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DreamThrower: An audio/visual display for influencing dreams

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ABSTRACT

The *DreamThrower* is a novel technology that explores virtually creating, throwing and catching dreams. It detects users' dream state by measuring rapid eye movement. Once the dream state is detected, sound and light stimuli is played to alter the dream. Users report on their dream, and they can send the stimuli that they have used to another person via an on-line website. A working prototype accurately detects REM sleep. Based on results from the first experiment with three subjects, light and environmental sounds such as a jungle and ocean were found to have little influence on dreams. The second experiment with five subjects found that voice sound stimulus could influence dreams in one case. Interestingly, our subjects felt that the *DreamThrower* system would be a fun gaming experience and many said that they would share their dreams for a collaborative gaming experience. User engagement with the social network may be sufficient to alter dreams. Two studies with different stimuli showed some evidence that dreams can be altered.

1. Introduction

The term *Dreamcatcher* has become a commonplace keepsake in North American culture. This idealized and over commercialized object originated from the North American Aboriginal Ojibwa Nation that, traditionally, hung above the bed as a charm to protect children from nightmares, as the *Dreamcatcher* acted as a snare for bad dreams, and only let good dreams through [12]. By taking this analogy of a *Dreamcatcher* and adding the concept of dream throwing and dream creating, we can start to conceive the *DreamThrower*. This research looks at how the knowledge of dream creation and control can be used to create a novel solution to "*throw*" dreams to other people.

Our digital *DreamThrower*, shown in Fig. 1, detects when a person has entered a dream state through eye movements using an infrared sensor. Its purpose is to enhance events using stimuli. When the user is awake, they may diary the events of the dream, as well as rank how pleasant or unpleasant (valence) the dream was. A user would be able to send another person a suggested stimulus via a social network service for them to try, i.e., they *throw* their dream to another user.

This potentially rich dream experience combines socialization of dream content and collaboration of sharing dream experiences. This is done by not only using stimuli to alter dream experiences, but also to share these experiences and stimuli with others to have fun and better understand if others will have the same or similar dreams. Our prototype's ability to detect REM (rapid eye movement) effectively coupled to a social network to share dream stimuli opens up the possibility of a fun game environment even if the stimuli itself does not have a significant impact. Instead, user engagement with the social network may be sufficient to alter dreams to discuss with their network of friends.

In the next section, we discuss the related work in the area of dreams and REM, dream stimuli and technologies related to dreams. In Section 3, we describe our system design. In Section 4, the user evaluation of our prototype is outlined, which is followed by our discussion of the results (Section 5), and finally the future works and conclusion is presented.

2. Related work

There has been significant work done in the area of dreaming from the perspective of behavioral psychology and brain science; however, the research done around the design of novel technologies in the domain of dreams is limited. Existing work includes understanding different dream states, lucid dreaming, effects of external stimuli while dreaming, and measuring physiological outputs when dreaming.

There has been research done in understanding different states when dreaming. It is widely accepted that REM strongly correlates to the dreaming state, and that REM dreaming state is qualitatively different than non-REM sleep and waking states [7,15].

The area of lucid dreaming has spurred both academic and non-academic studies. The concept of lucid dreaming is structured around being aware while one is dreaming, being able to control a dream and being able to remember dreams [16–20]. Technology

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Fig. 1. *DreamThrower* prototype being worn while sleeping.

has been created to assist a person to be lucid when dreaming [11,18,20,23]. These technologies include technologies that first detect when a person has fallen asleep such as the NovaDreamer® device [11,20]. The DreamSpeaker® provides audible signal and the DreamLight® provides light signals to assist the sleeper to understand that they have fallen into dream state to assist them in maintaining a lucid state while dreaming [11]. Similarly, the Lucid Dream Machine assists people in understanding that they are dreaming to help them in achieving lucid dreams [18]. The REM-Dreamer is another commercial product that works on the same premise but with the added functionality of being able to adjust the intensity of dream stimuli so that it is properly correlated for an individual in a dream state [23]. These technologies use an infrared sensor to detect eye movement (REM) to signal when a person is in a dream state; another study looked at methods to detect REM by non-visual means [1]. Our project will detect the dream state by measuring REM and also to understand the concepts of lucid dreaming; although our project will not focus on achieving and maintaining a lucid state when dreaming, it will need to be understood, so that our participants can remember and diary their dream experiences.

