



Added value of an autostereoscopic multiview 3-D display for advertising in a public environment

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ABSTRACT

The rapid development of new media has made it increasingly possible to present people with ever richer experiences. The two experiments in this paper examine the mediating role of presence in a 3-D display as compared to a 2-D display with respect to commercials in a public environment. The results show that an autostereoscopic multiview 3-D display enhances the feelings of presence and produces a more positive brand attitude. Hence, autostereoscopic 3-D displays outperform 2-D displays for eye-catching outdoor advertising.

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1. Introduction

In our society we are continuously exposed to advertising. As a consequence, all companies need to use more eye-catching ways of advertising in order to compete for the consumer's attention. One of the latest trends in promoting products and services is making use of 3-D visualization, which enables the consumer to interactively rotate the product, and to virtually study it from all sides, in order to simulate a natural shopping experience. This form of advertising is being applied on the Internet for the last few years now, and clearly adds considerable media-richness to the more traditionally used banners. Li et al. [1] demonstrated that advertising via 3-D visualization provides the consumer more product knowledge, and generates a more positive brand attitude. Both of these aspects are mediated by enhanced feelings of presence, i.e., enhanced feelings of being involved in the displayed environment.

A whole new dimension of 3-dimensionality can be experienced on stereoscopic displays, hereafter shortly indicated as 3-D displays. In these displays the left eye gets a slightly different perspective than the right eye, just as in real-life viewing. The brain then

extracts depth information from the difference between the left- and right-eye images [2]. Scientists have studied 3-D displays and their use since the nineties (e.g., [3,4]). Since then several techniques are developed that enable stereoscopic vision.

This paper evaluates the added value of advertising by means of a specific type of 3-D display, i.e., an autostereoscopic multiview display. Autostereoscopic refers to the ability to perceive stereoscopic depth without optical aids, such as glasses. In general, stereoscopic displays have two views, i.e., one for the left and one for the right eye. The disadvantage of autostereoscopic two-view displays, however, is that viewers are obliged to remain at a fixed position in front of the display screen. Especially for the application of advertising in public environments, this is an unacceptable limitation. A multiview display, for example one that uses a lenticular sheet in front of a LCD as shown in Fig. 1, generates a repetition of multiple views. In this way, a viewer continuously perceives stereoscopic depth when horizontally moving in front of the display. More details on this technology are provided in [5].

It is shown in literature (e.g., [6]) that 3-D displays applied in an entertainment context evoke more pronounced feelings of presence than the traditional 2-D displays. More recently, it is also stated that immersive virtual environments (usually based on 3-D head-mounted devices) provide viewers with a higher level of presence, as a consequence of which they process information more implicitly. In an advertising context, this leads to less recall of the commercial content, but also to a more positive brand

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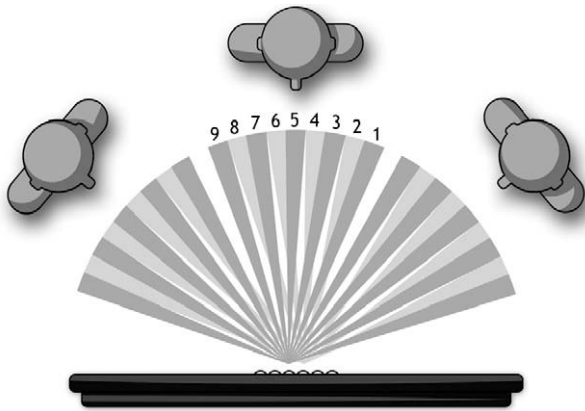


Fig. 1. Basic principle of autostereoscopic multi-view 3-D display.

attitude and purchase intention [7]. With respect to the enhanced feelings of presence and the positive brand attitude as a consequence of 3-D visualization or 3-D rendering, the studies of Li et al. [1] and of Grigorovici [7] are in line with each other. Their conclusions, however, seem contradictory on the effect of 3-D on product knowledge and/or recall of commercial content. Based on these findings, it is expected that also an autostereoscopic 3-D display in an advertising context enhances the feelings of presence, and as such mediates a more positive brand attitude, and possibly also a higher level of product knowledge as compared to a 2-D display. In this paper, these hypotheses are evaluated based on two studies, in which the effect of a 3-D display is investigated measuring participants' feelings of presence, their memory of and brand attitude towards displayed commercials. Additionally, the mediating role of presence to the advertising effect is analyzed.

2. Role of presence in 3-D advertising

The studies described in this paper for evaluating the added value of an autostereoscopic 3-D display in advertising, are based on the research done by Li et al. [1]. They examined the effect of commercial type, being a graphical 3-D visualization and a banner ad, on consumers. The effectiveness of the commercial was measured along feelings of presence, product knowledge and brand attitude. It was found that when watching a graphical 3-D visualization, participants experienced stronger feelings of presence than when watching a 2-D view. Participants also remembered more of the displayed products when presented in the interactive 3-D visualization way. Furthermore, they felt better informed about the product, were more willing to actually pursue it, and indicated to be able to make a better quality decision. Advertising by means of 3-D visualization thus appeared to be very valuable when it came to the effectiveness of a commercial.

