International Journal of Environmental & Science Education
Vol. 7, No. 1, January 2012, 53-69

Pathways for Learning from 3D Technology

L. Mark Carrier • Saira S. Rab • Larry D. Rosen
Ludivina Vasquez • Nancy A. Cheever

Received 24 November 2010; Accepted 11 March 2011

The purpose of this study was to find out if 3D stereoscopic presentation of information in a movie format changes a viewer's experience of the movie content. Four possible pathways from 3D presentation to memory and learning were considered: a direct connection based on cognitive neuroscience research; a connection through "immersion" in that 3D presentations could provide additional sensorial cues (e.g., depth cues) that lead to a higher sense of being surrounded by the stimulus; a connection through general interest such that 3D presentation increases a viewer's interest that leads to greater attention paid to the stimulus (e.g., "involvement"); and a connection through discomfort, with the 3D goggles causing discomfort that interferes with involvement and thus with memory. The memories of 396 participants who viewed two-dimensional (2D) or 3D movies at movie theaters in Southern California were tested. Within three days of viewing a movie, participants filled out an online anonymous questionnaire that queried them about their movie content memories, subjective movie-going experiences (including emotional reactions and "presence") and demographic backgrounds. The responses to the questionnaire were subjected to path analyses in which several different links between 3D presentation to memory (and other variables) were explored. The results showed there were no effects of 3D presentation, either directly or indirectly, upon memory. However, the largest effects of 3D presentation were on emotions and immersion, with 3D presentation leading to reduced positive emotions, increased negative emotions and lowered immersion, compared to 2D presentations.

Keywords: learning, 3d movies, presence, stereoscopy, memory, emotions, stereoscopy

Pathways for Learning from 3D Technology

Three-dimensional (3D) stereoscopic presentation involves controlling the images that are presented to the eyes in order to provide two different visual images to the brain simultaneously. With specially configured glasses, one image is presented to the left eye and a different image is presented to the right eye. The images are of the same object or scene, but with slightly different views; the difference in viewing angle between the two views is referred to as "binocular disparity." A common type of special glasses that produces this effect uses colored filters to select a red image for one eye and a blue image for the second eye (anaglyph presentation). Another type of glasses, often used in contemporary 3D theatrical presentations, uses polarized lenses to direct the different images to the eyes. Typically, two projectors are used to provide two different screen images with different polarizations.

ISSN 1306-3065

http://www.ijese.com/

The slightly differing images are processed in the brain starting in the occipital lobe. van Strien, Scholte and Witter (2008) found that stereoscopic images also were processed in the medial temporal lobe, which has connections to declarative memory functions including memory formation (Eichenbaum, 2000; Fernández, Effern, Grunwald, Pezer, Lehnertz, Dümpelmann, Van Roost & Elger, 1999; Suzuki & Amaral, 2004). The images are eventually fused to form a composite perception in depth of the object or scene. Three-dimensional stereoscopic presentation is distinct from 3D "perspective," which is another form of representing depth in images. While 3D perspective is an alternative method of representing spatial relationships, this type of "3D" presentation is actually presented in two dimensions, requires more inferences to derive depth information about a visual scene than stereoscopic presentation, and is generally agreed to be less effective in conveying spatial relationships and depth information (Frisby, 1980; Hubel, 1988; Perry, Kuehn, & Langlois, 2007).

3D images have been used in education, mainly in medical school or in biology courses. There are several recent studies on the use and evaluation of the effects of these types of 3D images upon learning in the United Kingdom and the United States (Henn, Lemole, Ferreira, Gonzalez, Schornak, Preul, & Spetzler, 2002; Hilbelink, 2009; Huk, 2006; Perry 2007; Petersson, Sinkvist, Wang, & Smedby, 2009). The use of 3D images in human biology education mostly rests on the key role of spatial relations between body parts and body regions in understanding. In other words, the type of knowledge that is required for a deep understanding of human anatomy is based on knowing the relationships among anatomical regions in three-dimensional space. The connection between the type of knowledge required in human anatomy learning (e.g., spatial information) and the type of information conveyed in a 3D image (spatial information) provides a straightforward theoretical basis for predicting the effectiveness of 3D presentation in this realm of education. Presenting target material in 3D rather than 2D should improve the acquisition of spatial knowledge, although empirical tests of this assertion have been mixed (Henn et al., 2002; Hilbelink, 2009; Huk, 2006; Perry et al., 2007; Petersson et al., 2009; Price & Lee, 2010)

There is a further possible theoretical connection between 3D presentation of target material and learning. This connection emanates from the literature on complex online learning environments and suggests 3D presentation of material (especially in video format) can increase a learner's interest in a topic and motivation to understand the topic. In other words, seeing target material in a moving, in-depth, realistic format can make learning more fun and therefore more effective (Dalgarno & Lee, 2010). The first stereoscopic presentation of a movie was in the Pi Suñer laboratory in 1914; a stereoscopic movie was presented to an audience there as early as winter 1922 (Pi Suñer, 1947; Smith, 1953; Southall, 1925). After the first 3D movie presentation, there was a brief surge of theatrical films in the United States shown in three dimensions during the 1940s and 1950s; a resurgence of interest in 3D movie presentations has occurred in recent years. The widespread viewing of 3D stereoscopic movies in U.S. theaters allowed for the present empirical investigation of the effects of 3D (versus 2D) presentation of information upon viewers' psychological processes. Despite the improvements in 3D viewing, there are still negative ramifications of 3D viewing such that prolonged viewing may cause nausea, motion sickness, headaches or other discomforts (Engber, 2009; "For Some," 2010; Sangani, 2009; Schwartz, 2010).

To place watching 3D movies in the context of interaction between technology and users, an immersion-involvement-presence framework was applied. Basically, human users may experience a sense of "being there" when exposed to a computer-generated or virtual environment (Ivory & Kalyanaraman, 2007; Witmer, Jerome, & Singer, 2005; Witmer & Singer, 1998). This sense of being there is known as "presence." Presence is multifaceted and many measures of presence have been proposed. For the purposes of the present study, presence was characterized as being influenced directly by the amount of attention paid to the medium ("involvement") and by the sense of being surrounded by the medium ("immersion"). Based on prior research, it was conceptualized that a user's involvement with a medium (in this case, a viewer's involvement in the 3D movie), and a user's immersion in an environment (a viewer's sense of being surrounded by a 3D film) would be directly related to presence (Ivory & Kalyanaraman, 2007; Singer & Witmer, 1999; Slater, 1999; Witmer, Jerome, & Singer, 2005). A variety of outcomes might be associated with high levels of presence, including cognitive benefits (e.g., improved memory), physiological responses (e.g., heart rate changes) and emotional responses (e.g, heightened reactions) (Ivory & Kalyanaraman, 2007; Meehan, Razzaque, Insko, Whitton, & Brooks, Jr., 2005). In summary, the following research questions were asked: Does 3D stereoscopic presentation alter memory for a film's contents? And, if so, how does 3D presentation function to alter memory? Several different connections between 3D stereoscopic presentation of target material and the ensuing memories of the material are possible (Figure 1). One connection is direct, such that the processing of 3D stereoscopic images might activate regions of the brain associated with memory formation. Another possible path from 3D presentation to learning could be mediated by immersion, such that the additional depth cues provided by 3D stereoscopy contribute to high levels of feeling surrounded by the medium's content. A third possible path is through general motivation, whereby 3D presentation could increase a viewer's interest in or liking of the content material, thus leading to higher levels of involvement (e.g., greater attention paid to the stimulus) and therefore higher levels of memory. Finally, a fourth path, this one having a detrimental effect on memory, could exist wherein the 3D goggles lead to discomfort that leads to reduced attention paid to the stimulus (e.g., lowered involvement) and therefore reduced movie memory content.