Another related research area is in understanding how external stimuli affect dreams. Sound stimuli while sleeping have been studied extensively: verbal sentences during REM sleep can assist in accessing declarative knowledge during sleep and help consolidate knowledge but this verbal cue will not be inserted into dream content [10]; the insertion of verbal content when sleeping also showed that external verbal stimuli are perceived as belonging to the events of the dream [3]; the insertion of verbal stimuli prior to falling asleep was also studied and shown to effect dream content as well as recall after waking [9]; and finally another study revealed that sound stimuli while sleeping cannot be used as an alert [5]. Smell stimuli have also been studied although it has been shown that olfactory senses are very limited while sleeping, and therefore have little effect on dream content [2,8]. Finally, the use of light has been used in the lucid dreaming domain to alert a person of a dream state [21]; therefore, we can also appreciate that light or visual stimuli have a cognitive effect while dreaming. Our project will use light and sound including verbal sound as stimuli to change the events of the dream and facilitate dream throwing.

There have also been several studies that look at measuring physiological outputs when dreaming. Various physiological signals correlate to REM or dreaming activity levels [15,16,22]. Hobson et al. in 2000 [15] developed the activation-input source-neuromodulation model (AIM), where electroencephalogram (EEG) activation and firing level of reticular, thalamic and cortical neuron correlates to the activation level; levels of presynaptic and postsynaptic inhibition and excitability of sensory motor patterns correlate to internal or external information sources; and activity of level of aminergic neurons correlates to mode or organization of data. Holzinger et al. in 2006 [16] studied the electrophysiological differences between lucid and nonlucid dreams in REM sleep by comparing the frequency of EEG signals. EEG signal frequency while sleeping and waking states has been stratified into seven levels; for example, the delta level is with frequency of 0.1–3 Hz, which corresponds to deep sleep and lucid dreaming and the 3–8 Hz is deep relaxation compared to 40 Hz is high-level information processing [4]. Other studies that aim to understand EEG signals have looked at the alpha level of EEG activity in REM sleep [6]. Our work will not look at physiological outputs, but rather rely on self-reports of the dream after the person wakes up.

Another related work that deserves mention is the Dream Communicator, which was one of nine conceptual design proposals for information appliances in [13]. Although the Dream Communicator was only perceived conceptually in this paper and never developed, its concept is to allow distant lovers to enter each other's dream state by stimulating their dreams with sounds or speech; this idea builds on the ability for external stimuli to enter the dream state. Although this design idea presents a portion of the *DreamThrower* of sending some stimuli to a remote person, it does not provide outputs from the person to visualize their dream experiences, nor the idea of dream crafting and sharing these creations through diary logs.

3. System overview

The *DreamThrower* is a system that allows a person to alter her/his dream by providing selected light and sound stimuli. The stimuli are triggered when REM sleep is detected indicating that the user is dreaming. This unique system has an on-line socialization of dreams component, where users can share their dream experiences by self-reporting their dreams, and then "*throw*" these stimuli to their on-line *DreamThrower* friends.

The system includes a *DreamThrower* eye mask component. The eye mask contains an IR (infrared) emitter and an IR detector to detect REM sleep. Once REM sleep is detected, the selected light and sound stimuli starts until REM sleep ends. Immediately after the dream state ends, the *DreamThrower* prototype plays an alarm sound that says, "wake up", in order to wake the person who is asleep, so that they can report on their dream. Dreams are self-reported on the *DreamThrower* website for sharing on-line with friends.

This study does not focus on lucid dreaming or try to invoke lucidity while dreaming. There has been significant work already done in lucid dreaming, so this study will not repeat this body of existing work. The focus of this work will be to invoke dreams by selecting stimuli, and to share dream experiences with others by sharing the same stimuli.

3.1. Design

The detailed design for the *DreamThrower* system is shown in Fig. 2. The main components of the design are the following:

(1) Eye mask: contains the IR emitter and detector, the light stimulus and the sound stimulus.
(2) Arduino board: provides the power and the processing and control for the dream detection and playing of the stimuli, which is coded in C.
(3) Computer: loads the stimuli onto the Arduino board and provides the link to the on-line website.