Li et al. [1] also found presence to be a mediator between commercial type on one hand, and memory and brand attitude on the other. Participants who experienced strong feelings of presence when seeing a commercial based on a graphical 3-D visualization remembered more of the commercial content and were more positive towards the brands displayed. Hence, it was concluded that the feelings of presence played a powerful role in increasing the advertising effectiveness.

The term presence has not been unambiguously used in literature. The concept of presence was introduced by Minsky in 1980 and was named telepresence. It concerns the feeling of "being there" in a mediated environment (e.g., television). Presence is stated to consist of "physical" and "social" presence [8,9]. Social presence is the sense of "being there" in a social environment, in which

there is contact with other social entities. Physical presence is the sense of "being there" in a physical environment. In the present study, presence refers to physical presence.

A frequently used instrument to measure presence is the ITC-Sense of Presence Inventory (ITC-SOPI), developed and revised by Lessiter et al. [10]. They distinguish four components of presence: physical space; engagement; naturalness; negative effects. In their revision [11], they recommend to exclude the last component and to only add up the scores of the first three components, assuming that when measuring presence the share of negative effects is small. Following this recommendation, the present study distinguishes physical space, engagement, and naturalness as main components of physical presence.

3. Added value of a 3-D display in advertising

For evaluating the effectiveness of a 3-D display for advertising purposes, we formulate hypotheses on feelings of presence, product memory and brand attitude in line with the study reported in [1].

3.1. Presence

Research on 3-D advertising showed that a 3-D visualization of the displayed products, in which these products could be interactively rotated in a 3-D environment, but are presented on a standard 2-D computer monitor, evoked feelings of presence [1].

Far more research was done on induced feelings of presence in an entertainment application, such as television. Lombard et al. [12] investigated the potential effect of the television's display size on presence. Their results revealed an increase in presence experience with display size. Bracken [13] evaluated the effect of display quality on presence varying the spatial resolution of the television source signal between SD (standard definition) and HD (high definition). She showed that watching HDTV content resulted in stronger feelings of presence than SDTV content.

The relationship between feelings of presence and stereoscopic depth has been investigated since the last decennium. Ijsselstein et al. [14] studied the effect of a stereoscopic display on feelings of presence and found that larger depth ranges increased the viewers' experienced level of presence. In an additional study [15] they found that moving stereoscopic image content evoked stronger feelings of presence than still content. Freeman and Avons [6] used focus groups to study the difference between experts and non-experts in the language they used to express their presence feelings about stereoscopic image material. Both groups confirmed increased feelings of presence with 3-D (versus 2-D) image material. Moreover, there was a strong consensus between both groups about the type of image content that best suited high-presence TV broadcasting.

In summary, 3-D visualization for advertisement as well as 3-D displays for entertainment proved to induce stronger feelings of presence than 2-D displays. In line with these results, the following hypothesis is formulated for the effect of display dimensionality for showing commercials on the experienced level of presence:

Hypothesis 1. A 3-D display results in stronger feelings of presence than a 2-D display.

3.2. Memory

Li et al. [1] demonstrated that consumers felt more knowledgeable of the commercial and of the product displayed, when having the possibility to interact with a graphical 3-D visualization than when seeing only a 2-D view. However, from this study it is not clear whether the dimensional perspective, the interaction, or the

interplay between both contributed to this effect. Studies that directly compared display dimension with memory task performance for commercials appear to be scarce.

Several studies indicated that the experienced presence had an impact on memory of the presented content. The study of Li et al. [1] showed that presence, along the physical and engagement dimensions, mediated the relationship between type of advertising experience (3-D versus 2-D) and self-reported product knowledge. Keng and Lin [16] studied the experience of presence for participants observing an Internet ad, manipulating the level of presence and the displayed product type between participants. They supplied additional evidence that feelings of presence were a significant predictor for content recall and recognition. Additionally, Suh and Chang [17] confirmed that the level of presence affected the consumer's memory of the content. In their Internet study, three types of interfaces were used, namely a graphical 3-D visualization, a video clip and a series of single static images. The group, who saw the 3-D visualization, experienced the highest level of presence, and simultaneously felt most knowledgeable of the on-line advertised products. Grigorovici [7], on the other hand, proposed a two-step theoretical model, with presence as a mediator for subsequent information processing and, consequently, for memory. He states that, at a certain point, more presence led to more arousal and affect, causing a more implicit and heuristic processing. This resulted in less ad recall. However, Grigorovici did not provide more specific information about the mediating influence of presence with respect to the difference between a 2-D and a 3-D environment.

Based on the previous discussion, the following hypotheses are proposed:

Hypothesis 2a. A 3-D display results in better memory (i.e., recall and recognition) for the advertised product and the commercial than a 2-D display.

Hypothesis 2b. Higher levels of *presence result in better memory* (i.e., recall and recognition) for the advertised product and the commercial in the 3-D display compared to the 2-D display.

