in dream reports from 2nd REM period of first and second night, respectively. Two subjects in their dream reports from 2nd REM period of first night and ten subjects in their dream reports from 2nd REM period of second night reported objects in their dreams, which were included at TR and ST. Subject reported dreams like "I participate in car racing", "My family and I go to trip with

Table 1. Word count, Dream content and sleep length across 4 groups of dream reports (mean ± SD)

	First Night		**Second (experimental) Night**	
	Dream A	**Dream B**	**Dream C**	**Dream D**
Word count	90 ± 47	89 ± 51	114 ± 66	78 ± 36
ST/TR percentage	4 ± 11	1 ± 6	24 ± 19	13 ± 21
Hearing Activity	46%	46%	46%	38%
Sleep length	401 ± 38		411 ± 45	

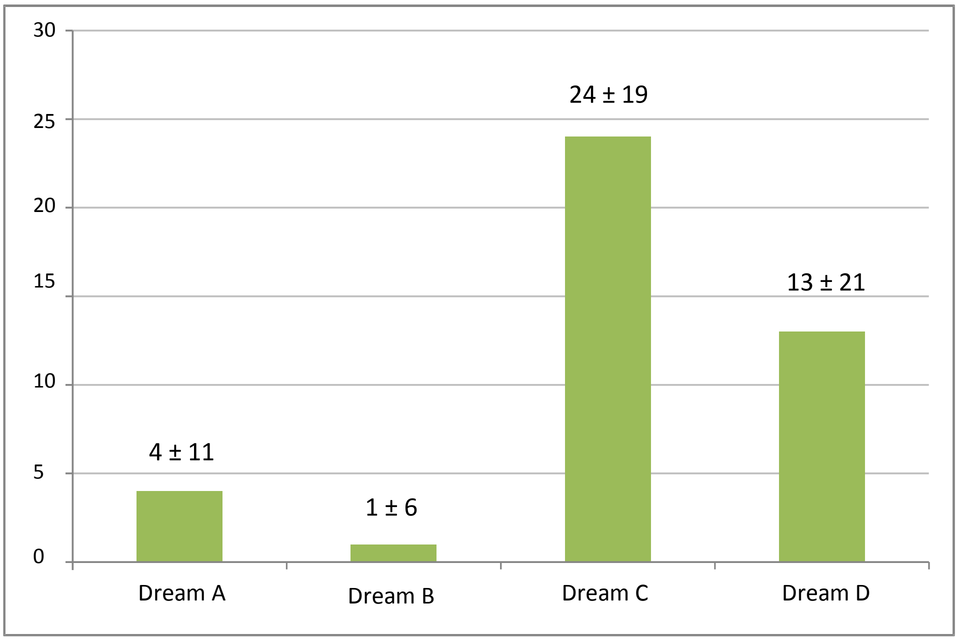

Figure 2. Percentage of reporting something related to traffic sound in each group of dream reports (mean ± SD)

a car, which doesn't have roof, and my mother give cheese sandwich to me", "I drive to capital with my car", "My sister and I came back to home in dark street", "I cross the street to buy a tableau from an art gallery". Just three subjects did not mention any thing about street in dream reports from 2nd REM period of the second night, but one of them mentioned that in dream report from 4th REM period of same night. No notable change in TR and ST percentage has been seen between dream reports from 2nd and 4th REM period of first night (P=0.893, Wilcoxon Signed Ranks Test) or dream report from 2nd and 4th REM period of second night (P=0.196, Wilcoxon Signed Ranks Test). For evaluating delayed effect of external stimuli, percentage of ST and TR were compared between dream reports from 4th REM period of first and second night, but no significant difference was found (P=0.66, Wilcoxon Signed Ranks Test).

Auditory content (like "I hear my mother and uncle discussion") was reported in twenty four dream reports, but no significance different was seen between first and experimental nights and between two dreams of each night (Fisher's exact test, $p > 0.05$). Just four dream reports contained activity of hearing something about traffic (like "I was in street and hear motorcycle sound" or "I hear truck sound from road, but when turn, no car was seen"). Three of these were in 2nd REM sleep of experimental night (dream C, when sound was played) and one was reported in dream D. No difference was found in TR and ST reports between group that reported hearing auditory sound and group didn't report (dream A: P=0.112, dream B: P=0.355, dream C: P=0.385, dream D: P=0.654, Mann-Whitney Test).

4. Discussion

The effect of external auditory stimuli on dream content was evaluated in this study and was found extremely effective. It revealed active processing of information during REM sleep. These findings are compatible with Schredl et al (2009) study, which examined the effects of olfactory stimuli on dream emotions. In their research, fifteen healthy volunteers were studied by intranasal chemosensory stimulation during REM sleep. For olfactory stimulation, hydrogen sulphide (smell of rotten eggs) and phenyl ethyl alcohol (smell of roses) was used (based on air-dilution olfactometry) and compared with a control condition without stimulation. The olfactory stimuli affected the emotional content of dreams significantly, the positively toned stimulus resulted more positively toned dreams, whereas the negative stimulus was yield more frequent negatively toned dreams.

