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Investigating the effects of publishing approaches using print, electronic and augmented reality media on user experience

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Abstract

To evaluate the potential role of modern augmented reality (AR) technology in publishing and its usefulness for interactive print, we conducted a study where we investigated the influence of different methods of presenting content on the users' story reading experience. The stories were produced in print and electronic media, with and without augmented reality component, using a multi-media setup consisting of a computer with the monitor display, a smartphone, and a printed material. A 2 × 2 within-subjects experimental design was implemented (2 levels of medium: print and electronic; and 2 levels of augmentation with video clips: yes or no), wherein 32 participants aged 18–29 years old were asked to read short stories produced with different publishing methods and evaluate their preferences for the presentation of the content, as well as interestingness, comprehension and overall experience with the stories on a 7 point scale using a questionnaire. AR and the medium–AR interaction were found to be significant in determining the preference for the publishing method. The paper–AR combination had the highest score among all the methods and was rated statistically different from the paper only version, which, in turn, had the lowest score. For the overal expeirence ratings a significant medium-AR interaction was observed, with the trend, similar to the publishing preference ratings. Overall experience was linked to the users' preference ratings for the publishing methods, interestingness and enjoyment of the stories, and the ease of understanding the story line. The results indicate that AR enhances user experience, particularly with print media, making it on par or even higher valued than commonly used electronic media. In contrast, the traditional print version without augmentation was least preferred.

Keywords: publishing, augmented reality, print, digital media, storytelling

1. Introduction

With the rapid development of digital technology, the emergence of cross-media publishing provides more opportunities for publishers to enrich content and broaden the audience. Recently, the concept of augmented reality (AR) emerged as an innovative approach to enhance print-based graphic communication and publishing (Perey, 2011). According to Vehmas et al. (2011), a significant rise of innovative interactive print products by 2020 is projected, with AR as one of the enabling technological platforms.

Furht (2011, p. 3) in the "Handbook of Augmented Reality" defines AR as "a real-time direct or indirect view of a physical real-world environment that has been enhanced/augmented by adding virtual computer-generated information to it". Augmented reality can be considered a combination of virtual and real environments, and also a new medium, which aims at providing relevant and useful digital (e.g. web-based) information to the user that can be linked and blended with any tangible medium including print.

AR attracts significant attention due to its interactive nature, multimodality (sound, video and 3D graphics), and ability to bring web information to a point of a user's physical interaction with the environment mediated by personal computing devices. Put differently, AR turns smartphones or tablets into a viewing pane that opens up an interactive 3D world around a physical object to people. These characteristics of AR have been recognized as particularly appealing in marketing, with the goal to cause consumers remember an experience or action related to a product, rather than a static image or text common to traditional print based advertising methods (Connolly et al., 2010).

While many professionals are excited by the prospects of AR applications in publishing, marketing, and advertising, some scholars and analysts think that it is the novelty factor that drives interest toward AR. As Craig (2013, p. 151) suggests, "augmented reality is new enough that people are interested in it just because it is augmented reality. This will wear off very quickly".

Additionally, Grushka (2013) points out some existing challenges with AR including cumbersome user experience, fragmented ownership of AR platforms, and a lack of value-added content.

Despite a recent heightened interest toward the AR technology and the existence of several popular products and open source tools, such as Aurasma, Layar, and Wikitude, commercial AR applications are still in their infancy.

It is not yet well understood how to make the most of this new medium for graphic communications, and even more so, how it can be used in the future. While AR technology is considered an enabler for the recently emerged concept of interactive print, research on the applicability and effectiveness of AR in publishing has been limited.

To assess the role and usefulness of AR in publishing, we ask the following questions: How do users evaluate their experience with different publishing methods, including AR? Is publishing with AR truly more attractive to people than the traditional publishing approach? How does it affect understanding and retention of communicated information? What is the role of print in novel publishing platforms?