3.2. REM detection

To apply the stimuli at the appropriate time, the *DreamThrower* system needs to detect when a person is dreaming by detecting the

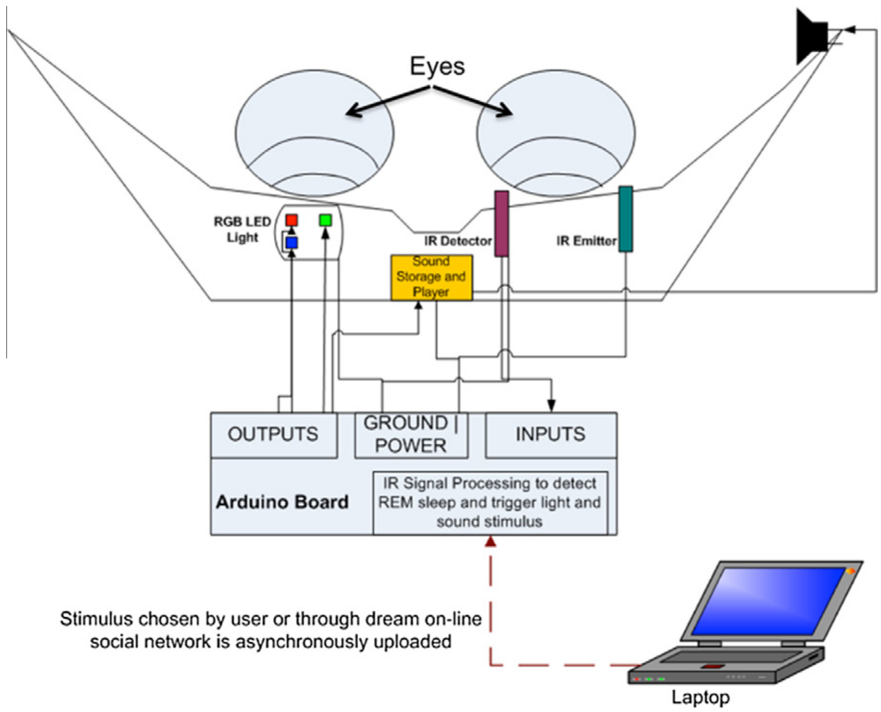

Fig. 2. Detailed design for *DreamThrower*.

REM state. In order to detect a REM state, an IR light signal is shone across one eye towards the IR detector. When the pupil of the eye is stationary, the IR light is blocked, and when the pupil moves the IR light is exposed towards the detector. This is shown in Fig. 3. The IR detector supplies different levels of voltage to the A/D converter on the Arduino board depending on the amount of IR light received. When the IR light is partially blocked, a low IR signal is detected, and when the IR light is exposed, a high IR signal is detected.

To accurately detect the REM stage, the system performs a series of signal processing algorithms on the sampled IR measurements. A pre-processing step is first done for noise reduction by a combination of windowing and integration. The basic rectangular window is used to divide the signal into blocks of data each containing the IR measurements over a small time interval. These blocks are then integrated to provide a single data value for each windowed period. Undesired high frequency noise is filtered, and therefore, makes the signal generated in the REM stage more distinct compared to the base signal where the eyes are quiescent.

The entire REM detection algorithm can be divided into three stages: calibration, REM start detection and REM terminate detection. The calibration stage is used to obtain a baseline for the signal

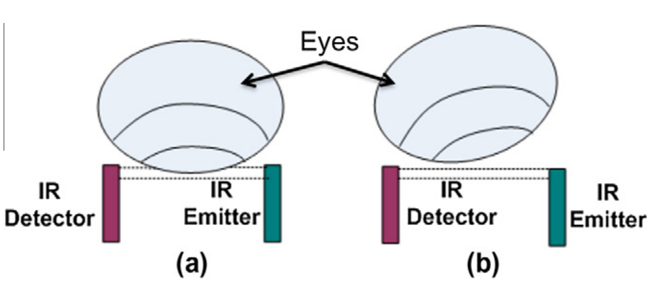

Fig. 3. REM detection using IR detector and emitter. (a) Shows the partial blocking of light when eye is in the position when the eye is not moving, (b) shows the full light signal being received when the eye moves to the side. This figure shows the same eye.

and is triggered after a pre-set waiting time. It is of import to not start the calibration before the user falls asleep since the eye activities of a person during the REM stage is relatively similar to the activities when he/she is resting but awake [14]. A threshold value, which is required in the later two stages, is set according to this baseline value.