3.3. Attitudes

Li et al. [1] provided evidence that offering a graphical 3-D visualization of a product resulted in a more positive attitude towards the displayed brand, as compared to offering only a 2-D view. This was demonstrated for different types of products. Again, due to the combination of interaction features and dimensionality in this study, this result should be interpreted with caution. Furthermore, this study found that strong feelings of presence led to a more positive brand attitude. Additional research supported this mediating role of presence. Grigorovici [7] postulated that strong feelings of presence would result in a more positive brand attitude, based on the two-step model described above. Thus, more presence led to more arousal and affect, causing a more heuristic processing, and providing more affective, automatic, and accessible attitudes. Hopkins et al. [18] also investigated to what extent presence affected the consumer's attitude towards the displayed brand and commercial, and his purchase intention, and found a positive influence of presence on brand attitude. Taken together, the following hypotheses are formulated for the present study:

Hypothesis 3a. A 3-D display results in a more positive brand attitude for the advertised product than a 2-D display.

Hypothesis 3b. Higher levels of *presence results in a more positive brand attitude* for the advertised product in the 3-D display compared to the 2-D display.

To enhance the external validity of this study, it was decided to test all hypotheses in both a controlled laboratory setting (Study 1), and in a natural shopping environment (Study 2), in which visitors were introduced to one of the displays in an unforced way.

4. Study 1: laboratory setting

4.1. Experimental design

The display dimension was manipulated as a between-subject variable: part of the participants saw four commercials monoscopically (2-D), whereas the remaining participants saw the same commercials stereoscopically (3-D). The amount of presence experienced, memory of and attitude towards the advertised brands were the dependent variables.

4.2. Participants

Fifty-one persons of different nationalities were invited to the experiment, of which 48 persons (38 men, 10 women) actually participated. They were aged between 22 and 56, 31.4 years on average (SD = 7.7). The participants were not familiar with the research topic. They had a (corrected to) normal acuity (as tested with the Landolt C-scale), were neither color blind (as tested with the Ishihara Color Blindness test), nor stereo blind (as tested with the Randot Stereo test).

4.3. Stimulus

Four different short videos, of which a 3-D version was available, and that contained image material coming close to a commercial, were selected. A 2-D version of these commercials was extracted from the 3-D version, by substituting the same image content in all views, which is equivalent to rendering the image content with a depth range of 0. The commercials advertised Heineken (30 s), Philips 3D Solutions (40 s), a mobile phone (58 s), and the Philips Sense and Simplicity campaign (71 s) (see Fig. 2 for a snapshot of two commercials as an example). All four commercials contained only visual stimuli; sound was not included.

4.4. Apparatus

Stimuli were presented on a 42" Philips WOWvx 3-D display (3D6W0I LCD, nine-views lenticular, 1920 × 1080 × RGB) resolution and a 3m optimal viewing distance) driven by a Dell Optiplex GX270 Pentium 4 PC. The depth range and depth offset with respect to the display screen were manually set in the standard user interface by experts to a value of 100 and 0, respectively. For a viewing distance of 3 m this corresponds to a maximal depth range of 20 cm behind the screen and 18 cm in front of the screen. More specific details on the display used can be found in [5].

4.5. Dependent variables

The dependent variables of the study were presence, memory based on free recall and recognition, and brand attitude. They were measured using a questionnaire, which consisted of six components: demographic information; brand attitude; feelings of presence; free recall; recognition; final questions. A short index of the questionnaire items for each of the components is provided in Appendix.

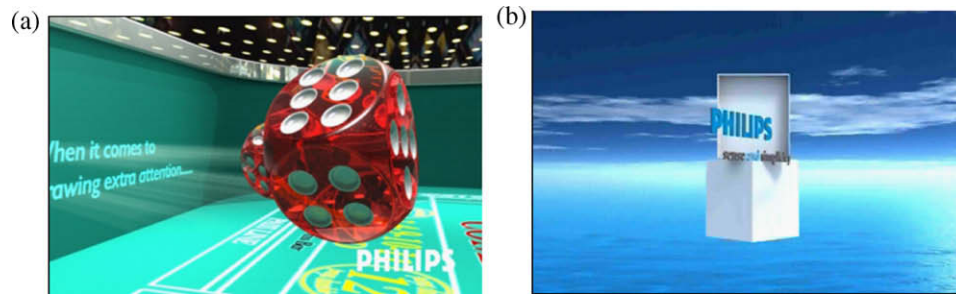


Fig. 2. Stills taken from the two commercials used: (a) dice “Philips 3D solutions” and (b) white cube “Philips Sense and Simplicity campaign”.

4.5.1. Presence

To assess feelings of presence, 14 items out of the ICT-SOPI questionnaire were used. They measured presence along the dimensions of physical presence (items 9, 10 and 13), engagement (items 1–4, 8, 11 and 14) and naturalness (items 5–7 and 12), after (items 1–4) as well as during (items 5–14) the viewing experience. Participants indicated their answer on a Likert scale, which ranged from 1 (strongly disagree) to 5 (strongly agree). From the results, three separate scale values (one for physical presence, one for engagement and one for naturalness) and a total score were calculated. The total score was the average over all items of the questionnaire.