In order to answer these questions, we compared several methods for publishing short stories from a user experince point of view. We implemented printed and electronic versions of the stories with and without the AR component. In the experiment, video clips on a mobile phone triggered by the story content served as AR, thus utilizing a basic definition of AR as "virtual computer-generated information".

2. Related work

The first AR systems appeared in 90-s, with early papers describing head mounted display prototypes for air force and military applications (see, for example, Rosenberg, 1993). Currently, studies involving AR technology focus primarily on its use for advertising, tourism and education and deal with either technology improvements or the evaluation of the technology benefits. Several recent research papers are described below. We categorized them as those related to advertising and those related to education.

2.1 AR in advertising

Connolly et al. (2010) examined effectiveness of AR use in advertising by evaluating observers' information retention from AR advertisements in comparison to standard paper-base media. Computer generated 3D representations of vehicle models were used as AR; 2D images with the same product information were used to simulate traditional print advertising. The stimuli were displayed on a computer screen. As a result, both traditional two-dimensional image and three-dimensional AR advertisements were shown as equally effective in presenting visual components of a product, or in generating product interest. The data also indicated that traditional 2D images were more effective in delivering factual text-based information. However, this latter result could have been caused by limitations of 3D visualization software to clearly show textual information.

Chehimi, Coulton and Edwards (2007) described a concept of a unique system that allowed complex and highly interactive visual 3D advertisements to be viewed on mobile phones equipped with a camera. One of the key features of the proposed system is its capability to provide a location-based service. According to Chehimi, Coulton and Edwards (2007, p. 7), "interactive and entertaining location-based services systems will have the greatest impact of all mobile marketing on customers' experiences and businesses' logistic marketing mixes."

Shiva, Raajan and Jayabhavani (2013) implemented and tested an AR system prototype for virtual tourism and advertisement using computer vision algorithms. Their system augments physical objects in the real world environment with 3D video to increase persons' conceptual understanding of the surrounding objects.

While researchers recognize potential benefits of the AR systems for marketing and advertising, none of the papers described above have provided significant measurable empirical evidence for AR advantages nor used the technology to augment printed material for publishing. Connolly et al. (2010) attempted to simulate traditional print advertising in their study but they did not use actual printed material, and instead, showed the images on the computer screen.

2.2 AR in education

Several studies demonstrated the effects of AR on learning, engagement and enjoyment in the context of education. According to Di Serio, Ibáñez and Kloos (2013), motivational factors of attention and satisfaction in an AR-based learning environment were rated higher than those obtained in a traditional, slidesbased presentation of teaching material in a visual art course. Participants in the experiments reported higher levels of engagement and enjoyment when using AR, and appreciated its multimedia nature. In other studies, AR was shown to influence learning outcomes. Using Augmented Books (purposefully created educational AR books that overlay 3D virtual content over real book pages with the help

of an AR system) for teaching electro-magnetism at the highschool level tended to improve test performance and retention of the material compared to traditional textbooks (Dünser et al., 2012). Similar positive results were obtained in Gutiérrez et al. (2010), where an AR book has been designed to provide 3D virtual models to help engineering students perform visualization tasks. The study concluded that the training had a measurable and positive impact on students' spatial ability.

Although the above-mentioned studies show the positive effects of AR on learning and students' experience, their primary goal was to demonstrate the role of AR in education, underscoring its interactivity and 3D visualization. There was no attempt to address the role of print or any type of tangibility factor in such systems. Di Serio et al. (2013) did not use printed material at all, and for Gutiérrez et al. (2010) and Dünser et al. (2012) the experimental variable under investigation was the presence or absence of AR, which, in principle, does not require print.

Yet, many scholars and industry leaders acknowledged specific advantages of the print medium: physicality/tangibility, portability, unique sensory qualities, its association with more effective reading comprehension, and information retention; emphasizing therefore, its significance in the media communication realm (Mangen, Walgermo and Brønnick, 2013). These observations suggested that not only augmentation and interaction with the virtual data, but presence of a tangible carrier of the original information to which AR is linked, and with which the user could interact, might be important factors to influence effectiveness and user experience with the AR systems, including AR–enhanced publications.