Once the threshold obtained, the system is now ready to perform REM detection. The data points within a window of few seconds are used to observe the level of eye movement activities. After comparing each point with the threshold, a percentage of the number of points excessing the threshold level can be calculated. A low percentage indicates that the eye was mostly stationary and pointing straight ahead whereas a high percentage indicates that the eye spent most of the time pointing away from the center which is caused by extraocular muscle twitches during REM state.

Fig. 4 shows the calculated integrated IR signals over one sleep cycle. This plot shows the pre-set waiting time, the calibration step, the non-REM sleep is shown during the low values, and the REM sleep can be seen in the figure as the high values.

3.3. Sound and light stimuli

Once REM sleep is detected by the *DreamThrower*, light and sound stimuli that are selected by the user will be played until REM sleep ends. The light stimulus will be sent from the Arduino board to a multi-colored LED light that will be on the eye mask. This LED light will be able to emit any light color, which will be flashing on and off at a set frequency. The intensity of light could be controlled by the Arduino programme, and the user was allowed to adjust the intensity to their needs. The frequency was set to be 2 Hz. This will be done by controlling the output signals of the Arduino board that are sent to the red, green and blue inputs on the RGB LED light.

The sound stimulus will be triggered when a command is sent from the Arduino board to a VMusic2 module. This VMusic2 module will continuously play the selected sound file from a connected memory stick when REM sleep is detected. The VMusic2 module will

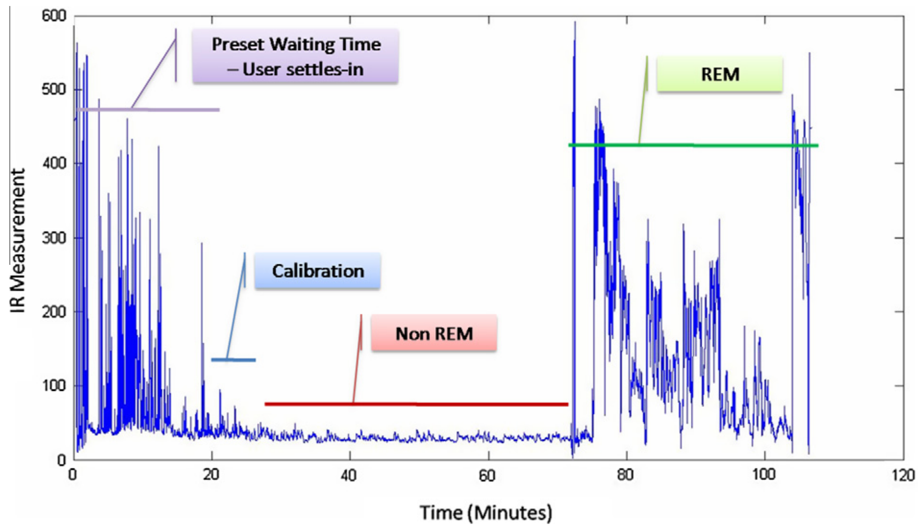

Fig. 4. Plot of integrated IR signal using the *DreamThrower* prototype. After settling in time (0–20 min) we calibrate the background signal (20–25 min). The subject is sleeping but not dreaming (27–70 min) and then enters REM sleep (70–110 min).

also play a sound to wake the user after the REM sleep has ended. The volume of the sound stimulus was adjustable to the user's needs.

3.4. Prototype

A prototype for the *DreamThrower* was developed. This prototype closely followed the detailed design for the eye mask as described in Section 3.1 of this paper. Fig. 1 shows a photograph of the prototype. Laboratory safety glasses were used for the structure of the *DreamThrower* eye mask. The IR detector and IR emitter were placed on the left eye of the goggles, and the light stimulus emitter was placed on the right eye of the goggle. We have at this preliminary stage of the prototype decided to only emit the light stimulus on one eye, as we want to determine if light has any influence on the dreams, which is not to preclude the importance of physiological coupling between both eyes. Future iterations of the prototype can include light stimulus on both eyes. The Arduino board, battery, and VMusic2 were placed on top of the goggles.