4.5.2. Recall

The free-recall task consisted of five open-ended questions related to the content of the image material shown. Specifically, participants were asked the amount of commercials, the name of the products and brands shown, and the order, in which they saw the commercials (see also Appendix). To calculate a total score on recall, all scores per item were added up. For item 1 (i.e., number of commercials) and 4 (i.e., order of commercials) one point was awarded for the right answer, and zero points for a wrong or missing answer. For the other items one point was awarded for each correctly recalled aspect of the commercial.

4.5.3. Recognition

The recognition task was measured with a list of 16 multiple-choice questions, each completed with four or more possible answers. The exact number of answers depended on the difficulty of the question. In general, three to five questions per commercial were asked, with the first question being one concerning all commercials (see also Appendix). To calculate a total score, the number of correct answers was summed (each correct answer was awarded one point) and divided by the total number of questions.

4.5.4. Brand attitude

Brand attitude was measured with bipolar adjectives from the list of Bruner [19] that was also used in earlier studies to judge commercials (e.g., [1]). In total, 37 of the 53 adjective pairs of Bruner’s list were considered appropriate and were selected for this study. Participants were asked to indicate their score on a 7-point semantic differential scale only once for the combination of the four commercials. Thus, possible differences in brand attitude between commercials were not evaluated. To prevent a response tendency, the position (left or right end of the scale) for the positive and negative adjective varied per pair. To calculate a total score on brand attitude, the scores per item were summed, and divided by the number of items. Where needed inversions on the scores were applied such that a higher total score referred to a more positive attitude.

4.6. Procedure

The experimental set-up is shown in Fig. 3. The display (either in 2-D or 3-D version) was placed on a table in an artificially illuminated room. A chair was placed right in front of the display at a distance of 3 m, and its height was adjusted such that the display was at the participant’s eye level.

Participants were presented an instruction sheet, both in English and Dutch, which they had to read before the start of the experiment. They were randomly assigned to either group 1 ($N = 24$) or group 2 ($N = 24$), seeing the commercials in a 2-D or 3-D version, respectively. Then, all four commercials were shown, in one out of four presentation orders, hereafter referred to as play lists. Hence, twelve participants saw the same presentation order, half of them in a 2-D and half of them in a 3-D version. After having seen the fourth commercial, participants received the first part of the questionnaire. This part consisted of the components demographic information, brand attitude, feeling of presence and free recall. When they had completed the first part, they received the second one (i.e., the Recognition component). This was done to avoid that they used recognition items to answer the free-recall questions.

4.7. Results

The scales physical presence ($M = 2.84$, $SD = .72$, $\alpha = .72$), engagement ($M = 3.11$, $SD = .73$, $\alpha = .78$), naturalness ($M = 3.02$, $SD = .45$, $\alpha = .75$), total presence ($M = 3.03$, $SD = .62$, $\alpha = .89$) and brand attitude ($M = 4.43$, $SD = .70$, $\alpha = .95$) all complied to the generally accepted Cronbach’s alpha of .70 for measuring reliability. Hypotheses that predicted direct effects of display dimension on

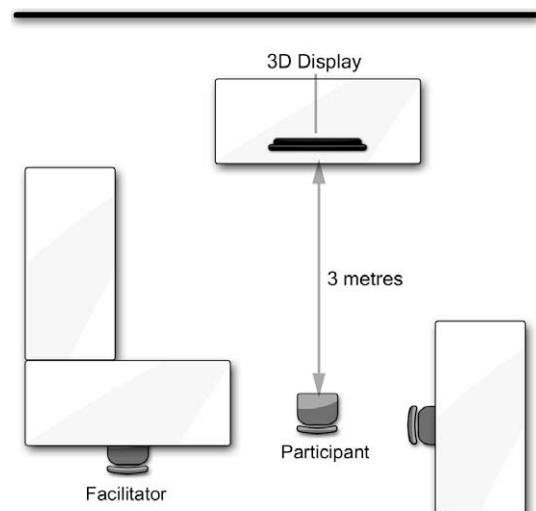


Fig. 3. Experimental setting for Study 1.

Table 1

Results for display dimension on presence, memory and brand attitude measured in the laboratory setting (Study 1).

Dependent measure	2-D M (SD) (n = 24)	3-D M (SD) (n = 24)	t (df)	p
Physical presence	2.33 (.92)	3.18 (.64)	-3.35 (46)	.0005
Engagement	2.76 (.70)	3.46 (.57)	-3.81 (46)	.0000
Naturalness	2.61 (.83)	3.43 (.71)	-3.64 (46)	.0005
Total presence	2.63 (.68)	3.43 (.53)	-4.60 (46)	.0000
Free recall	3.04 (.69)	2.59 (.72)	2.22 (46)	.0155
Recognition	.77 (.20)	.79 (.17)	-.30 (46)	.3840
Brand attitude	4.07 (.84)	4.78 (.62)	-3.35 (46)	.0010

the dependent variables were tested using independent-samples *t*-tests. These tests were performed with the statistical package SPSS version 14.

4.7.1. Impact of display dimension

Table 1 provides an overview of the effect of display dimension on the dependent variables.

The first hypothesis predicted that participants watching a 3-D version experience stronger feelings of presence than participants watching a 2-D version. *T*-tests revealed that indeed the 3-D group scored significantly higher than the 2-D group on physical presence, engagement, naturalness and total presence (see Table 1; $p < .001$ on all dependent measures of presence). Thus, Hypothesis 1 was confirmed by the results: watching a 3-D display resulted in stronger feelings of presence than watching a 2-D display.

