Using a Short Video Animation to Assist with the Diagnosis of Sleep Disorders in Young Children

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Abstract. A short video animation is designed to mitigate the fears of children admitted to hospital for the diagnosis of their sleep disorders. The video animation was produced following recommendations from medical staff involved in the diagnosis. Images taken from the animation decorated the hospital ward, to bring the video characters to life in the children's minds. Finally, standard diagnosis of sleep disorders was performed by means of polysomnography on two groups of children: a reference and an evaluation group. Both parents and children responded to questionnaires that measured their satisfaction and the perception of their experiences. Preliminary findings extracted from the polysomnography showed that the videos helped to relax nervous children, especially sensitive to the hospital environment, and shortened Sleep Onset Latency and Non-REM latency. Besides, the responses to the questionnaires suggested that the video also reassured the parents whose moods helped the children to accept their hospitalization.

Keywords: Short video animation · Sleep disorders · Children · Polysomnography · Blender

1 Introduction

Sleep-disorder diagnosis techniques for children can be helped by the use of non-intrusive methods such as questionnaires. Nevertheless, hospitalization is in all cases required to perform polysomnography during sleep time [1]. Polysomnography involves continuous, supervised monitoring of the patient's sleep and waking states, for over 6 night hours without pharmacologically induced sleep. But children suffer stressful situations in hospitalization that can affect the sleep process: late bedtimes, nighttime wakings, and shorter total sleep time; these difficulties have been identified in children of very different ages, from toddlers [2] to children [3]. Stress is intensified because the polysomnogram test is a very uncomfortable diagnosis technique that involves the connection of multiple electrodes to the child's head throughout the night.

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L.T. De Paolis and A. Mongelli (Eds.): AVR 2016, Part II, LNCS 9769, pp. 13–29, 2016.
DOI: 10.1007/978-3-319-40651-0_2

Although the children could be monitored at home through the use of telediagnosis [4, 5], new ways of relaxing children during hospitalization would improve the diagnosis process. In the case of babies, the use of neuro-based music appears to be a suitable solution [6], but this technique is not so suitable for children, because their reasoning ability requires an understanding of the need for hospitalization. In the case of sleep disorder diagnosis, the children will hold some conception, within their limited capabilities, of what a sleep disorder is, and the need for polysomnography. This observation prompted staff at the Sleep Diagnosis Unit of the University Hospital of Burgos (Spain) and the University of Burgos to search for new ways of helping children to enter a relaxed state of sleep under polysomnography conditions in hospital environments.

This research proposes a solution from a perspective that is not usually associated with hospitals: the ad-hoc development of a short 3D video animation and its integration in the hospital environment where the children are treated. Children are eager to watch video animations that can stimulate the infantile imagination much more than non-fiction films, awakening greater empathy in the child with the characters in the video [7]. The use of short video animations to explain sleep disorders to children were first described in 2014 for jet-lag [8]. However, only 2D animations were created and no measurements were taken of its effect on the children's own understanding of jet lag in terms of a sleep disorder. The absence of any analysis of its effects is comprehensible as the video was designed for in-flight viewing; quite unlike the scientific context of a diagnosis based on a polysomnogram test while in hospital.

This research seeks to take a step further through the production of a short video animation; we propose the modification of the children's hospital environment to create an association between their immediate surroundings and the video animation. In this way, the positive feelings that relax the children while viewing the film may stay with them until they fall asleep in bed, allaying any fearfulness associated with the electrodes attached to their heads for the polysomnogram test. Besides, if the explanation convinces the children to accept the need for a polysomnogram test, it will reaffirm the parent's willingness to leave the children in hospital overnight, in such a way that the parents will in turn transmit confidence in the diagnostic process to the children. All in all, mutually reinforced confidence between parent and child will help to reduce stress and will improve sleep quality, the quality of the polysomnogram test and the eventual diagnosis of the sleep disorders.

The production of the short ad-hoc 3D video animation was limited to a very low budget. The idea was to produce the 3D video animation with only two modelers/animators over 3 months. If such an audiovisual product can be produced in the basis of a very low budget, it can open the production of very customized video animations for different purposes. Therefore the traditional workflow and the techniques in use had to be adapted to this requirement. In this study, some methodologies for the 3D modeling of cultural heritage items [9, 10] were used for 3D character modeling and shading, although their effect on final production costs were not as significant as planned. The main costs were due to the animation stage of the characters, as outlined in Sect. 2.