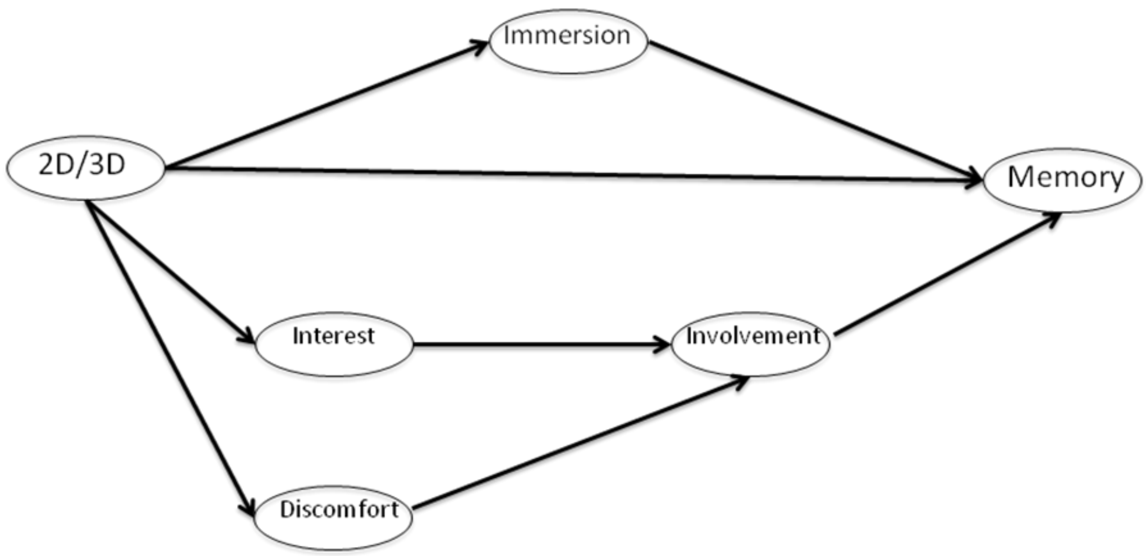

Figure 1. Four possible pathways from 3D presentations to memory.

Based on the literature previously cited, the four possible paths from 3D stereoscopic presentation to altered memory were explored using path analysis. Additionally, other related outcome variables were explored in order to understand the user's experience of viewing a 3D film. The additional outcome variables were presence and emotions during the film viewing. A sample of recent moviegoers in the United States completed an online questionnaire about their movie-going experience. The questionnaire was administered within three days of having seen the movie and contained items that measured movie memory, presence levels, immersion levels, involvement levels, and positive and negative emotions.

Methods

Participants

Participants were 426 friends, family members and associates of students in an undergraduate general education course at a Southern California state university. The participants were recent moviegoers who had seen one of a small set of targeted theatrical films. These movies were selected because they were being shown at theaters during the time the survey was conducted. Participants were allowed to see a movie in either 3D or 2D format. Through word-of-mouth, participants received a link to an online questionnaire and a snowball method was used for others to be invited to take the questionnaire. All participants were adults (18 years old or older). Demographics mirrored the demographics of the Los Angeles area, yielding a diverse sample: Asians (mostly of Chinese, Korean or Japanese descent) (14%), African-American (mostly of African or Caribbean descent) (18%), Caucasians (mostly of European descent) (22%), and Hispanics (mostly descended from Central America, South America or Mexico) (46%). The average estimated yearly income was US $41,254 (SD = $15,621) and the average age was 26.6 years old (SD = 8.1). The gender distribution was fairly even: 56% were females 44% were males.

Procedure

Institutional Review Board approval was obtained before the study was performed. Participants had to answer the survey questions within three days of having seen a movie to keep their movie-going experiences fresh in their memories. The online questionnaire took less than an hour to complete and was anonymous and voluntary. The survey was conducted through the online website SurveyMonkey.com. Informed consent was provided at the start of the survey and participants could stop answering questions at any time. The 100-item questionnaire included several scales measuring memory, emotion, and presence, along with questions measuring the conditions under which participants viewed the movie. It also included a section assessing the participant's demographic background. All questions required answers or the participant was not able to continue to the next survey page.

Materials

Movies. The movies selected for the study were all being shown in movie theaters in the Southern California region during the months of November and December 2010. The films, all full-length feature films, were shown in both 2D and 3D and included "Alpha and Omega," "The Chronicles of Narnia: The Voyage of the Dawn Treader," "Megamind," "Saw 3D: The Final Chapter," "Tangled," and "TRON: Legacy." Three of the movies were animated. The films represented a variety of genres including adventure, comedy and science fiction. Detailed descriptions of the films are presented in Table 1.

Table 1. Descriptions of the Films used in the Study

Movie	Movie Genre and Length	Movie Summary
Alpha and Omega	Animation, Adventure, Comedy (88 minutes)	Two young wolves at opposite ends of their pack's social order are thrown together into a foreign land and need each other to return home, but love complicates everything.
The Chronicles of Narnia: The Voyage of the Dawn Treader	Adventure, Family, Fantasy (113 minutes)	Lucy and Edmund Pevensie return to Narnia with their cousin Eustace where they meet up with Prince Caspian for a trip across the sea aboard the royal ship The Dawn Treader. Along the way they encounter dragons, dwarves, merfolk, and a band of lost warriors before reaching the edge of the world.
Megamind	Animation, Action, Comedy (95 minutes)	The supervillain Megamind finally conquers his nemesis, the hero Metro Man–but finds his life pointless without a hero to fight.
Saw 3D: The Final Chapter	Crime, Horror, Mystery (90 minutes)	As a deadly battle rages over Jigsaw's brutal legacy, a group of Jigsaw survivors gathers to seek the support of self-help guru and fellow survivor Bobby Dagen, a man whose own dark secrets unleash a new wave of terror.
Tangled	Animation, Comedy, Family (100 minutes)	The magically long-haired Rapunzel has spent her entire life in a tower, but now that a runaway thief has stumbled upon her, she is about to discover the world for the first time, and who she really is.
TRON: Legacy	Action, Adventure, Science Fiction (125 minutes)	The son of a virtual world designer goes looking for his father and ends up inside the digital world that his father designed. He meets his father's creation turned bad and a unique ally who was born inside the digital domain of The Grid.