Consequently, we hypothesized that users would prefer printed stories with AR than any other production methods, whether or not they included the same virtual material.

The objective of our study was, therefore, to evaluate the influence of two factors, AR and publishing medium, on participants' reading effectiveness, preference and experience by comparing different methods of content production: using print or electronic display with or without augmented reality. To our knowledge this is the first attempt to perform such an assessment.

3. Study methodology

3.1 Experimental set up

In the present study we used a multi-media setup, consisting of an iMac computer with the 27-inch monitor display, a Google Nexus 5 smartphone, and printed material produced on the 8.5" × 11" Mohawk 215 g/m^2 (80 lb) Color Cover paper with a Canon imagePress C1 printer according to SWOP standards. A free version of the Aurasma Android application was installed on the smartphone and was used to create AR content. The monitor was calibrated with a white point of 5000 K, gamma 2.2 and the 80 cd/m^2 maximum luminance level.

The experiment took place in the lab that approximated a typical office environment with the artificial "Cool white" fluorescent illumination (5000 K) and the illuminance level around 320 lux.

3.2 Study design

In order to investigate the influence of AR and the publishing medium on the user preferences and experience when reading short (two-page) cartoon stories, we used a 2 × 2 within-subjects experimental design with two independent variables and two levels for each variable: (1) medium: print versus electronic medium, and (2) augmentation with the smartphone using video clips: the presence versus absence of AR.

The following conditions were compared: 1) a print version that contained text and illustrations; 2) a print version with text, illustrations and an AR component in the form of video clips; 3) a webpage with text and illustrations; 4) a webpage with text, illustrations and an AR component. To represent a typical modern interactive electronic publication we also included 5) a webpage with text and video clips, which could be played by clicking. Thus, we have used two versions for the electronic medium without the AR condition.

Each participant viewed five different stories produced using five different methods, 1) through 5), to eliminate familiarity with the story content. The story and publication method pairings were pseudo-randomized across participants making sure each combination had the same number of occurrences across the participants. The webpages were displayed on the monitor screen, while AR video clips were accessible by positioning a smartphone over images that served as triggers for an AR application installed on the smartphone.

The participants filled paper-based questionnaires after reviewing each story and also at the end of the experiment, after experiencing all five stories. Study questionnaires consisted of seven-point Likert-type scales to rate several attributes of the story reading experience, including understanding, ease of reading, interestingness, liking of story content and the method of publishing, and

overall experience. Additional questions to recall specific information about the stories and indicate preferred features from the list were also included. In comparison with the questionnaires after each story, the final questionnaire contained both rating and ranking items. The scales were represented graphically as lines with the seven equal intervals numbered from 1 to 7, where 1 corresponded to the lowest value for the rated attribute, 4 – the neutral value, and 7 – to the highest value for the attribute to help participants visualize the scale.

The goal was to obtain an interval-level measurement, whereas a category based Likert-type scale typically provides an ordinal-level measurement. The questionnaire example is provided in Appendix. Additionally, post-study follow-up phone interviews were conducted to collect recall data.

3.3 Stimulus material

Five different cartoon stories of similar genre and comparable interest level adapted from Oliver Jeffers' picture books for children ("Lost and Found", "How to Catch a Star", "The Way Back Home", "The Incredible Book Eating Boy", and "The Heart and the Bottle") were chosen for the experiment. For every story five versions were prepared using different publishing methods described above. Each story had two pages that included text and two illustrations per page. The pages were designed using Adobe InDesign. The page layout was similar for all the stories and is illustrated in Figure 1. For the text we used American Typewriter 15 pt (body) and 35 pt (title). The story pages were saved as PDF files.

For the print-based publishing, the files were printed as such. For the print–AR publishing method, slight modifications of the PDF files were prepared and printed. Those copies had play button tags near the illustrations to inform the participants about the AR availability as illustrated in Figure 1.