The paper is structured as follows: Sect. 2 describes the process of producing the short video animation with low-budget techniques; Sect. 3 shows its practical use to help in the diagnosis of sleep disorders in children; Sect. 4 summarizes the results of this experiment, using the surveys administered to both parents and children and the polysomnogram test results on both the reference and evaluation groups of children. Finally, Sect. 5 presents the conclusions and future lines of work.

2 Development of the 3D Video Animations

The production of a video animation includes many tasks that are usually grouped into 3 main stages: preproduction, production and postproduction. As it was a small-scale project, these 3 stages were simplified. Additionally, a making-of of the short film has been done and uploaded in Internet [11].

2.1 Pre-production

First, the identification of the main objectives of the video was done in collaboration with the Sleep Diagnosis Unit of the University Hospital of Burgos. The objectives of the video were as follows:

1. To induce feelings of happiness in children, within an age range of 3 and 6 years old, in such a way that the hospital ward is perceived as a harmless environment and the polysomnogram test as a beneficial technique.
2. To help the children understand the need for a polysomnogram test, so that they could vanquish their sleep disorders, associated with nightmares.
3. To prompt associations between the short video animation and the real hospital environment; between the avatars in the video animation and the medical staff caring for the children while in hospital; and, between the video scenarios and the real hospital wards.
4. To prompt a direct association between the main avatar in the video and the child, reproducing in a quiet and positive way the main steps that the children will follow while in hospital.

With regard to sleep disorders, the search to establish empathy and co-identity between the video viewer and the main avatar is a common objective in many other short video animations [8]. However, these videos are mainly designed for a more general use than in our case and marked associations with the hospital environment and secondary characters, such as doctors and nurses, is uncommon.

The short video animation of between 5–10 min was designed to respond to the above requirements. It included 3D animations, 2D animations and real recorded sequences. This mixture exploits the attraction that 3D animation exercises over children, the power to explain concepts and to lower production costs of 2D animation and the power that filmed sequences of real life have to provide quick identification of persons and places.

The second stage is to create the characters and storyboard. The short video animation included 5 characters: Alberto, a happy child as the main character, Morfea, the sweet and smiling Queen of Dreamsland, two warm and quiet fairies that help Morfea and, finally, Susto, the ‘monster’ in the short animation that lives in the child’s nightmares. Morfea is meant to be identified with the doctor during the polysomnogram test and the fairies with the nurses. Susto is needed so that the children can make sense of their hospitalization. Figure 1 shows some preliminary drawings of some of the main characters.

Fig. 1. Some draft drawings of the fairies and the character of Morfea.

Four scenarios were likewise identified for inclusion in the storyboard: Dreamsland, the dreams-machine, Alberto’s room, and the Forest. Dreamsland is a complex scenario that will be presented in 2D, 3D and real images, as it will include images of the Hospital (inside and outside). The dreams-machine is the place where the medical staff conducts the diagnosis and will be presented in the 3D video animation and in real images. Some concepts on sleep and the genesis of dreams are explained in Alberto’s room at home that bridges the real life of children and the video narrative. Finally, the forest is the place where Susto is presented. It differs from the other scenarios as it separates the bad feelings that Susto represents from the hospital and home environments. Besides these three well-defined scenarios, some actions are presented in undefined scenarios: clear and well-lit for positive actions and dark scenarios for negative actions during the dream stages.

Finally, the storyboard was created including 2D, 3D, and real recorded sequences following the various previously presented strategies. The storyboard was divided into 3 stages: the characters and scenarios were presented first of all. Then the hows and whys of sleep-disorder diagnosis and, thirdly, the confrontation between the child and “Susto”, the monster, during his sleep in the hospital drew the animation to a close giving it a happy ending after the child’s nightmare.

2.2 Production

Although the short film also included real recorded sequences (8 %) and 2D sequences (48 %). only the production steps performed for the 3D animation sequences are presented in this research. Blender software (www.blender.org), 3D modeling and animation software developed as open-source software and distributed under GNU GPLicense was used for all of these production processes.