The prototype had the following sounds available for the evaluation of the *DreamThrower* system:

- Jungle sound.
- Ocean wave sound.
- Verbal speech.

The light stimulus could also be changed in the prototype. The RBG LED light could take any combination of signals from the Arduino program to create a multitude of colors. The current Arduino program will create a flashing light at a set frequency of the color that is chosen. The sound and light stimuli can be changed directly in the Arduino program and uploaded to the board.

The on-line system was not developed for the prototyping of the system; however, the self-report questions were asked using a questionnaire in the evaluation experiments.

4. User evaluation

This prototype was used for the user evaluation of the *DreamThrower* system. The purpose of the evaluation was to answer the following research questions:

(1) Does the *DreamThrower* system accurately detect dreaming state while sleeping and play the stimuli while dreaming?
(2) Does the user of *DreamThrower* feel that the system influenced his/her dreams?
(3) Did the user feel that the *DreamThrower* system could be fun to use and share stimuli?

There were two experiments that were conducted: the first one used light and natural sounds while the second tried just verbal sounds to determine whether one was more effective than the other. These two experiments are preliminary with the main purpose to understand if the sound and/or light can influence a user's dreams. The number of subjects in each experiment is admittedly very small, 3 in the first and 5 in the second. For this reason, we recognize that the results will be difficult to generalize to a broad user base; however, the experiments will provide an understanding for the efficacy for a *DreamThrower* system. We want to understand through these experiments if this type of game experience will be fun, if people would be willing to use it and share their dream experiences with others, and if there is any influence even if the influence is a placebo.

4.1. Experiment 1

The first set of experiments was done using sound and light stimuli. The sound stimulus that was used was jungle sound and ocean wave sounds, and the light stimulus used was a flashing green light and a flashing blue light. These sounds were chosen as they are easy to recognize by individuals and it would be simple to discern if the sound had any influence on the content of the participant's dream.

The system was tested using three subjects, who were outside of the research team. The small number of subjects for this evaluation was to establish an initial foundational understanding of the *DreamThrower* system. There were one male and two female subjects. The experiments took between 2 and 5 h each to complete. They took place in the subject's home, and one researcher observed them throughout the entire experiment. The timing of the experiment took place at a time that was convenient to the subject. They were not compensated for their participation. Each subject fell asleep on their own with no aids. The *DreamThrower* prototype detected REM, and when it was detected the sound and light stimuli was played continuously until the subject awoke or the REM state stopped being detected, at which time the subject was awoken by the prototype playing "wake up" at a loud volume.

Each subject participated in one experiment. The eye mask was calibrated for each subject to ensure that the REM detection would function properly for her/his eye shape. The purpose was to gain an initial understanding of the influence of external stimuli on dreams. Table 1 shows the type of stimuli that were used on each subject.

In order to answer the first research question, data was also collected using the Arduino program to help facilitate the evaluation of the system. This included a flag to confirm if the user entered REM sleep and a flag to confirm that the sound and light stimuli was played. This was confirmed by asking the participants if they just had a dream.

The subjects were informed which sound and light stimuli will be played while they are dreaming. Subjects were informed of the stimuli as this is inline with the usage scenario for *DreamThrower,* where users download the stimuli onto the device. They would wear the mask while sleeping, and when they wake up, each subject was interviewed. They were asked the following questions: (1) what was the nature of your dream that you had during the experiment; (2) did you notice the stimuli; (3) did you feel that your dream was influenced by the stimuli; (4) would you share this dream with your family and/or friends; and (5) do you feel that this type of system would be fun and enjoyable to use. This will provide an understanding of the dream that the subjects had during the experiment. The purpose of the interview questions was to answer the second and third research questions.

4.2. Results 1

Based on the data retrieved from the Arduino program, we were able to determine that the *DreamThrower* prototype was able to accurately detect REM sleep and play the selected stimuli for each of the three subjects. This was confirmed by the plot of the IR integrated signal for each user and correlating this with the flag of when the stimuli were played.