Memory scale. Participants were asked, “Do you have any permanent memory loss?” “Have you experienced any temporary memory loss?” and “Are you taking any medications that can affect your memory?” This part of the survey was related to their movie memory recall and was used to exclude participants. Participants who answered "yes" to any of the items were excluded from the analyses (n = 17 [4% of the sample]). The movie memory section had five questions relevant to the viewed movie in a multiple-choice format. A typical memory question would be a multiple-choice question (e.g., “___ is Sam’s father” from “TRON: Legacy”) that had the correct answer and three incorrect answers listed as options for the viewer to choose from. Not surprisingly, participants remembered the movies' contents well. Across all participants and all films, the mean memory score was 4.6 items correct out of 5 (92%). Because the test scores were high, the memory scores were dichotomized into two categories: those with a perfect score and those with a less-than-perfect score. One hundred and thirty-four participants (34%) made one or more errors on the memory test.

Conditions of viewing. Participants were asked what day and time they saw the movie. They also were asked if they saw the movie in 2D, 3D, or IMAX 3D (a large-scale format). Other items included questions about how much the movie ticket cost, if the participant wore corrective lenses, and how much money the participant spent on snacks. The survey also asked participants how many other people they were with while watching the movie, and asked them to rate the quality of the movie on a scale of 1-10, with 1 being "very poor" and 10 being "very good."

Attitude toward 3D films. Two items were included in the questionnaire to measure participants' attitudes toward viewing 3D movies. The items were "More movies should be in 3D" and "All kinds of movies should be shown in 3D." Both items were measured on a 5-point Likert-type scale and, since the two items were highly correlated ($r = .76$), the mean of the responses was calculated as the measure of attitude toward 3D movies.

Presence. Thirty-five items measured participants' feelings of "being there" in their movie experience. Twenty-four items were based on Witmer and Singer's (1998) presence scale. The original scale was designed for use in virtual environments; therefore, the authors adapted the items to be relevant to 2D and 3D movies. To make the new items, the original items were reworded to place them in the context of viewing a theatrical film. The full set of items was subjected to a factor analysis with a Varimax rotation. Factors with an eigenvalue greater than or equal to 1 were considered for inclusion in the analyses. Further, only items that had factor loadings of .4 or higher were considered for use in a factor. Items that loaded on more than one factor were discarded, as was one item that appeared to have been interpreted incorrectly by the participants.

Factor 1: Presence. Six items were derived from the first factor to define presence: "I was responsive to actions in the movie," "My physical response to the movie was natural," "All of my senses were engaged," "The visual aspects of the movie involved me," "The sound aspects of the movie involved me," and "My sense of objects moving in the movie was compelling." The inter-item reliability was .82 (Cronbach's alpha) and therefore the subset of items was considered acceptable for use as a measure of presence.

Factor 2: Immersion. The second factor, immersion, consisted of the following items: "I was able to actively survey or search for small details/background during the movie using my vision," "I could easily identify sounds in the movie," "I could easily recognize any of the sounds in the movie as real-life sounds," "I could easily localize sounds in the movie theater," "I could easily recognize a change in tone or pitch of a sound or the area where a sound came from," and "I was able to closely examine objects in the film." The inter-item reliability of this subset of items was .76 (Cronbach's alpha) and therefore the subset of items was considered acceptable for use as a measure of immersion.

Factor 3: Movie interest. The third factor measured interest in the movie and included the following items: "I felt stimulated, awake and excited during the movie," ""I enjoyed the movie," and "The film's special effects enhanced by viewing." The inter-item reliability of this subset of items was .73 and therefore the subscale was considered acceptable for use.

Factor 4: Involvement. The fourth factor measured involvement and included the following items: "I was distracted during the movie (e.g. getting up to get a snack)," "I was able to carry on a conversation during the movie," "The movie captured my full attention," and "I responded as quickly to the movie as did the rest of the audience." The first two items were reverse scored. The inter-item reliability of this subset of items was .66. This value is below the recommended reliability value for acceptable use (George & Mallery, 2003). Because attempts to increase the reliability of the scale by removing individual items did not succeed, the factor was used with the caveat that the relatively weak involvement scale would potentially be a limitation of the study.

Emotions. Participants were asked to check the emotions they felt while watching the movie using an emotions checklist containing 60 words and phrases. The items were taken from the Positive and Negative Affect Schedule--Expanded Form (PANAS-X) (Watson & Clark, 1994). The emotions were split into two types: positive and negative emotions. The positive emotions were: active, alert, amazed, at ease, attentive, bold, calm, cheerful, concentrating, confident, daring, delighted, determined, energetic, enthusiastic, excited, fearless, happy, inspired, interested, joyful, lively, proud, relaxed, and strong. The negative emotions included afraid, alone, angry, angry at self, ashamed, astonished, bashful, blameworthy, blue, disgusted, dissatisfied with self, distressed, downhearted, drowsy, frightened, guilty, irritable, jittery, loathing, lonely, nervous, sad, scornful, shaky, sheepish, shy, sleepy, sluggish, surprised, timid, tired, and upset. The emotion items were presented in a scrambled order; the same scrambled order was used for all participants. For the analyses, two variables were computed: the number of negative emotions experienced and the number of positive emotions experienced.

Discomfort. A nine-item checklist of discomfort items was included in the questionnaire. The items included disturbing images, dizziness, eye strain, headache, motion sickness, nausea, neck strain, restlessness and trouble with vision. Participants could check as many items as they felt had been experienced during the movie. Only three of the items were retained in the analysis—eye strain, neck strain and restlessness—as none of the other items had more than 10% of the participants choose them. Eighty-seven participants (22%) chose eye strain, 45 participants (11%) chose neck strain, and 40 participants (10%) chose restlessness. These items were combined into a count of symptoms (ranging from 0 to 3) as a measure of discomfort.

Demographics. Finally, participants were asked their birth years, ethnicities, genders and employment statuses. The survey also asked for the participant's zoning improvement plan (ZIP) code. The ZIP code is used in the United States to code specific geographical regions for use by the postal service and was used in the present study to link participants to United States Census Bureau data on median household incomes to determine their socio-economic status (U.S. Census Bureau, 2006).

Results

All analyses were performed after first removing participants with memory problems and participants who represented outliers on the age variable (e.g., respondents with ages greater than 3 standard deviations from the mean) (n = 15 [3 %]). Thus, the final sample size included 396 respondents.

Descriptive Statistics

Two hundred and nine participants (53%) viewed movies in 2D, while 187 participants (47%) viewed movies in 3D. The numbers of participants viewing each of the movies was as follows: "Alpha and Omega," (n = 7; 2%), "The Chronicles of Narnia: The Voyage of the Dawn Treader," (n = 45; 11%), "Megamind," (n = 137; 35%), "Saw 3D: The Final Chapter," (n = 24; 6%), "Tangled," (n = 167; 42%), and "TRON: Legacy" (n = 16; 4%). The mean score on the scale that measured attitude toward 3D movies was 2.75 (SD = 1.09) (out of 5) while the mean value on the movie interest scale was 3.97 (SD = .69) (out of 5). Immersion and involvement scores could range from a score of 1 to 5. The mean immersion score was 3.53 (SD = .57) and the mean involvement score was 3.80 (SD = .64).