First, the 3D Modeling step was created. Different 3D models were built limiting both human and computational resources, by following previously developed methods for complex 3D Cultural Heritage reconstruction models [10], although some minor changes were introduced into the overall process. Most of the 3D meshes were created using standard 3D CAD tools that modify 3D standard meshes such as spheres and cubes, giving them a final smooth appearance through the application of smooth operators, see Fig. 2 as an example. The hair of each character, one of the most critical elements for final visual quality was created with meshes, without using real hair operators or Blender software plugins, as it would strongly increase the computational rendering time. Besides, this short video animation targets a public of children younger than 10 years old, a public that is not usually very critical of the visual appearance of characters. Instead, they tend to focus on the transmission of feelings, due to their empathy with the characters, which are evoked in the animation.

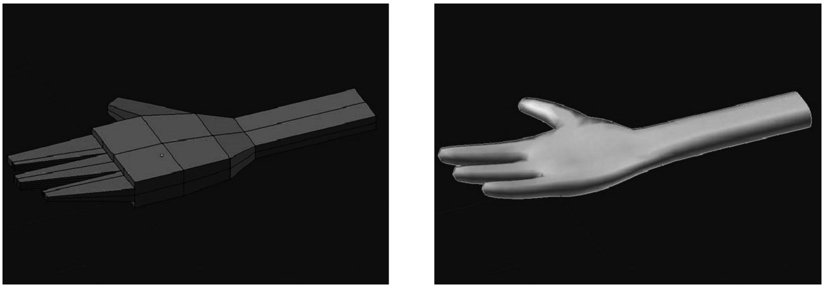

Fig. 2. The model of a character's hand: from easy geometrical meshes to final result.

Following 3D modeling, two different strategies were followed for the shading step, depending on the final appearance of the various 3D models. The first one shaded Susto's skin, the child's armor, the fairies wings and some objects in the rooms such as the bed and the walls in the hospital ward. Image textures were UV-mapped on the meshes of these objects [9], to improve their final visual quality, but without increasing the number of polygons that shape the meshes. In the case of Susto's skin, Fig. 3, a procedural noise texture for Normal Mapping was subsequently applied to give the avatar the appearance of a stuffed toy and, therefore, to attenuate the negative feelings that this character might arouse in the children. The second strategy was followed for the rest of the 3D meshes: only one-color materials without specular shaders were created. This technique simplified the shading step and was accepted because child spectators usually overlook this lack of realism. Only metal objects and the eyes

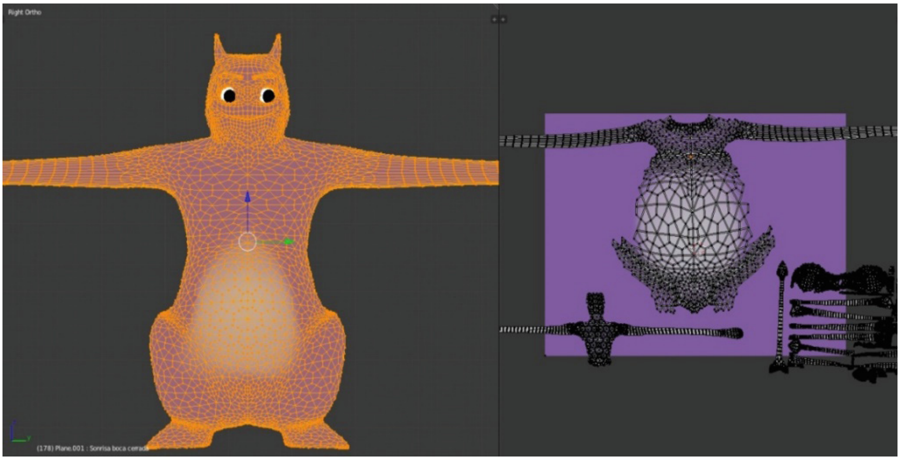

Fig. 3. UV mapping of Susto's character (Color figure online)

included specular shaders to reflect bright light when illuminated. Transparent objects were reduced as much as possible, due they increase the rendering computational time: only Alberto's glasses, the fairies' wings, and the windows of the hospital ward and Alberto's room included transparency levels.

Reductions in rendering time for lighting were achieved by using only one main soft spotlight and 2–3 secondary spotlights, to produce eye brightness and other elements. The main lighting was mainly a light warm (yellow or orange) color in all the scenes and cold colors (blue) were used in only two scenes, to increase the dramatic effect. Figure 4 shows some final renders of the main characters of the short video animation.

Fig. 4. Final renders of the main characters.