The results of each subject's retention and influence of the stimuli on their dream are summarized in Table 2.

Although the amount of dream content that the subjects remembered varied from little to very little, all three subjects can recall that they had a dream, and they had some recollection of the content of the dream.

The awareness of the stimuli varied for each of the subjects. Subject 1 did notice the light and sound stimuli while dreaming and was awakened by them. Subject 2 only noticed the sound but not the light stimulus, where as subject 3 did not notice any stimuli at all. In the case where the subjects did notice the stimuli, the stimuli were treated by the subjects as actual phenomenon happening in the real world rather than in their dreams. None of the subjects felt that the content of the dream was affected by the stimuli.

No correlation can be observed between the contents of the dreams of the three subjects: subject 3 dreamed about the *DreamThrowe*r device itself whereas subject 1 dreamed about a TV series that she watched shortly before starting the experiment, and subject 2 dreamed about sport highlights. All three subjects rated their dreams to be neither disturbing nor pleasant.

The interviews with the subjects also revealed some thoughts on their perception of the level of influence that the device had on their dreams. One subject felt that he/she would like to test the device multiple times:

> "I think, you have to have a series of experiments in your subjects because it is not easy to get familiar with the device as I was affected by the device itself and not by the stimuli."

Another subject commented about the comfort of the device itself, which speaks to how the device needs to be improved:

> "The device itself is too uncomfortable to wear. Also, I was awoken by the stimuli shortly after I started dreaming."

When the subjects were asked if they found the device and the concept of altering dreams based on stimuli "enjoyable", all three answered "no". Although, two of the three subjects said that it was because the device did not alter their dreams.

Table 1
Stimuli that were used on each subject.

Subject	Sound	Light
1	Jungle	Green
2	Jungle	Green
3	Ocean	Blue

4.3. Experiment 2

It is recognized that the sounds used in experiment 1 were limited to environmental sounds. Therefore, experiment 2 was conducted to include verbal speech sounds, as it has been recognized that speech sounds can influence dreams [9,10]. There were five subjects in this experiment, who were not participants in Experiment 1. Each participant was compensated $20 for her/his participation. All experiments were conducted at the University in a sound proof room, and they took place during the day. Participants were provided with a foam mattress, sleeping bag and pillow; however, they were encouraged to bring their own bedding if it would assist them. Two researchers observed the subjects from an adjacent room visually and through the data being collected by the *DreamThrower* prototype. In order to control the sound stimulus in the experiment, each subject was given the same verbal stimulus, which was a female voice softly saying the following simple statements:

> "Hello, where are you going?"
> [pause]
> "Come over here"
> [pause]
> "Go that way"
> [pause]
> "Come their way"
> [pause]
> [repeat]

A directional theme was used, as it will have the same meaning to all the subjects in relatively few words. We decided to use these four sentences rather than a single sentence, so that the sound stimulus would not become mundane or annoying if the subject did notice the stimulus while dreaming. By using the same sound stimulus on each subject, it can be determined if subjects have similar dreams due to the stimulus/stimuli used. This will provide an understanding of whether a dream can be thrown to another person.

Light stimulus was not used in this experiment for two reasons: (1) to add further control to the experiment so that an understanding of a stimulus on only one human sense can be determined; and (2) light stimulus had little effect on the subject in the first experiment, as it was noticed by only one participant, who was awoken by the light and sound stimuli.

Each subject participated in one experiment. The eye mask was calibrated for each subject to ensure that the REM detection would function properly for her/his eye shape. The experiments took between 3 and 4 h to complete. As sufficient time was required to allow each subject to fall asleep and then enter into a dream state. There were three female and two male subjects aged between 22 and 27 years old. Table 3 shows the gender and age of each subject.

Table 2
Results of experiment 1.

Subject	Remembered dream?	Noticed stimuli?	Felt their dream was influenced by stimuli?	Subject of dream
1	Little	Yes, sound and light	No	TV series
2	Very little	Sound only	No	Sports highlights
3	Very little	No	No	*DreamThrower device*

Once again data was collected using the Arduino program to help facilitate the evaluation of the system. This included a flag to confirm if the user entered REM sleep and a flag to confirm that the voice stimulus was played. Furthermore, each subject was interviewed after their sleep and dream states. The same interview questions were used as in experiment 1.