Hypothesis 2a proposed that participants watching a 3-D display remember (i.e., recall and recognize) more of the advertised product and the commercial, as compared to participants watching a 2-D display. As Table 1 shows, on free recall the display groups were significantly different ($t(46) = 2.22$, $p = .016$). However, the mean scores were in the opposite direction: the 2-D group ($M = 3.04$) outperformed the 3-D group ($M = 2.59$). On recognition no significant difference was found between the 2-D and 3-D group. Taken together, the predicted effects on memory were not confirmed in this study.

The third hypothesis stated that watching a 3-D display results in a more positive brand attitude, compared to watching a 2-D display. The difference between the 2-D group ($M = 4.07$) and the 3-D group ($M = 4.78$) was significant ($t(46) = -3.35$, $p = .001$). Hence, it can be concluded that Hypothesis 3a was confirmed: participants showed a more positive brand attitude when shown a 3-D display instead of a 2-D display.

4.7.2. Mediating role of presence

The existence of a potential interaction effect of presence on the relationship between dimension type, on the one hand, and memory (Hypothesis 2b) and brand attitude (Hypothesis 3b) on the other hand, was tested using a mediation analysis, as suggested in [1]. For presence to be a mediator for another dependent variable, three conditions have to be met. First, dimension type needs to be positively related to presence. Second, dimension type needs to be positively related to the dependent variable. Third, presence needs to positively affect the dependent variable, when regressed together with dimension type.

The first and second conditions are already discussed in the previous paragraphs. For the third condition, physical presence ($\beta = .45$, $t(2, 45) = 3.30$, $p < .001$), engagement ($\beta = .66$, $t(2, 45) = 5.60$, $p < .001$), naturalness ($\beta = .46$, $t(2, 45) = 3.34$, $p < .001$) and total presence ($\beta = .67$, $t(2, 45) = 5.33$, $p < .001$) were all proven to be significant mediators on brand attitude. The introduction of presence in the regression analysis reduced the predictive power

of dimension type on brand attitude. Thus, Hypothesis 3b was confirmed, while Hypothesis 2b was not.

5. Study 2: shopping setting

5.1. Experimental design

The purpose of Study 2 was to investigate the added value of a 3-D display for commercials under a more natural shopping condition, in which participants differ substantially in viewing duration and attention. The same hypotheses as formulated for Study 1 were tested with again the display dimension as a between-subject variable. The major difference with Study 1 was the number of uncontrolled factors, which was obviously much higher in Study 2. In the latter case participants were neither explicitly asked to take a look at the displayed commercials nor at the display itself. Also, they were initially unaware of their participation in this study. Furthermore, the factors viewing time and viewing distance differed per participant.

5.2. Participants

For this experiment, the Philips employee shop, open to national and international Philips employees, their relatives and friends, was chosen as location. In total 162 visitors of the shop were invited to participate to the study. Of all participants seven turned out to be unable to fill in at least one component of the questionnaire next to the demographic information. As a result, the analysis was performed on the remaining 155 participants (113 men, 42 women). Their age ranged from 16 to 75 years ($M = 40.5$ years, $SD = 13.9$, $n = 152$). They were not familiar to 3-D TV on a professional base. They indicated not to be stereo blind, but there were no means to check this. It should be noted that people are not always aware of being stereo blind or not, so this information is not fully reliable. Of these 155 participants, 74 watched the 2-D display (divided over play lists 1–4 as 22, 24, 14 and 14 participants, respectively), and 81 visitors watched the 3-D display (divided over the play lists 1–4 as 20, 17, 24 and 20, respectively).

5.3. Apparatus and stimuli

Exactly the same display and the same commercials as in Study 1 were used. Also the four play lists as used in Study 1 to balance the order of seeing the commercials, were used in Study 2. In the latter case, however, what participants actually saw, depended on the moment at which the display was encountered and the time spent watching it.

5.4. Dependent variables

The dependent variables of Study 2 were the same as for Study 1, namely presence, memory, measured as free recall and recognition and brand attitude, and apart from a few adaptations, they were assessed by means of the same questionnaires. To limit the time needed to complete the questionnaire, some items on brand attitude were omitted, leaving a limited selection of 15 items that appeared relevant in the first study. From the presence questionnaire items referring to a fixed viewing duration (i.e., "I felt sad my experience was over" and "I would have liked the experience to continue") were omitted, since in this study participants could make their experience as long as they liked. From the recognition questionnaire the first item (i.e., "the sequence of the displayed commercials is?") was omitted, since there was no control on the moment in time participants started seeing the list of commercials.