Finally, the animation of the 5 characters was done using standard armature techniques. Rigging and skinning were done first, followed by Weight Painting, to define the weight that each bone might have in the movement of each polygon of the mesh. Figure 5 shows two examples of Weight Painting of the hair of the Queen and the body of the child. It is worth mentioning that automatic skinning modifications, using the Weight Painting technique in joints, such as elbows and shoulders, created many problems. This stage requires substantial manual modification in the areas that use large deformations, to avoid undesired deformations when the character movements are exaggerated.

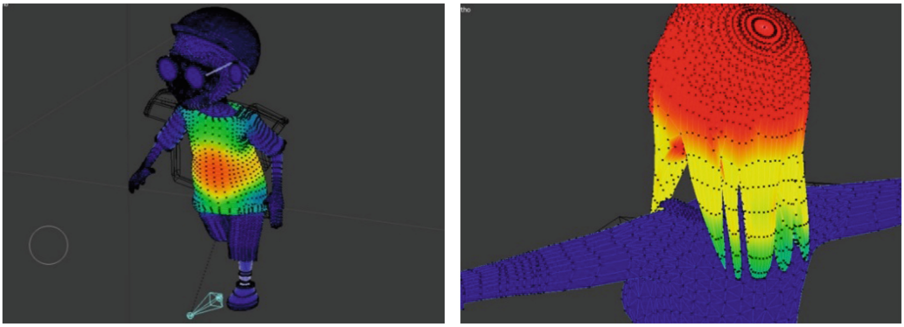

Fig. 5. Examples of Weight Painting of two characters.

Finally, some movement cycles were created (running of child and Susto) and shapekeys or morph keys were used for faces movements while speaking or expressing feelings. Figure 6 shows some examples of shapekeys for the 4 main characters. As happens with Weight Painting, this step was one of the most complex of the whole animation project. A very extended and exaggerated gestures gallery for each character was necessary, to obtain natural expressions on the faces of the characters with different refinements, which is necessary to overcome the artificiality of 3D-video animation characters.

Fig. 6. Examples of two shapekeys for each character.

Once the keyframing of the action was ready, the final renders were generated, before moving on to the postproduction stage.

2.3 Post-production

At this stage Premiere and After Effects software were used. The different frames were joined regardless of the technique: real recorded video, 2D animation and 3D animation. Then, the sound effects, the voices, and the music were included in the short film. Finally, some minor effects were included: the presence of Susto in real video scenes (using the chroma effect) or brightness on some objects in the 3D animation scenes when necessary to improve the visual quality of the final product. Some color management of certain scenes, to increase overall brightness increased the attractiveness of the video for children. Figure 7 shows some examples of postprocessed images of the short film. The short film has been also uploaded in Internet [12].

Fig. 7. Examples of two animated scenes after postproduction.

A study of workload distribution for the completion of this 3D animation short film appears in Fig. 8, showing the percentage allocation of working time for the different tasks. The whole virtual production described in Sect. 2 took 400 working hours. The distribution of working time between the different activities was as follows: preproduction stage (storyboard and character and scenario definition) 10 %, 3D modeling and shading 20 %, animation 40 %, rendering 20 % and post-production 10 %. Rendering time can not be considered a sequential task compared with the others. Ten computers with Intel Core 2 Quad processors (2.8 GHz, 4 GB RAM DDR2) from a 3D Editing Room [13] worked simultaneously on this task.

Finally, a comparison of workload distribution for 2D scenes and 3D scenes appears in Table 1. Although there were no significant differences between the time length of 2D and 3D animation in the video (around 3 min each), both human and computer time spent on 3D animation was at least 10 times higher than similar tasks for 2D animation scenes. This observation shows that as much 2D animation as possible in any short 3D animation will reduce the costs of the audiovisual product considerably.