4.4. Results 2

Based on the data retrieved from the Arduino program, we were once again able to determine that the *DreamThrower* prototype was able to accurately detect REM sleep and play the voice stimulus for each of the five subjects. The voice stimulus played for a minimum of 1 min and a maximum of 5 min. For subjects 3 and 4 the voice stimulus played more than one time during their sleeping state. For each of the subjects, the stimulus continuously played at least once for 1 min or more. This was confirmed by the plot of the IR integrated signal for each user and correlating this with the flag of when the stimulus was played.

The results of each subject's retention and influence of the voice stimulus on their dream are summarized in Table 4. Furthermore, Table 5 shows the results of the interview questions that pertain to sharing their dreams and if they found the *DreamThrower* device to be a fun experience.

The first subject did not remember having a dream; however, we observed the subject talking while she was sleeping. Based on this observation it was thought that the participant did dream. Furthermore, the *DreamThrower* did play the stimulus while she was in the observed dream state; however, she was awoken by the voice stimulus. Although the stimulus did not influence her dream, she did feel that using a system like *DreamThrower* would be fun, "*I would like to try* [*DreamThrower*] *in my house*". She also spoke about how external stimuli have influenced her dreams in the past:

> "Always when I listen to something [while sleeping], it comes in my dreams like a nightmare."

The second subject did remember her dream. Similar to subject 3 in experiment 1, she dreamed about the *DreamThrower* experiment and device suggesting the *DreamThrower* device acted like a stimulus itself. However, this subject did not wish to share her dreams, and she thought a *DreamThrower* system might be fun; however, she said the following:

> "You want your dreams to be your own dreams, and [I am] not sure if I would want my dreams to be changed."

The third subject remembered his dream, noticed the voice stimulus and felt that this stimulus influenced his dream. In his dream, he was in a familiar room and two people walk in, and while he is interacting with these people, he starts to hear voices around him. The voices created intensity in his dream. He said the following:

> "It was very intense and suddenly I woke up and I was sweating and the heart rate was over 180 [beats/min]... it was due to the voices, I heard something."

He also suggested that the external voice stimulus had a haptic response while sleeping, as "*it was almost like a pin prick*" and the "*room felt pressurized*". He also said that when the stimulus played, "*it felt like someone was watching me*". He also mentioned that he was not accustom to the bed that was provided, and he would like to try the *DreamThrower* device at home. He was also interested in making the system for himself and he would prefer *DreamThrower* to play music.

The fourth subject did not remember her dream very well, but thought that it was about a character in a video game that she was thinking about before she fell asleep. She did feel that the *DreamThrower* system would be a fun and enjoyable experience, but she said that she may not always remember her dreams.

The fifth subject could not remember his dream in any amount of detail. He did notice the voice stimulus while he was dreaming. He said the following:

> "I am pretty sure I did notice [the stimulus]. I was noticing this for sometime and I know that I heard [the words]. Yeah, I hear it clearly enough. It is not like it is muffled or anything, but I don't really feel like responding to it."

He did not feel that the stimulus influenced his dreams, especially since he could not remember his dream. He also said that as he became more conscious of the voice stimulus, he started to feel "*creepy*". However, he said that he would be very interested in this type of gaming experience. He shared that he has played music while he is sleeping to influence his dreams, and he has found that this music stimulus has influenced his dreams.

Table 3
Subjects' demographic data.

Subject	Gender	Age
1	Female	22
2	Female	24
3	Male	26
4	Female	24
5	Male	27

5. Discussion

The data that was collected from the user evaluations confirms that the *DreamThrower* device does accurately detect the dream state of people while they are sleeping. This is because it accurately detected the REM state of all of the experiment subjects. Therefore, we can confirm our first research question: the *DreamThrower* system does accurately detect dreaming state while sleeping and play the stimuli, while dreaming.