The mean presence score was 3.66 (SD = .59) on a scale from 1 to 5. The mean number of positive emotions was 7.03 (SD = 4.66) and the mean number of negative emotions was 1.71 (SD = 2.57).

Path Analyses

Path analyses were conducted to determine the effects of 3D presentation upon memory, presence and emotions. The analyses were structured around the theoretical model described in the introduction with basic input variables (age and movie content) being used as covariates. Separate analyses were performed on the dependent variables of presence, memory, number of positive emotions and number of negative emotions. The following variables were included in the analyses as input variables: 2D versus 3D, movie seen and age. Also included in the first stage of the path analyses was attitude toward 3D films. For the path analyses, several categorical variables were dummy-coded for use in the multiple regression equations. These variables included memory scores (perfect versus non-perfect), movie content (i.e., the movie seen), and 2D versus 3D.

Memory. The various paths for 3D presentation to affect memory are described in Figure 1. The results of the path analysis will be described below for each of those paths separately. In addition to the paths of interest in that figure, several other variables were included in the analysis. First, attitude toward 3D movies was viewed as influencing movie interest, as well as involvement. Second, movie content was viewed has having a direct effect on the dependent variable, as was age. The beta weights representing the strengths of the relationships between the variables in the model are shown in Figure 2.

Direct effect of 3D presentation upon memory. There was not a significant direct effect of 3D presentation upon memory (*ß* = -.02, $p = .64$).

Indirect effect of 3D presentation through immersion. The effect of 3D presentation upon immersion was small and not significant (*ß* = -.06, $p = .26$). The effect of immersion upon memory also was small and not significant (*ß* = .06, $p = .25$). Thus, the indirect effect of 3D presentation upon memory through immersion was very weak.

Indirect effect of 3D presentation through interest and involvement. The effect of 3D presentation upon interest was small (*ß* = .02, $p = .68$). However, the effect of interest upon involvement was relatively large (*ß* = .48, $p < .001$). The effect of involvement upon memory was very small (*ß* = .08, $p = .14$). Thus, the indirect effect of 3D presentation upon memory through interest and involvement was essentially non-existent.

Indirect effect of 3D presentation through discomfort and involvement. 3D presentation did not significantly predict discomfort (*ß* = .01, $p = .77$), but discomfort was a significant negative predictor of involvement (*ß* = -.13, $p < .01$). Thus, the total indirect effect of 3D presentation upon memory is very small. Combined with the direct effect of 3D presentation upon memory, the total effect of 3D presentation upon memory also was very small.

Other effects in the model. There were several significant effects in the path analysis that did not bear directly upon the question of how 3D presentation affects memory. First, movie content had a significant effect upon memory, with two of the movies ("Saw" and "Tangled") resulting in significantly worse memory performance. Second, participants' attitudes toward 3D movies significantly and positively affected their interest in the movie. Third, high interest levels were associated with high levels of involvement. The beta weights for these effects are shown in Figure 2.

Presence. The beta weights representing the strengths of the relationships between the variables in the model are shown in Figure 3.

Direct effect of 3D presentation upon presence. There was not a significant direct effect of 3D presentation upon presence (*ß* = -.03, *p* = .54).

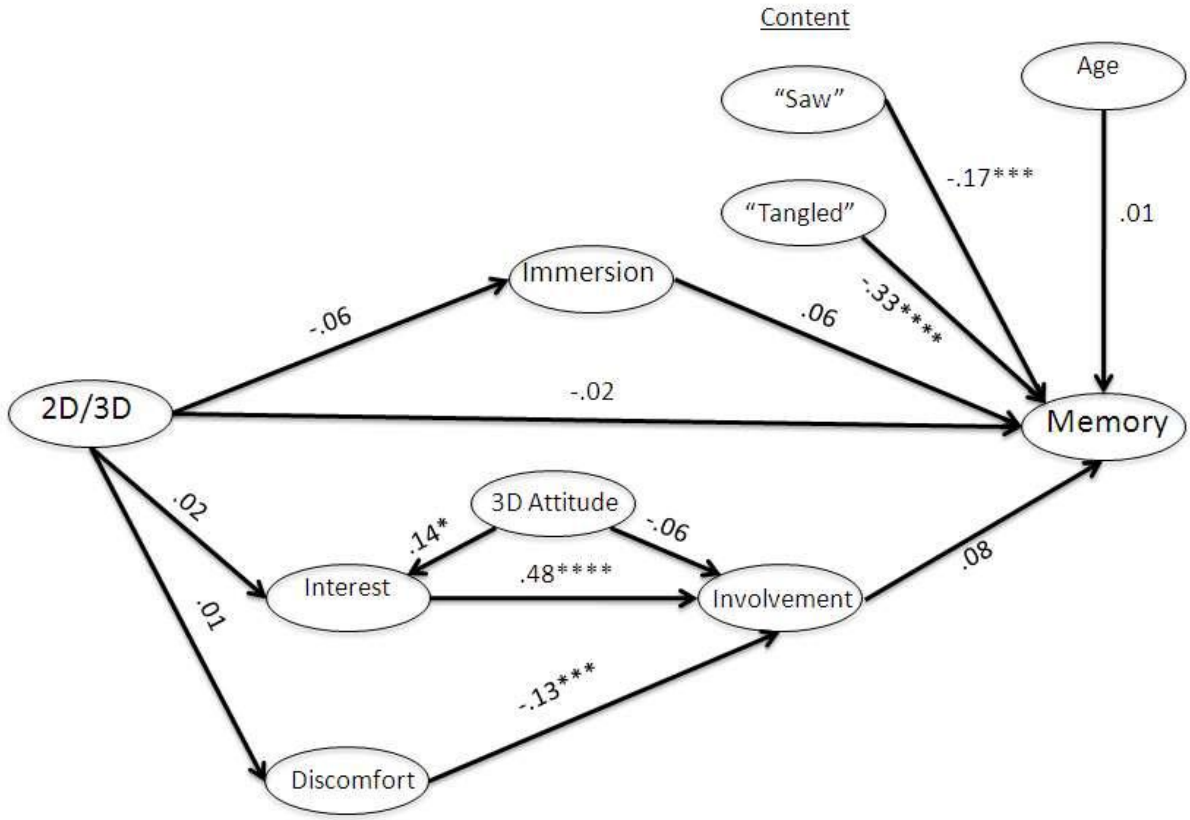

Figure 2. Path analysis of effects of 3D presentation on memory.
* < .05, ** < .01, *** < .005, *** < .0001.

Indirect effect of 3D presentation through immersion. Immersion significantly predicted presence (*ß* = .36, *p* < .001); however, as mentioned above, 3D presentation did not significantly impact immersion. The value of the path from 3D presentation through immersion to presence is a very small, almost nonexistent effect.

Indirect effect of 3D presentation through interest and involvement. Involvement significantly predicted presence (*ß* = .32, *p* < .001); however, as mentioned above, 3D presentation did not significantly impact interest. The value of the path from 3D presentation through interest to involvement to presence is very weak.