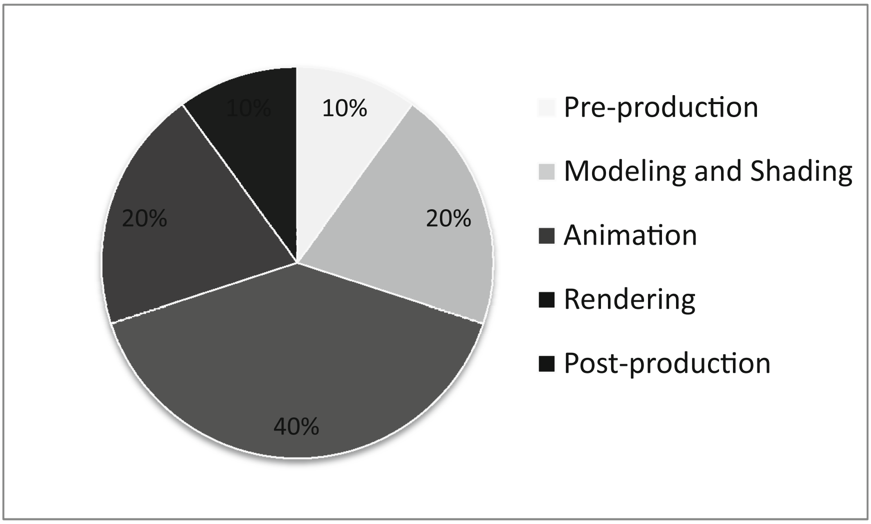

Fig. 8. Workload distribution for the 3D video animation

Table 1. Comparison of human and computer time in the 2D and 3D video animation process.

	Time in the video (s)	Working time per video's second (min)	Rendering time per video's second (min)	Total time per video's second (min)
2D Animation	186	12.6	4.16	16.76
3D Animation	170	141	35.4	176.4

3 Study Case: The Diagnosis of Sleep Disorders in Children

Once the short video animation was ready, the hospital rooms were decorated with characters and objects from the video so that the children would create associations with them in their minds. Then, the effect of the video view was evaluated with the two groups of children: first, 10 children slept in the hospital for sleep disorder diagnosis after viewing the video, the evaluation group, and then another 10 children who had not seen the video were evaluated, the reference group.

3.1 Creating a Full Environment Based on the Short Animation

Several complementary add-ins were designed to accompany the short video animation and to accentuate its effects on the children. On the one hand, material delivered to the child directly after having viewed the video and, on the other, material to decorate the hospital wards.

The first group is included in the DVD box that the children receive when they come to the hospital for sleep diagnosis in the form of a comic that transcribes all the dialogues in the video. Although this material might be relatively less interesting for very small children, it will have its interest for children up to 6 years old. Also, some cut-outs of the main characters of the short film, and a book of stickers that can be folded together to re-build the short film, are included in the box. Figure 9 shows some examples of these materials. As the children pay significant attention to any material that can be physically touched and manipulated, this material is aimed at extending exposure to the video content, encouraging the children to watch the pictures and to read the dialogues.

Fig. 9. Materials to boost the effect of viewing the video: stickers and cut-outs

The second group of materials was composed of posters and cut-outs of the different characters that were placed in the different hospital wards of the Sleep Diagnosis Unit -especially in the sleep rooms-. Some stickers are also included, to identify the medical equipment with the machines shown in the short video animation such as the dreams-machine. Figure 10 shows some examples of these materials. The idea is that, first of all, the children make the strongest associations between the real hospital environment where they are being diagnosed and the environment in the short film and, second, to create a positive and colored environment for children that is different from the children's neutral or hostile view of the standard hospital wards.

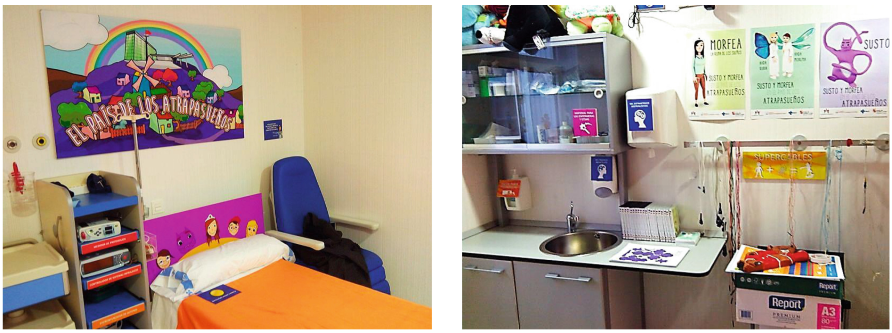

Fig. 10. Materials to boost the effect after having viewed the animation: decoration

3.2 Goals and Children's Profiles

The short film view and the full environment based on the characters in the video are intended to achieve the following objectives:

- Improve sleep disorder diagnosis by shortening SOL (Sleep onset latency), meaning a longer and more peaceful sleep
- Create a less hostile environment for the children during their hospitalization night
- Measure the effect of viewing the video on the sleep profiles of the children
- Evaluate the satisfaction with the experience among both parents and children, and their perception of the sleep