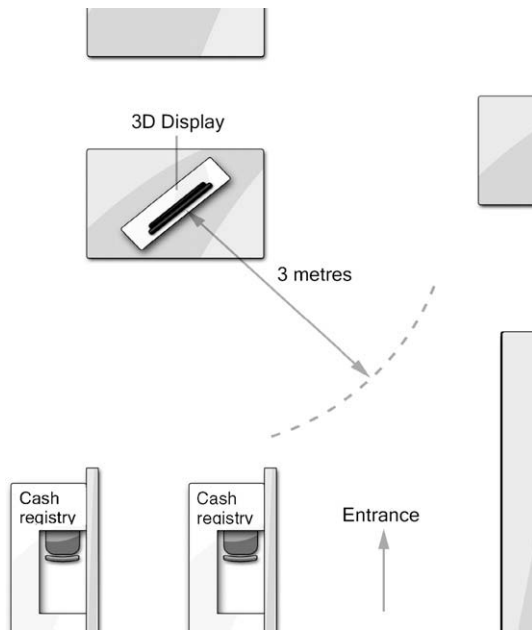


Fig. 4. Experimental setting for Study 2.

5.5. Procedure

During ten days, the display was positioned on a small table at the left side of the main entrance of the shop (see Fig. 4). The commercials were displayed in a continuous loop (i.e., as soon as the last commercial of the list finished, the first commercial of the same list started). One play list per day was used.

Visitors who obviously had taken some time to watch the display near the entrance, were contacted about 1–2 min later somewhere deeper into the shop, and were invited for participation in the survey. On a quiet location in the shop two tables were placed, where participants were handed over the questionnaire to fill it in. Apart from this, the procedure of Study 1 was followed also in the second study.

5.6. Results

Since in this study the viewing duration was not fixed, most participants only saw part of the full length (of nearly 200 s in total) of the four commercials. As a consequence, especially for the free recall and recognition questionnaires, this resulted in the problem of a huge amount of missing data. To cope with this problem, two scientifically approved methods [20] were evaluated: (1) in case of a non-response on one or more items, the whole questionnaire of that participant was omitted from further analyses, or (2) the missing data was substituted by the mean of the given responses on that item. The disadvantage of the first method was that part of valuable information was lost, and that responses given on part of a questionnaire were not taken into account in the analysis. The advantage of the second method was that it prevented losing valuable data. The disadvantage, however, was that part of the data was estimated from the mean of given responses, and thus, added value without noise to the statistical test, making it artificially more powerful. Hence, for both methods interpreting the results needs to be done with caution. In practice, almost all participants fully filled out the presence questionnaire ($n = 143$ for total presence), and most participants fully filled out the brand attitude questionnaire ($n = 135$). Therefore, in this case either method to cope with non-responses yielded the same overall conclusions, and it did not matter much which method was chosen. For the free-recall questionnaire, however, the number of participants that fully completed it was only 48, which was too

low to find statistical significance when using the first method. As a consequence, the second method (i.e., substituting missing data with the mean over responses given) was used for further analysis, and was, as a consequence, also applied to the dependent variables presence and brand attitude.

The recognition questionnaire was fully filled in by only eight people, a group which was far too small to perform a reliable statistical analysis with any of the two methods. The reason behind the huge number of missing data was that most participants did not watch the display long enough to see all four commercials. They only answered the questions on the commercials they had seen, and neglected the other questions. To cope with this issue, the analysis on the recognition task was done per commercial. To this end, a recognition score per commercial, summing the scores of the questions per commercial and dividing it through the number of questions for that commercial was calculated (the number of questions was 4 for the commercial “Philips 3D Solutions”, 5 for the commercial “Philips Sense and Simplicity campaign”, and 3 for the commercials of “Heineken” and “mobile phone”). Moreover, it was decided that if people had answered at least two questions of a given commercial, they most probably had seen it, and as a consequence, they should have been able to answer all questions of that commercial. The fact that they did not, could thus be interpreted as a wrong answer. Doing so, the number of responses included in the statistical analysis was substantially increased to about $N = 40$.

The scales physical presence ($M = 2.58$, $SD = .21$, $\alpha = .81$), engagement ($M = 2.86$, $SD = .39$, $\alpha = .81$), naturalness ($M = 3.23$, $SD = .20$, $\alpha = .75$) and total presence ($M = 2.91$, $SD = .38$, $\alpha = .91$), as well as the instrument to measure brand attitude ($M = 4.74$, $SD = .25$, $\alpha = .90$) all met the generally accepted Cronbach’s alpha of .70. Hypotheses that predicted direct effects of display dimension on the dependent variables were tested using independent-samples t -tests.

5.6.1. Impact of display dimension

Table 2 provides an overview of the effect of display dimension on the dependent variables for study 2.

The first hypothesis stated that stronger feelings of presence are evoked when watching a 3-D display than when watching a 2-D display. T -tests indeed revealed significant differences (see Table 2). For physical presence, engagement, naturalness and total presence a significantly higher score was found for the people watching the 3-D display than for the people watching the 2-D display ($p < .001$ on all dependent variables). Therefore, Hypothesis 1 was confirmed.