Indirect effect of 3D presentation through discomfort and involvement. The path value from 3D presentation to presence through discomfort is .01 * -.13 * .32 = .00. The total indirect effect of 3D presentation upon presence is -.02. Combined with the direct effect of 3D presentation upon memory, the total effect of 3D presentation upon presence was very small.

Other effects in the model. Age was a significant, positive predictor of presence. Both immersion and involvement were positively associated with presence. In other words, film viewers who experienced relatively high levels of immersion or involvement also experienced relatively high levels of presence. The beta weights for these effects are shown in Figure 3.

Emotions. The various paths for 3D presentation to affect emotions were modeled after the paths in Figure 1. In addition to the paths in that figure, additional paths were conceptualized as reasonable effects to expect. A direct link from discomfort to emotions was postulated, as it is logical that discomfort levels would also lead to a change in emotions. Also, a direct link from discomfort to emotions was postulated, as it is logical that discomfort would lead to a change in emotions, as well. These additional links are portrayed in Figures 4 and 5 and are tested below.

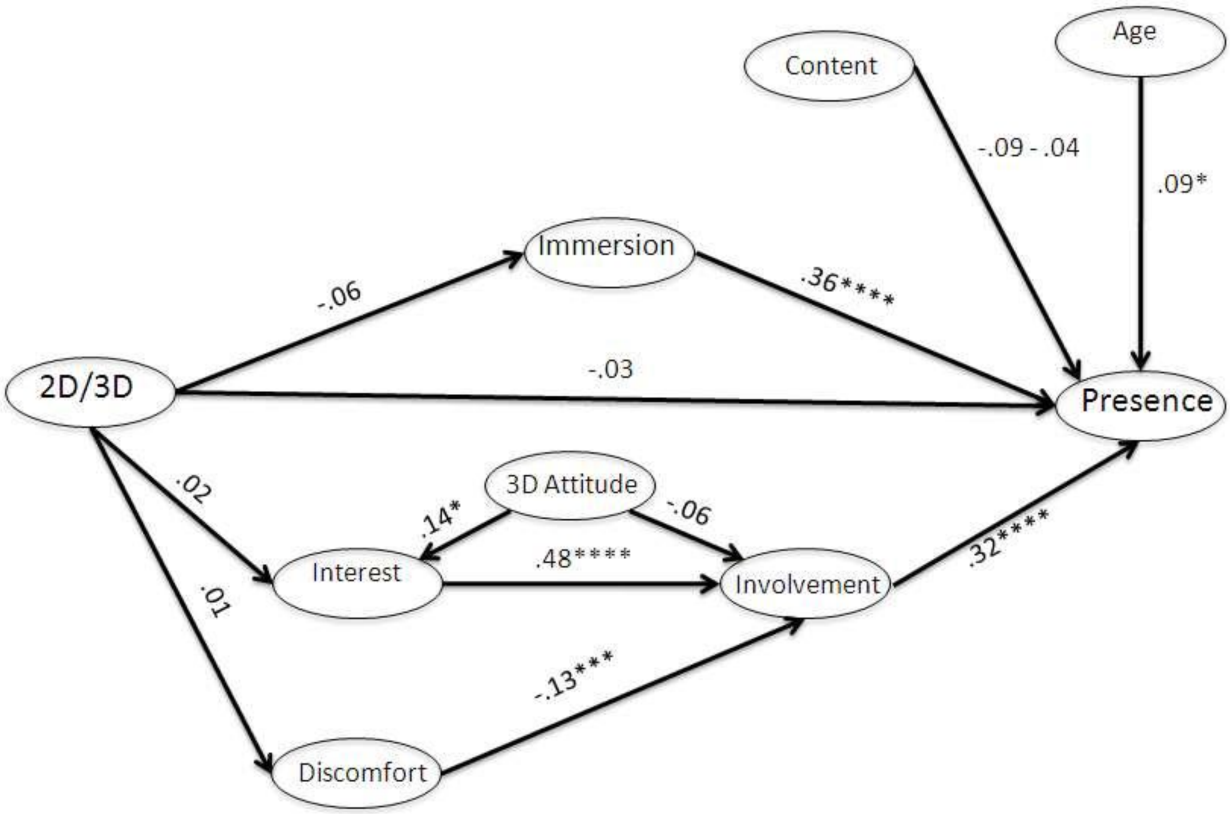

Figure 3. Path analysis of effects of 3D presentation upon presence.
* < .05, ** < .01, *** < .005, *** < .0001.

Direct effect of 3D presentation upon emotions. There was neither a significant direct effect of 3D presentation upon positive emotions ($ß = -.05$, $p = .25$) nor a significant direct effect of 3D presentation upon negative emotions ($ß = .07$, $p = .20$).

Indirect effect of 3D presentation through immersion. Immersion did not significantly predict positive emotions ($ß = .01$, $p = .78$) nor did it significantly affect negative emotions ($ß = .03$, $p = .60$).

Indirect effect of 3D presentation through interest. For positive emotions, there was a significant positive direct effect of interest ($ß = .35$, $p < .001$) and a significant direct effect of involvement *(ß* = .15, *p* < .01). For negative emotions, there was neither a significant direct effect of interest *(ß* = .06, *p* = .30) nor a significant direct effect of involvement *(ß* = -.01, *p* = .92).

Indirect effect of 3D presentation through discomfort. Discomfort *(ß* = .03, *p* = .47) did not significantly impact positive emotions directly. Involvement was found to have a significant direct effect upon positive emotions *(ß* = .15, *p* < .01).

Discomfort *(ß* = .08, *p* = .10) did not significantly impact negative emotions directly. Involvement was not found to have a significant direct effect upon negative emotions *(ß* = -.01, *p* = .92).