The children in the study were aged between 3 and 6 years. Twenty children diagnosed with sleep disorders at the University Hospital of Burgos were separated into two groups on the basis of age. The first group, the reference group, was formed of children from 3 to 5 years old (average age: 3.5 years), while the second group, the evaluation group, included children from 4.5 to 6.25 years old (average age: 6 years). Note that both groups had children between 4–5 years old. The reason for dividing the groups on the basis of age came from the medical staff, because they considered that the short animation was not suitable for very young children as Susto, the monster in the short video, might affect the children negatively. The small hospital wards reduced the number of children that could be evaluated, so the reference group in this case presented a significant difference with the evaluation group. With regard to gender, the reference group and the evaluation group had female populations of 60 % and 70 % respectively, therefore, the groups may be considered equally balanced, despite a slight imbalance. Table 2 shows the gender division, age and numbers of children in these groups.

Table 2. Profile of children in the reference and the evaluation groups

	Male	Female	Average age	Age range
Reference group	4	6	3.5	3–5
Evaluation group	3	7	6	4.50–6.25

3.3 Sleep Disorder Diagnosis Procedure

Before the children went to bed they were prepared for a standard overnight polysomnogram test. Standard overnight polysomnography identifies the time a person either spends in each sleep state or spends awake, by performing three simultaneous studies: electroencephalography (EEG), electrooculography (EOG), and surface electromyography (EMG). The standard procedure and the parameters these tests monitor are explained in detail in the bibliography [14]. The monitoring system records 12 channels, requiring the attachment of 12 wires to the patient's head. The electrodes provide a readout of the brain activity that is classified as REM (Rapid Eye Movement sleep), non-REM (NREM) and wakefulness. Usually NREM sleep is divided into three levels: N1, N2 and N3 (N1-REM, N2-REM and N3-REM, respectively).

Once the child is awake in the daytime, different parameters are extracted from the polysomnogram: total sleep time in REM, N1-REM, N2-REM and N3-REM stages, wakefulness time, sleep efficiency (night sleep duration expressed as percentage of total sleep time in bed), REM latency (period of time from sleep onset to the first appearance of REM stage), NREM latency (period of time between lights off and the first 30 s of N1 or sleep onset), number of sleep interruptions or wakefulness stages, Arousal Index (number of abrupt change from sleep to wakefulness, or from a "deeper" stage of NREM sleep to a "lighter" stage per hour of sleep), and RDI (Respiratory Disturbance Index). Sleep stages were scored according to the Rechtschaffen and Kales's criteria [15]. Arousals were defined as recommended by the American Sleep Disorders Association Task Force criteria [16].

Finally, the morning after the children's night in the hospital, the parents filled in a short survey while the children were asked 5 questions, the responses to which were recorded in another questionnaire. The questions related to the perceptions of both children and parents of the child's sleep experience in the hospital and the role of the video in relaxing and falling asleep. The questions included in both questionnaires are described below in Sect. 4. The use of questionnaires and polysomnograms are well-established techniques to evaluate sleep disorders in children [1].

4 Evaluation of the Influence of the Animation Film on Facilitating the Diagnosis

Both parents and children responded to 5 questions. All the questions had ten possible responses (on a scale from 1 to 10) to evaluate either agreement or disagreement with the proposed question. While the questions for the children referred to impressions on how they fell asleep (quietly, quickly, etc.) and their sleep (deep or light, dreams or nightmares or periods of wakefulness), the parents questions referred, also, to their impressions of the child's sleep and, besides, to their opinion of the effect of the short video animation and the clarity of the message transmitted to the child. The questions and the average scores of the answers for both groups are presented in Table 3.

The polysomnogram parameters are described in detail in Subsect. 3.3. The average values, mainly expressed in percentages, are also collected in Table 3 for both the evaluation and the reference groups.

Some conclusions can be directly extracted from Table 3. First, although average sleep efficiency and wakefulness time are the same for both groups, the dispersion of these parameters is somewhat smaller in the evaluation group: the cases with lower sleep efficiency and higher wakefulness time are presented in the reference group (e.g. the worst sleep efficiency was 74.5 % in the reference group and 80.2 % in the evaluation group and the longest wakefulness time dropped from 147 min in the reference group to 112 min in the evaluation group). These parameters therefore indicate that the short video animation had no effect on whether the children slept more during the night in average, but it did help the most nervous children who are especially sensitive to the hospital environment to relax.