It was hypothesized that people watching a 3-D display recall and recognize more (Hypothesis 2a) of the commercials and displayed products than people watching a 2-D display. A t -test showed a significant difference for recall ($t(119) = -8.54$, $p < .001$) (see Table 2), with the group of people watching 3-D ($M = 1.43$) outperforming the group watching 2-D ($M = .93$). It should, however, be mentioned that the scores of both groups were very low, indicating that all viewers had a limited recollection of the commercials shown. The t -tests for the recognition per commercial (see Table 2) showed a significantly higher score for the 3-D group ($M = .56$) than for the 2-D group ($M = .32$) for only one out of the four commercials (i.e. commercial 2: $t(36) = -2.70$, $p = .01$). The scores of the other commercials showed the same tendency, but were not significant. Hence, it can be concluded that free recall was positively influenced by display dimension, whereas recognition only showed a tendency. As a consequence, Hypothesis 2a was plausible, but could not be convincingly confirmed.

Hypothesis 3a stated that watching a 3-D rather than a 2-D display results in a more positive brand attitude. The outcome of a t -test provided a significant difference (see Table 2), consistent with the hypothesis. The group watching a 3-D display ($M = 4.97$) was significantly more positive towards the displayed brands ($t(153) = -3.41$,

$p < .0001$), compared to the group watching a 2-D display ($M = 4.49$). Based on his result, **Hypothesis 3a** was confirmed.

5.6.2. Mediating role of presence

The potential interaction of presence on the relationship between dimension type and brand attitude or memory was again tested by means of a mediation analysis. For memory it was predicted that the experience of stronger feelings of presence would result in better recall and recognition (**Hypothesis 2b**) of the product and commercials displayed. For brand attitude it was hypothesized that stronger feelings of presence would result in a more positive brand attitude (**Hypothesis 3b**).

Again, the first and second condition of the mediation analysis was already discussed in the previous paragraphs. For free recall the positive relation with display dimension was confirmed, but it was not for recognition. As a consequence, the third condition of the mediating analysis was not evaluated for recognition. For free recall the third condition showed that physical presence ($\beta = .01$, $t(2, 152) = .12$, *ns*), engagement ($\beta = .02$, $t(2, 152) = .28$, *ns*), naturalness ($\beta = -.08$, $t(2, 152) = -1.07$, *ns*), or total presence ($\beta = -.02$, $t(2, 152) = -.23$, *ns*) did not significantly reduce the effect of dimension type on free recall. In other words, presence could not be considered as a mediator for the increased memory with display dimension, and so, **Hypothesis 2b** was not confirmed.

For brand attitude, however, physical presence ($\beta = .23$, $t(2, 152) = 2.75$, $p < .005$), engagement ($\beta = .43$, $t(2, 152) = 5.41$, $p < .001$), naturalness ($\beta = .25$, $t(2, 152) = 3.15$, $p < .001$) and total presence ($\beta = .36$, $t(2, 152) = 4.45$, $p < .001$) all were significant mediators. It implies that the group of people watching 3-D and having strongest feelings of presence was also most positive towards the displayed brands. This confirmed **Hypothesis 3b**.

6. Discussion and conclusions

The main goal of our research was to determine the value of an autostereoscopic multiview 3-D display for advertising in a public environment, where consumers are free to go, and hence, the advertisement should be sufficiently impressive or immersive to attract people's attention. To evaluate the added value of the 3-D display, we decided to follow the approach, published earlier in [1]; i.e., comparing the feelings of presence, the memory for the displayed products and brands, and the brand attitude between a 2-D and a 3-D display. Two different settings were used: a laboratory setting, in which all viewers saw the same commercials for the same period of time at the same viewing distance, and a more natural shopping environment, in which viewing time and distance could not be controlled. The hypotheses of the two studies were formulated in line with the results of [1], who found that a 3-D visualization of a product that can be freely rotated by the viewer, evoked stronger feelings of presence, supported a better memory about the product shown and resulted in a more positive brand attitude than just a 2-D view of a product. In our studies, we found in both settings clear evidence that a 3-D display evoked stronger feelings of presence and a more positive brand attitude than a 2-D display. It was also shown that the feelings of presence could be considered as a mediator for the more positive brand attitude.

The impact of the 3-D display on the memory of the products and brands shown was in both studies less obvious. The impact on the memory was measured in two ways: via free recall, i.e., open questions on the complete set of commercials shown, and via recognition, i.e., a number of multiple-choice questions per commercial. By means of these questionnaires we found in the laboratory setting no statistically significant difference in recognition for commercials shown on a 2-D or a 3-D display, and a significantly better free-recall rate for commercials shown on a 2-D display

as compared to 3-D display. This clearly is contradictory to the results of [1], which showed that people reported to feel more knowledgeable when watching commercials in a 3-D visualization than in a 2D-view. It is also not in line with results published by Keng and Lin [16] and by Suh and Chang [17], who both stated that enhanced feelings of presence improved memory performance and gave consumers the feeling of being more knowledgeable about the product. Only the work published by Grigorovici [7] can be considered to support our findings in the laboratory setting. He used a theoretical model indicating that enhanced feelings of presence evoke a stronger arousal and more affect, and, as a consequence, less attention is paid to the displayed message. The results obtained on memory in the shopping environment, on the other hand, seemed to be more in line with the results found in [1,16,17]. At least they showed the tendency that people recall and recognize more of the commercials shown on a 3-D display than on a 2-D display.