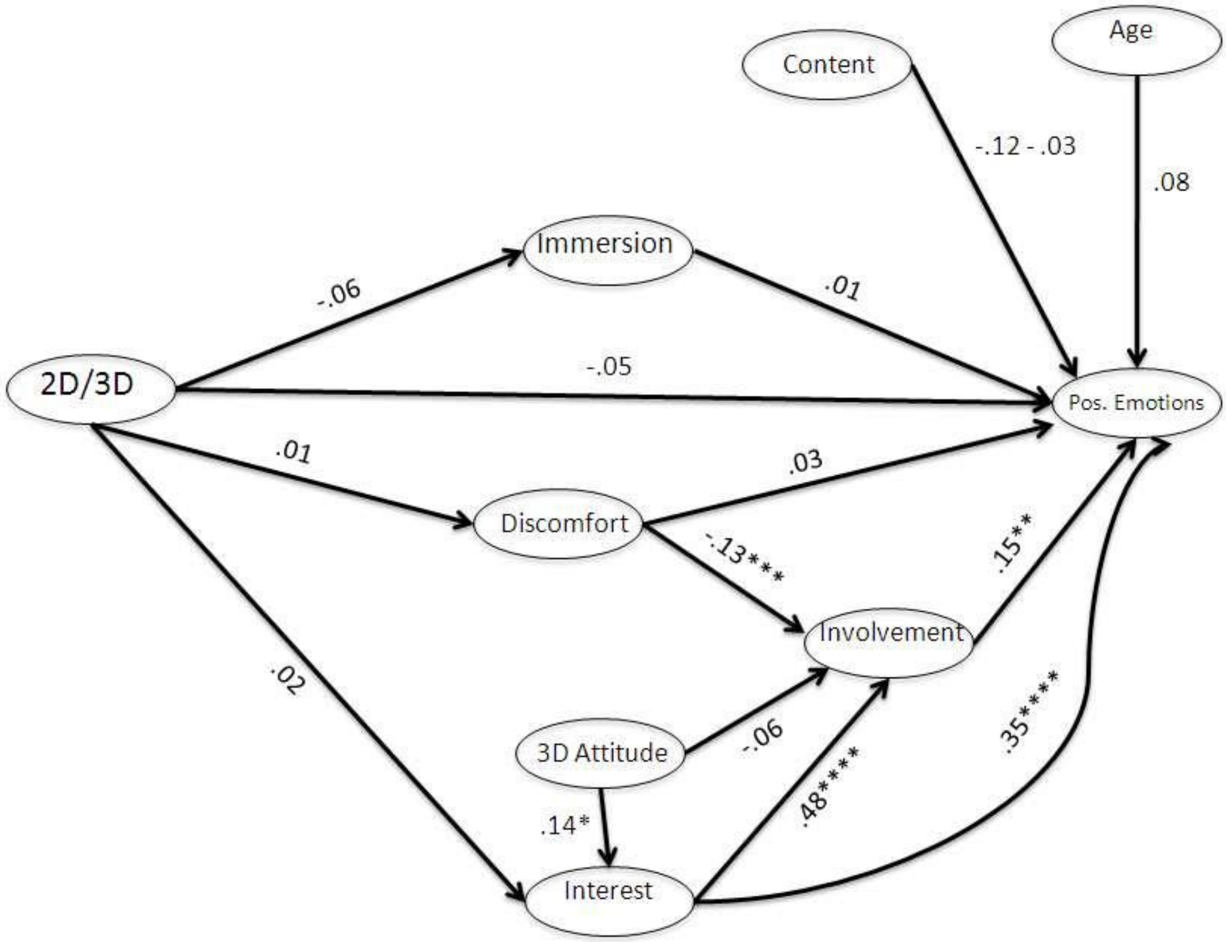

Figure 4. Path analysis of effects of 3D presentation upon positive emotions. * < .05, ** < .01, *** < .005, *** < .0001.

Other effects in the model. For negative emotions only, the content of the movies had a significant effect upon scores. In particular, participants who viewed the movie "Saw" reported more negative emotions than other participants *(ß* = .31, *p* < .001).

Discussion

The purpose of this study was to find out if 3D stereoscopic presentation of information in a movie format changes a viewer's experience of the movie content. In the present study, an online questionnaire was administered to a large sample of individuals who had very recently seen 2D or 3D presentations of a small set of theatrical films. Participants in the study were required to have seen one of the target films no more than three days prior to completing the questionnaire. It was assumed, based on prior literature, that the effect of film presentation format could follow four different paths. The first path was a direct effect upon memory. The second path was an indirect effect through "immersion" (the sense of being surrounded by the medium). The third

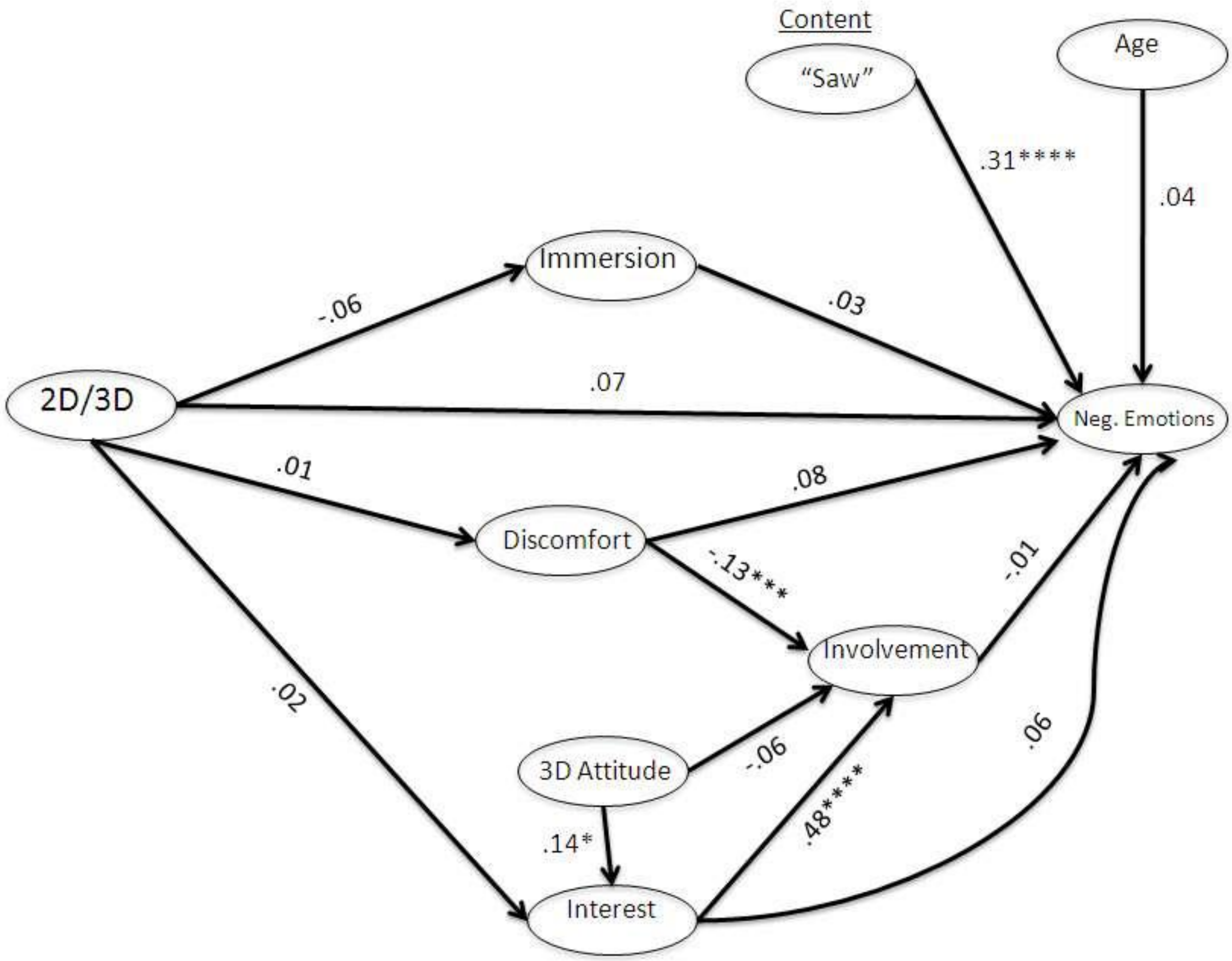

Figure 5. Path analysis of effects of 3D presentation upon negative emotions. * < .05, ** < .01, *** < .005, *** < .0001.

path was an indirect effect through interest and "involvement" (the attention paid to the stimulus). The fourth path was an indirect effect through discomfort. However, the results did not find that film presentation format made a meaningful contribution to any of the paths investigated.