Second, the time needed to fall asleep (NREM latency) was almost half in the case of the evaluation group (25 min to 46 min). It is interesting to note that this conclusion,

Table 3. Average values of polysomnography parameters and questionnaires.

Parameter/Question	Source	Group			
		Reference (average and range)		Evaluation (average and range)	
Sleep efficiency (%)	Polysomnography	84	(74.5 - 87)	84	(80.2 - 86.2)
NREM latency (min)	Polysomnography	46	(28.5 - 74)	25	(12.5 - 43.7)
REM latency (min)	Polysomnography	96	(61.7 - 120)	93	(71.5 - 133)
Wakefulness time (min)	Polysomnography	90	(58.7 - 147.5)	90.5	(80.5 - 112.2)
Number of sleep disruptions	Polysomnography	8	(5.5 - 17.7)	13	(7.7 - 16.2)
Arousal index	Polysomnography	11	(8.4 - 13.7)	93	(67.7 - 144)
Respiratory Disturbance Index (RDI)	Polysomnography	4	(1.4 - 8.7)	3.55	(1.2 - 12.05)
% Time in N1-REM	Polysomnography	7.3	(4.7 - 7.6)	10.3	(8.3 - 13.03)
% Time in N2-REM	Polysomnography	32	(29.2 - 41.9)	32.7	(27.6 - 44.5)
% Time in N3-REM	Polysomnography	35	(30.7 - 38.7)	34.55	(27.2 - 39.3)
% REM	Polysomnography	22	(20.4 - 25.1)	19.35	(17.03 - 24.9)
Q1. Child was quiet while sleeping (10 = I completely agree, 1 = not at all)	Parent questionnaire	7	(9 - 5)	7	(9 - 5)
Q2. Child slept like at home (10 = I completely agree, 1 = not at all)	Parent questionnaire	7	(8 - 6)	6	(8 - 5)
Q3. Sufficient information shared with the parents (10 = I completely agree, 1 = not at all)	Parent questionnaire	9	(10 - 8)	10	(10 - 10)
Q4. The test will help towards the improvement of the child's sleep (10 = I completely agree, 1 = not at all)	Parent questionnaire	8	(10 - 6)	10	(10 - 10)

(*Continued*)

Table 3. (*Continued*)

Parameter/Question	Source	Group			
		Reference (average and range)		Evaluation (average and range)	
Q5. Sufficient explanations were given to the child (10 = 100 % agree)	Parent questionnaire	10	(10 - 10)	9	(10 - 8)
Q6. How did you feel at night? (10 = very quiet, 1 = very nervous)	Child questionnaire	9	(10 - 8)	9	(10 - 8)
Q7. Was it easy to fall sleep? (10 = very easy, 0 = very difficult)	Child questionnaire	5	(8 - 4)	7	(9 - 6)
Q8. Did you sleep the whole night through? (10 = yes, 1 = not at all)	Child questionnaire	8	(10 - 6)	6	(10 - 5)
Q9. Did you dream? (10 = yes, 1 = no)	Child questionnaire	5	(10 - 6)	7	(10 - 6)
Q10. Did you have dreams (10) or nightmares (1)?	Child questionnaire	8.5	(10 - 6)	8.5	(10 - 6)

extracted from the polysomnography, agreed with the perceptions of the children (responses to question Q7), but it was not reflected in the answers from parents on their impression of their child's sleep (Q2).

Lastly, the other polysomnography parameters offered no clear conclusions; in some cases, they are very similar in both groups, %N2, %N3, %REM, RDI and REM latency, in others, they are very different, %N1, RDI, Arousal index and Number of sleep disruptions, but with no immediate explanation. In these cases, the age difference between the reference and the evaluation group can play an important role. For instance, if the presence of respiratory disorders was the main cause for sleep disorders among the children aged between 6–9 years but there would be other reasons among the younger children, these parameters would present a significant difference between both groups. Unfortunately, the small size of the groups under study provided no statistically significant conclusions to support this hypothesis.

The questionnaires provided further conclusions. The parents felt they had more information on the diagnosis procedure and more confidence in it when the short video animation was used rather than the oral explanations. Although there is no objective explanation for these perceptions, the influence of the parents' mood on their children towards acceptance of hospitalization was significant and more positive moods, in the case of the short video animation, can help to obtain a more reliable diagnosis, because the child will be more relaxed before falling asleep in bed. Moreover, the older children had more frequent and shorter interruptions in the night, which was also detected in the polysomnogram, that reflects the previously explained respiratory disorders, considered the main cause for sleep disorders in the evaluation group.