Based on the results of the first experiment, jungle sounds and light stimuli did not influence dreams. Although the number of subjects is low, and we cannot generalize these results broadly, the results from the first experiment show that these types of stimuli have no effect on dreams. However, the third subject did dream about the *DreamThrower* prototype, which could have been because she was wearing the device. Therefore, no hard conclusion can be drawn on whether *DreamThrower* is able to influence dreams. In order to fully understand how environmental sound influence dreams, we conducted the second experiment with voice stimulus. The second experiment revealed that one participant did indeed feel that the external stimuli influenced his dream. Subjects

Table 4
Results of experiment 2.

Subject	Remembered dream?	Noticed stimuli?	Felt their dream was influenced by stimuli?	Subject of dream
1	No[a]	Yes	No	N/A
2	Little	No	No	Being in a experiment and about the *DreamThrower*
3	Little	Yes	Yes	Being in a room sitting on a chair with a book interacting with two people that walk in
4	Very little	No	No	Video game character
5	Very little	Yes	No	Some thoughts about things

[a] By observing this subject while she was sleeping, it was determined that she did dream.

Table 5
Feedback of the dream sharing and *DreamThrower* device as a fun experience.

Subject	Would you share your dream?	Is *DreamThrower* a fun experience?	Other comments
1	Yes	Yes	Has experienced external stimuli changing her dreams at home
2	No	Might be	Feels that dreams should not be changed
3	Might share dreams with some people	Yes	He wants to build a similar device to try it out on his own
4	Yes	Yes	
5	Yes	Yes	Has tried to play music while sleeping at home and it influenced his dreams

3 thought that his dreams had been influenced by the voice stimulus. Therefore, dreams can be influenced by external voice stimulus, but a dream cannot be thrown to another person. In other words, the dream experiences are still unique. It is evident that each subject had very different interaction with the stimulus when it was playing. This suggests the high variability in people to filter out external sounds and light when dreaming.

The most encouraging aspect of the second set of experiments was that the subjects were generally excited by the notion of a gaming experience using *DreamThrower*. They wanted to try the device at home, where they would be more comfortable. Some subjects also had ideas on the type of audio signal they would like to choose, such as a familiar song. Certainly, the novelty of this new gaming experience maybe a contributing factor to the subjects' excitement to the prototype.

6. Future work and conclusion

Based on the results of the user study, it is evident that the idea of dream sharing and dream influence presents an interesting and entertaining concept. Even within the limitations of a lab environment, subjects wanted to try using the device to experience how external stimuli influence their dreams. Furthermore, the concept of sharing their dreams and sharing the stimuli/stimulus that was used was very positively received. This suggests that there is potential for this currently largely untapped area of gaming experience.

Further testing on different sounds such as music and different voices may yield different results. This presents an area for future evaluation of the device.

Some possible suggestions on future experiments to fully understand the influence of external stimuli on dreams include:

(1) Use of haptic stimulus to understand if this human sense is more sensitive during dream state.
(2) Allow subjects to choose an audio stimulus themselves to allow for greater familiarity and personalization with the stimulus.
(3) Run the experiment for the full length of a sleep cycle such as 6–8 h.
(4) Allow subjects to run the same experiment many times to allow for acclamation to the prototype.
(5) Have subjects diary their experiences and dreams to help them to remember and reflect on their dream experiences.

Furthermore, it is possible that the stimuli did have an effect on the lucidity of the subjects' dreams since subjects were able to recall that they in fact had a dream. However, further experiments need to be performed to support this argument.

Testing the system on more users, where each user goes through the test several time with different stimuli is needed to better understand which sound, light, and haptic signal on human subjects would influence their dreams the most. Allowing users to develop their own stimuli based on their own interests would also provide an interesting study, as the content of the dreams are personalized to people's individual context, thoughts and activities.

The study focused on the *DreamThrower* device and only touches on the self-reporting component of the whole system. Therefore, future work should also conceptualize and design the on-line system to diary dreams, collaborate with friend and create/choose sound and light stimuli. Additional studies to understand the placebo effect of providing pre-sleep stimuli through a rich social network needs to be explored.

The extension of entertainment to dreaming by incorporating a rich social network environment to share dream experiences and pre-sleep stimulus presents a novel concept. Additionally, the concept of altering dreams by detecting dream state and providing stimuli is novel and presents a challenging yet interesting concept. By understanding the types of stimuli that will alter the dreams of the majority of people, a new human interface paradigm can emerge. For these reasons, it is worth further study.

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