More specifically, path analysis was used to find the relationships between the movie-viewing format (2D versus 3D) and movie content memory. The path analysis was structured on a model of user experience at the theater and included the four possible paths from 3D presentation to the outcome variable. The direct effect of 3D presentation was largest upon immersion, with the results showing a non-significant negative relationship between 3D presentation and immersion *(ß* = -.06; *p* = .26). In other words, viewing a film in a 3D format decreased the viewer's immersion levels very slightly. However, the impact of immersion upon memory was small *(ß* = .06; *p* = .25). So, although 3D presentation decreased a viewer's immersion, it did not appear to result in a significant change in movie memory. In terms of path values, the direct path from 3D presentation to memory was the largest of all, with a path value of -.02. This shows a non-significant, very small negative effect of 3D presentation upon memory. The other possible effects of 3D presentation upon movie memory were calculated to be even smaller, with path values all less than .10.

In contrast to the non-significant effects of 3D versus 2D presentation upon memory, there were significant effects of other factors upon involvement and memory. Movie memory was affected by the choice of movie, with two movies ("Saw" and "Tangled") being harder to remember than the others. Also, a viewer's attitude toward 3D movies was positively associated with interest in the movie and interest in the movie was positively associated with involvement. Therefore, having a positive attitude toward seeing 3D films led to relatively high levels of interest in the movie which in turn led to relatively high involvement levels. Finally, discomfort while watching the movie was negatively associated with involvement level.

The results of the path analyses performed on the other dependent variables were interesting. Presence levels were affected both by immersion levels and by involvement levels, supporting the general immersion-involvement-presence framework employed in the model. Age also was a significant predictor of presence so that relatively old individuals experienced relatively high levels of presence in both 2D and 3D presentations. As with memory, the largest path value of the paths from 3D presentation to presence was the direct path from 3D presentation, with a path value of -.03. 3D presentation did not have significant effects on the number of positive or negative emotions experienced, but the path values from 3D presentation to emotions, either directly or through immersion, were larger for the emotional outcomes than for memory and presence. For the number of positive emotions, the path value of the direct effect of 3D presentation was -.05 and the path value of the effect upon immersion was -.06. For the number of negative emotions, the path value of the direct effect of 3D presentation was .07. It appears that 3D presentation decreased the number of positive emotions and increased the number of negative emotions, although these effects were neither large nor statistically significant. In terms of other effects upon emotions, involvement and interest (both directly and through involvement) increased the number of positive emotions (Figure 4). Finally, a similar pattern was found for the number of negative emotions, with no meaningful effects (either directly or indirectly) of 3D presentation. Only movie content, in this case the movie "Saw," had an effect on the number of negative emotions. The increase in negative emotions is not surprising given that "Saw" is the only horror film that was examined in the study.

Limitations

The study found no significant mnemonic, emotion-related or presence-related benefits of viewing a 3D version of a theatrical film compared to a 2D version of the same film. However, it must be noted that the inter-item reliability of the involvement measure was just below the level deemed acceptable and is suspect. Further, the present results do not rule out the possibility that there could be beneficial effects of 3D imagery in films upon learning and memory under the right circumstances. The present study took place in the context of entertainment; hence, viewers might not have been engaged in the kinds of mental processing that would normally occur in a learning environment. A controlled environment might be required to manipulate viewers to intentionally memorize movie content and to measure real-time responses to the film types. Further, the test of movie content memory did not specifically focus on scenes or images that were presented using 3D stereoscopic effects and it is possible that those particular scenes and images do benefit from a mnemonic boost due to 3D presentation.

In conclusion, the present results suggest that one cannot count on a meaningful positive impact of viewing 3D movies compared to 2D versions of the same movies upon memory and learning. In fact, the largest—albeit small—effects of 3D presentation observed in the present study were a decrease in positive emotions, an increase in negative emotions and a decrease in immersion level. Of course, there still might be mnemonic benefits of 3D presentation formats with respect to learning facts involving spatial relationships. These were not studied in the present research.

References

Dalgarno, B., & Lee, M. J. W. (2010). What are the learning affordances of 3-D virtual environments? *British Journal of Educational Technology*, *41*(1), 10-32.

Eichenbaum, H. (2000). A cortical-hippocampal system for declarative memory. *Nature Reviews Neuroscience*, *1*, 41-50.

Engber, D. (2009). The problem with 3D. *Slate*. Retrieved from http://www.slate.com/id/2215265/

Fernández, G., Effern, A., Grunwald, T., Pezer, N., Lehnertz, K., Dümpelmann, M., Van Roost, D., & Elger, C. E. (September 3, 1999). Real-time tracking of memory formation in the human rhinal cortex and hippocampus. *Science*, *285*(5433), 1582-1585.

For some, 3D movies a pain in the head (January 12, 2010). FoxNews.com. http://www.foxnews.com/story/0,2933,582829,00.html

Frisby, J. (1980). *Seeing: Illusion, brain, and mind*. Oxford: Oxford United Press.

George, D., & Mallery, P. (2003). *SPSS for Windows step by step: A simple guide and reference. 11.0 update* (4th ed.). Boston: Allyn & Bacon.

Henn, J., Lemole, M., Ferreira, M., Gonzalez, F., Schornak, M., Preul, M., & Spetzler, R. (2002). Interactive stereoscopic virtual reality: A new tool for neurosurgical education. *Journal of Neurosurgery*, *96*(1), 144-149.

Hilbelink, A. J. (2009). A measure of the effectiveness of incorporating 3D human anatomy into an online undergraduate laboratory. *British Journal of Educational Technology*, *40*(4), 664-672.

Hubel, D. (1988). *Eye, Brain, and Vision*. New York: Scientific American Library.

Huk, T. (2006). Who benefits from learning with 3D models? The case of spatial ability. *Journal of Computer Assisted Learning*, *22*, 392-404.

Ivory, J. D., & Kalyanaraman, S. (2007). The effects of technological advancement and violent content in video games on players' feelings of presence, involvement, physiological arousal, and aggression. *Journal of Communication*, *57*, 532-555.

Meehan, M., Razzaque, S., Insko, B., Whitton, M., & Brooks, Jr., F. P. (2005). Review of four studies on the use of physiological reaction as a measure of presence in stressful virtual environments. *Applied Psychophysiology and Biofeedback*, *30*(3), 239-258.

Perry, J., Kuehn, D., & Langlois, R. (2007). Teaching anatomy and physiology using computer-based, stereoscopic images. *Journal of College Science Teaching*, *36*(4), 18-23.

Petersson, H., Sinkvist, D., Wang, C., & Smedby, Ö. (2009). Web-based interactive 3D visualization as a tool for improved anatomy learning. *Anatomical Sciences Education*, *2*, 61-68.

Pi Suñer, A. (1947). The third dimension in the projection of motion pictures. *American Journal of Psychology, 60*(1), 116-118.