To summarize, it can be concluded that an autostereoscopic multiview 3-D display clearly has added value for advertising in a public environment. It evokes to the viewers significant stronger feelings of presence and a significant more positive brand attitude. There is also a tendency that when viewers are not aware of their participation in an experiment and can freely decide how long to look to the displayed image content, they remember more of the commercials shown on the 3-D display than on a 2-D display.

7. Implications

This paper evaluates the added value of advertising by means of a specific type of 3-D display, i.e. an autostereoscopic multiview display, such as e.g. the Philips WOWvx 3D display. Compared to the more traditional 2-D displays, 3-D advertising outperforms 2-D in a public environment when it concerns product memory and brand attitude. The implications for advertising in a public environment seem obvious. Nowadays it is increasingly difficult to capture the attention of consumers with stimulating and eye-catching advertising messages. 3-D displays are very promising in this respect: they grab the attention of passers-by in shopping malls and at other forms of out-door advertising.

Care should be taken, however, in generalizing the results of this study. In the laboratory setting the 3-D display proved to be inferior to a 2-D display when it concerned memory tasks, although brand attitude still improved compared to 2-D. There seems to be a point at which the cognitive system of viewers is overloaded and, consequently, the effectiveness of a 3-D advertisement in terms of memory diminishes. In this respect, theoretical issues like the two-step model, proposed by Grigorovici [7], deserve more attention. He postulates that, at a certain point, more presence leads to more arousal

Table 2

Results for display dimension on presence, memory and brand attitude measured in the shopping environment (Study 2).

Dependent measure	2-D M (SD) (n = 74)	3-D M (SD) (n = 81)	t (df)	p
Physical presence	2.26 (.91)	2.87 (.67)	-4.72 (134)	.0000
Engagement	2.53 (.79)	3.16 (.58)	-5.56 (132)	.0000
Naturalness	3.02 (.78)	3.42 (.64)	-3.58 (153)	.0000
Total presence	2.63 (.74)	3.17 (.53)	-5.27 (130)	.0000
Free recall	.93 (.23)	1.43 (.46)	-8.54 (119)	.0000
Brand attitude	4.49 (.93)	4.97 (.83)	-3.41 (153)	.0005
<i>Recognition for commercial</i>				
1 (n = 54)	.38 (.15)	.48 (.23)	-1.71 (52)	.094
2 (n = 38)	.32 (.12)	.56 (.22)	-2.70 (36)	.01
3 (n = 25)	.00 (.00)	.33 (.27)	-1.74 (23)	.10
4 (n = 39)	.36 (.20)	.36 (.21)	-.07 (38)	.95

and affect. When arousal reaches a higher level, this might cause an overload in the viewer's information processing capacity and, consequently, lead to less memory. It may be that in an environment with little distraction, and total concentration on the display, feelings of presence lead to so much arousal, that information processing decreases. Further research should therefore concentrate on the relationship between presence, level of arousal, and the environment where the viewing takes place, to explore the full potential of advertising on a 3-D display.

In crowded public environments, like shopping centres, train stations, and airports, 3-D advertising seems to be a very suitable medium for visual, billboard-like applications that can catch the eye and can have a positive effect on brand attitude. The results reported in [1] showed that viewers felt more knowledgeable after experiencing 3-D compared to 2-D. It would be interesting to use this subjective measure of judgement in future research on 3-D advertisement. It might well be that viewers feel more positive about 3-D advertising in terms of knowledge, experienced presence and in their attitude towards the advertised brand compared to traditional advertising media.

Appendix A

Index questionnaire items (Study 1).

<i>Brand attitude</i>		
1 Good	14 Convincing	27 Refreshing
2 Like	15 Complete	28 Enjoyable
3 Irritating	16 Well-structured	29 Fun to watch
4 Interesting	17 Agreeable	30 Helpful
5 Trustworthy	18 Tasteful	31 Useful
6 Informative	19 Artful	32 Fond of
7 Believable	20 Meaningful	33 Well made
8 Impressive	21 Valuable	34 Likely
9 Attractive	22 Important to me	35 Affectionate
10 Eye-catching	23 Beautiful	36 Strong
11 Clear	24 Positive	37 Familiar
12 Pleasant	25 Satisfactory	
13 Nice	26 Original	
<i>Presence</i>		
1 Sad experience was over	8 Experience was intense	
2 Like experience to continue	9 More attention to displayed environment	
3 Parts vividly remembered	10 Being in scenes displayed	
4 Recommend experience to friends	11 Move displayed objects	
5 Content seemed believable	12 Scenes were realistic	
6 More than just watching something	13 In same space as displayed objects	
7 Environment part of real world	14 Participate in displayed environment	
<i>Free recall</i>		
1 Number of commercials	4 Order of commercials	
2 Number of brands	5 Number of texts and messages	
3 Number of products or objects		

Appendix A (continued)

<i>Recognition</i>	
1 Sequence of commercials	9 White cube composition
2 Color of dice	10 Background white cube
3 Text in dice commercial	11 Content Heineken commercial
4 Color of play table	12 Absent in Heineken commercial
5 brand names in dice commercial	13 Text in Heineken commercial
6 Location "sense and simplicity"	14 Content telephone commercial
7 Location message Philips	15 Color telephone display
8 Route white cube	16 Text in telephone commercial

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