Our results are comparable with studies which argued that dream content has been changed by external stimuli (Berger, 1963; Dement & Wolpert, 1958; Hoelscher et al., 1981). As mentioned in introduction, such studies use different stimuli and examine direct incorporation of them into dream content. Nielsen reported that 31% of the subjects dreamed something related to pain, on the effects of somatosensory stimulation administered during REM sleep (Nielsen, McGregor, Zadra, & Ilnicki, 1993) and Koulack reported a 42% incorporation rate for using cold water spray on skin during sleep (Koulack, 1969).

Actually, a few studies exactly discussed the effects of auditory stimuli on dream content in our method and the differences of our result in comparison to the previous studies like earlier study by Dement & Wolpert (1958) can be interpreted by the difference of the methodological aspects of both studies and revealed importance of sophisticated method (in presenting of auditory stimuli and elimination of all possible interrupting factor) is necessary. As mentioned in introduction, Dreamthrower was the name of project, which Kamal et al. (2012) tried to changes subject dream content, by simulation of jungle environment during his/her sleep. They administered voice and light of jungle by high technology devices, but did not found meaningful change in dream content. Very low sample size (three subjects) and not suitable sound amplitude (as they said in their paper) might have been responsible for the difference between their results and result of present study.

Although researches support effect of external meaningful acoustic stimuli on dream content, but reported incorporation rate are varies. As mentioned above, Berger (1963) reported incorporation rate of 41.9 percent, by administration of personal names, which has been presented randomly during REM periods. Strauch and Meier (Strauch & Meier, 1996) studied effect of acoustic stimuli by presenting jet fighter or weepy sound during REM period. Then, independent judges established whether dream is related to stimuli or not and if related, to which one. According to their study results, incorporation rate is about 33 %. Our studies indicated incorporation rate of 78.07% for meaningful auditory stimuli (traffic sound). The difference can be explained by difference methodological feature of studies, especially method of dream report judging. We applied Hall & van de castle coding rules for precise evaluating traffic content in dream reports. One the other hand, we applied traffic sound for all subject, because everyone had experience of being in street and it's familiar sound for every one (compare to applied jet fighter sound in Strauch & Meier study), because using unfamiliar sound might have caused different brain processing in different subjects (according to sound is familiar for him or no) and interrupting the study. Besides, It would also be interesting to Investigate the aspect of novelty of auditory stimuli for subjects on their dream content, on future studies, e.g. in regard to persons who sleep near traffic noise. It might be possible that familiar but not highly frequent stimuli can more incorporated in dream content, but would needed more evidence to approve that.

Amplitude, duration and time of playing stimuli were some of the issues investigated in our study. Since it was one of our objectives to prevent subject be awakened by stimuli, we used 40-60 db sound (normal conversation amplitude is 60-70 db) (Takegata, Heikkilä, & Näätänen, 2011) for 1 minute. Two expert experimenters controlled polysomnography of subjects during stimulation and if participants were awake during presenting auditory stimuli, he was omitted from study. It might be expected that a stronger and more repeated sound causes more incorporation effect. No studies were found to compare our result, so further studies is needed to discuss effects of these parameters. Subjects didn't know the time in which the sound was played (which night and when) and we played auditory stimuli in second night for all subjects to prevent possible effect of first night dreams (which has affected by stimuli) on second night dreams. On the other hand, presleep thinking about a specific thing can incorporate in dream (Cipolli, Fagioli, Mazzetti, & Tuozzi, 2004). To control this factor, subject's dream on experimental night was compared to his dream on control night. Additionally, the subjects were not informed about the content of stimuli. The experimenter was not blind to the condition; but he only awakened the participants by calling their names and asked them to record their dream and had no other interaction with participants.

Most experiments which concern administering various sensory stimulations during sleep have shown that there are large differences in physiological responses when comparing low-wave sleep (SWS) to rapid-eye-movement (REM) sleep (Cipolli et al., 2004; Oswald, Taylor, & Treisman, 1960). But our study like almost all other study in this field was unfortunately limited to stimulation during REM sleep, because dreams are recalled more often after REM (Foulkes & Schmidt, 1983). However, it could be interesting to perform study, with stimulation during non REM sleep to investigate effect of stimuli on these sleep stages. On the other hand, because of very few samples, we did not analyze EEG of subjects during sleep and stimulation. Further studies are needed to investigate possible coordination of dream content and EEG changes caused by external auditory stimuli.

Due to some cultural limitations, our study was performed only on male volunteer subjects. As reported in studies (Domhoff & Schneider, 2008; Schredl & Piel, 2005), gender difference affect dream content. But no studies were found, which discussed the differences between male and female dream response to external stimuli during REM sleep. It would be interesting that other studies evaluate this on female subjects.

Overall, it seems cortical processing of external auditory stimuli continued during REM sleep and can change dream content. Our findings revealed external meaningful stimuli can incorporated in dream content, much more than previously assumed. The result of present study might be useful in treatment of sleep disorder, especially in case of nightmare, as use of positive tone stimuli can change the dream content and improve patient's quality of sleep. To better understanding how manipulate content of dreams by sound, we recommended more studies in this field to clear the exact effect of various external acoustic stimuli on dream content.

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