Price, A., & Lee, H-S. (2010). The effect of two-dimensional and stereoscopic presentation on middle school students' performance of spatial cognition tasks. *Journal of Science Education and Technology*, *19*, 90-103.

Sangani, K. (2009). A sight for sore eyes? *Engineering & Technology*, *4*(19), 30-31.

Sas, C., & O'Hare, G. (2001). The presence equation: An investigation into cognitive factors underlying presence within non-immersive virtual environments. Presence 2001. The 4th Annual International Workshop on Presence. 1-14.

Schwartz, P. (2010, February 27). *Willingness to Wear 3D Glasses by Content Type*. Meant to be Seen’s U-decide Initiative. Retrieved March 23, 2010, from www.mtbs3d.com/findings.shtml

Singer, M. J., & Witmer, B. G. (1999). On selecting the right yardstick. *Presence*, *8*(5), 566-573.

Slater, M. (1999). Measuring presence: A response to the Witmer and Singer Presence Questionnaire. *Presence*, *8*(5), 560-565.

Smith, W. M. (1953). Apparent size in stereoscopic movies. *American Journal of Psychology*, *66*(3), 488-491.

Southall, J. J. C. (1925), Ed. English trans., Helmholtz, *Physiological Optics*, 3.

Suzuki, W. A., & Amaral, D. G. (2004). Functional neuroanatomy of the medial temporal lobe memory system. *Cortex*, *40*(1), 220-222.

The Internet Movie Database (2011). *Alpha and Omega*. Retrieved from http://www.imdb.com/title/tt1213012/

The Internet Movie Database. (2011). *The Chronicles of Narnia: The Voyage of the Dawn Treader* Retrieved from http://www.imdb.com/title/tt0980970/

The Internet Movie Database. (2011). *Megamind.* Retrieved from http://www.imdb.com/title/tt1001526/

The Internet Movie Database. (2011). *Saw 3D: The Final Chapter* Retrieved from http://www.imdb.com/title/tt1477076/

The Internet Movie Database. (2011). *Tangled* Retrieved from http://www.imdb.com/title/tt0398286/

The Internet Movie Database. (2011). *TRON: Legacy.* Retrieved from http://www.imdb.com/title/tt1104001/

U.S. Census Bureau (2006). American community survey. Available from http://factfinder.census.gov/servlet/ACSSAFFFacts?_event=Search&_langx=585en&_sse=on&geo_id=05000US06037&_county=Los+Angeles+County.

van Strien, N. M., Scholte, H. S., & Witter, M. P. (2008). Activation of the human medial temporal lobes by stereoscopic depth cues. *NeuroImage*, *40*, 1815-1823.

Watson, D., & Clark, L. A. (August, 1999). The PANAS-X: Manual for the Positive and Negative Affect Schedule - Expanded Form. The University of Iowa. Retrieved from http://www.psychology.uiowa.edu/faculty/clark/panas-x.pdf

Witmer, B. G., Jerome, C. J., & Singer, M. J. (2005). The factor structure of the Presence Questionnaire. *Presence, 14*(3), 298-312.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence*, *7*(3), 225-240.

Authors

L. Mark Carrier is Professor and Chairperson in the Department of Psychology at California State University Dominguez Hills. He earned his Ph.D. in Experimental Psychology from the University of California, San Diego. He is a Co-Founder and Director of the George Marsh Applied Cognition Laboratory. He does research on the effects of technology upon people in their everyday lives, especially on how technological devices and computer use relate to multitasking.
Correspondence: Department of Psychology, CSUDH, 1000 E. Victoria St., Carson, CA 90747.
E-mail: lcarrier@csudh.edu.

Saira S. Rab is a senior undergraduate student studying Psychology at California State University, Dominguez Hills and is aiming to receive a Ph.D. in Educational Psychology. Her research interests are in technology and applying its use to educational settings. She has been a part of the George Marsh Applied Cognition Laboratory since 2009 and is a McNair Scholar.

Larry D. Rosen, Ph.D. is a Professor and past chair of the Department of Psychology at California State University, Dominguez Hills. He has published five books on the "psychology of technology" including his latest, "iDisorder: Understanding Our Obsession With Technology and Overcoming its Hold on Us" (Palgrave Macmillan 2012). His research includes: generational differences, multitasking, and the impact of technology in the family, the educational system and the workplace.

Ludivina Vasquez is an MBRS RISE (Minority Biomedical Research Support Research Initiative for Scientific Enhancement) Scholar at California State University, Dominguez Hills. She has been a research assistant and lab coordinator at the George Marsh Applied Cognition Laboratory since 2010. She aspires to get a Ph.D. in Clinical Psychology and her research interests include resilience, appraisal, emotion dysregulation, and trauma.

Nancy A. Cheever, Ph.D. is an Associate Professor and Chair of the Communications Department at California State University Dominguez Hills. She is the research coordinator in the Communications Department, and a co-founder of the Psychology Department's George Marsh Applied Cognition Laboratory. Her research focuses on the ways media content impacts people's attitudes, thoughts, opinions, and behaviors.

3D teknolojiden öğrenmek için yollar

Bu çalışmanın amacı bir film formatında bilginin 3D stereoskopik sunumunun izleyenin film içeriğine yönelik tecrübesini etkileyip etkilemediğini ortaya çıkarmaktır. 3D sunumdan hafıza ve öğrenmeye dört yol düşünüldü: bilişsel nörobilim araştırmalarına dayanan bir doğrudan bağlantı; bir gömülü bağlantı ki 3D sunumlar artı duyusal ipuçları sağlayabilir (örneğin, "derin ipuçları") ki bunlar uyartı tarafından sarılmış daha yüksek duyumlara neden olabilir; genel ilgi aracılığı ile bir bağlantı ki bu 3D sunumu bir izleyenin ilgisini daha fazla uyarana yöneltmesine neden olabilir (örneğin, "katılım"); bir sıkıntı aracılığı ile bir bağlantı ki 3D şaşılığı katılıma ve hafızaya engel olur. Güney Kaliforniya'da film tiyatrosunda iki boyutlu ve üç boyutlu filmleri izleyen üç yüz doksan altı katılımcının hafızaları test edildi. Bir filmi seyrettikten sonraki üç gün içerisinde katılımcılar; film içeriğine yönelik hafızaları, duygusal reaksiyonları ve varlık durumlarını içeren öznel film tecrübeleri ve demografik temellerini ortaya koyan bir anket doldurdular. Anket cevapları 3D sunumların hafızaya ve diğer değişkenlere araştırıldığı farklı bağlantıları olan pat (yol) analizine tabi tutuldu. Sonuçlar, doğrudan ya da dolaylı olarak 3D sunumunun hafıza üzerinde hiç bir etkisini ortaya koymadı. Fakat 3D sunumunun en büyük etkileri duygular ve gömülüm için ortaya çıktı ki burada 2D sunumlarla karşılaştırıldığında 3D sunumlar daha düşük olumlu hislere yol açarken olumsuz hisleri arttırdı.

Anahtar kavramlar: öğrenme, 3D filmler, varlık, steroskopi, hafıza, hisler,