5 Conclusions and Future Works

This paper has presented the use of short video animations and adapted environments to mitigate the fear of hospitalization in the diagnosis of sleep disorders in children. The research followed 3 steps: in the first one, the video animation was designed following recommendations from the doctors; in the second, the hospital wards were decorated so that the children would associate the characters in the video animation with their immediate surroundings; finally, a standard polysomnogram test monitored the sleep disorders of a reference group and an evaluation group at the University Hospital of Burgos (Spain).

The short video animation included real recorded sequences (8 %), 2D animation sequences (48 %) and 3D animation sequences (46 %). Each technique is used with a different purpose: children are clearly attracted to 3D animation; 2D animation has a strong power to explain concepts and it has lower production costs than 3D animation sequences and real sequences help children to identify real scenarios of the short video animation while admitted to hospital.

When analyzing the human and computer efforts necessary to create the 3D and the 2D animation sequences, the results show that 3D animation requires around 10 times more efforts than 2D animation, meaning as many 2D scenes as possible in such projects to optimize final costs. Most work in the 3D animation process of this project is in the animation step. Two tasks are especially complex in the animation process: the Weight Painting of the skinning to avoid incorrect deformations in joints such as elbows or shoulders, when the character movement is very exaggerated and very extended exaggerated-gestures gallery for each character are needed, it is necessary to obtain natural expressions on the faces of the characters with different refinements, avoiding the common artificiality of 3D animation-created characters. Therefore an optimized definition of the characters in the pre-production stage, with fine and slender limbs (reducing the number of polygons in the joints) is fundamental to reduce the time consumed in the animation step.

Several complementary elements were created, so that the children can associate them with a short animation. These elements can be divided into two groups: on the one hand, material that will be delivered to the child directly after the viewing the short film and, on the other, material that will be used to customize the hospital wards where the study is conducted. The first group is included in the DVD box that the child receives on arrival at the hospital for sleep diagnosis and includes a comic, stickers and cut-outs of the main characters of the short animation with the idea of extending their exposure to the content of the animation. The second group of materials is composed of posters and cut-outs of the different characters of the short film that are attached to walls and furniture of the hospital wards of the Sleep Diagnosis Unit, to strengthen the children's association of the real environment and the environment shown in the short film, creating at the same time a positive and colored environment.

Sleep disorder diagnosis is monitored by overnight polysomnography. In addition, two short questionnaires are filled in by parents and children, to measure their satisfaction and the perception of their experience. Although a main difference in the age between the reference group and the evaluation group exists and the limited size of both groups (10 children each) makes it impossible to extract statistically significant conclusions, some preliminary findings can be extracted from the experience. The sleep efficiency and the wakefulness time, extracted from the polysomnogram, show that the video helps to relax the most nervous children who can be especially sensitive to the hospital environment. The time necessary to sleep (SOL latency) was half as long among the children who viewed the short film than among the children in the reference group. Finally, the questionnaires show that the parents thought that they were given more information on the diagnosis procedure and had more confidence in it, when the short video was used rather than the ordinary oral explanations. Although there is no objective explanation for these perceptions, the influence of the parents' mood in their children's acceptance of hospitalization is a strong influence on the children and these positive moods in the case of the short video animation can help to obtain a more reliable diagnosis, because the child will fall asleep in more relaxed way.

Further research will focus on extending this experience to larger numbers of children of specific ages, to gain reliable statistical significance of the conclusions. Moreover, the adaptation of the story to other plots that lead to interaction between the child and the story and its characters, such as games or augmented reality when smartphones and tablets are used, can increase the positive effect in the children's mood and a better sleep disorder diagnosis.

Acknowledgments. This work was partially supported by the Program "Impulso de la Industria de Contenidos Digitales desde las Universidades" of the Spanish Ministry of Industry, Tourism and Commerce. The authors would especially like to thank Dr. Joaquin Teran and his team at the Sleep Unit at the University Hospital of Burgos for performing the sleep disorders diagnosis included in this research.

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Augmented Reality, Virtual Reality, and Computer Graphics
Third International Conference, AVR 2016, Lecce, Italy, June 15-18, 2016. Proceedings, Part II
De Paolis, L.T.; Mongelli, A. (Eds.)
2016, XVIII, 403 p. 222 illus., Softcover
ISBN: 978-3-319-40650-3