The webpages for all five stories were created separately using HTML, CSS, and JavaScript languages in Adobe Dreamweaver. Compared with the printed versions, the webpages used the same PDF files, which were designed in Adobe InDesign. For the webpage with the video clips conditions – the appropriate video clips were embedded in the HTML files.

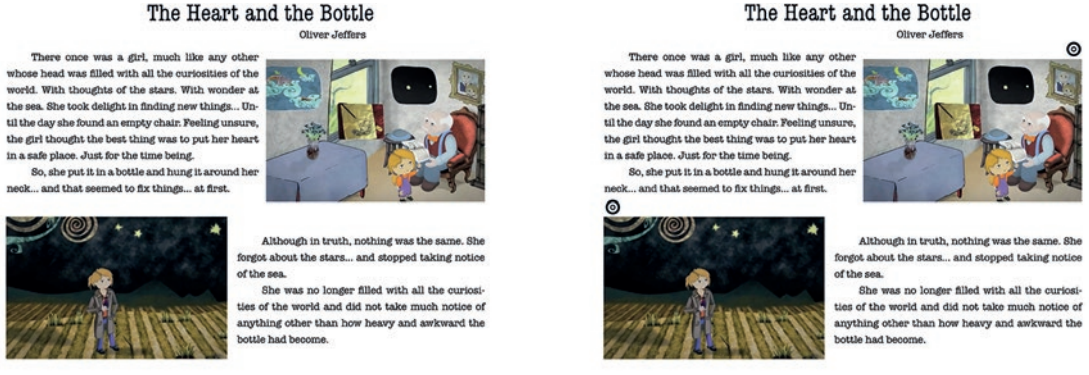
Video clips for the stories, four clips for each story, were created from animations found on YouTube and Vimeo. The video clips started with the same frames as the corresponding illustrations and lasted about 20 s in duration.

To enable AR, the video clips were uploaded onto the smartphone, together with the trigger images (the same images that were used for the illustrations), and processed by Aurasma software installed on a Google Nexus 5 smartphone to create AR projects for each story.

The appearance of stories on print and on the screen was equalized in terms of the page size, font size and color reproduction.

3.4 Participants

Student participants were recruited via email and flyers posted throughout the RIT campus. A simple survey to collect information about the name, gender, college, and available time was emailed to people who volunteered to take part in the experiment. Based on the survey, prospective participants were screened prior to the experiment to select equal number of female and male students from different colleges. This was done in order to avoid potential gender and education biases. As a result, sixteen male and sixteen female RIT students in the 18–29 years old age group participated in the experiment with the average age of 23 years old. They had normal or corrected to normal vision and no reading difficulties. As an added incentive, every participant was rewarded with a $ 20 gift card to Java's, a local Rochester coffee shop.



a) *b)*

Figure 1: An example of a story layout: a) print version, b) print with AR version

3.5 Procedure

All participants were informed, prior to their participation, about the commitment involved in the experiment. Upon arrival, the participants read the introduction sheet, signed the consent form and filled in the pre-test questionnaire with some basic information including their reading habits and familiarity with AR. Next, they were asked to read and interact with the content (when appropriate) of five two-page cartoon stories published using five different methods described above. For every subject the order of the stories was randomized before the experiment. Table 1 shows the stimulus presentation sequence for two experimental participants, as an example. Both participants saw all five stories and were exposed to all five methods, however the story-publishing method combinations and the presentation order were different.

We allowed a maximum reading time of 10 minutes per story, and recorded the actual time participants spent with the material. After reading each story, every participant filled the story questionnaire (see Appendix) and rated his or her understanding of the content; readability; interestingness; overall story liking; publishing method liking; and provided their assessment of interactivity, and other features. At the end of the experiment, the participants were asked to compare (rank) all five stories on the same attributes and overall experience, as well as rate these attributes for the second time using the post-test questionnaire. The average duration of the experiment was approximately 30 minutes per participant. There were a few subjects who completed the experiment in more than 30 minutes, but no one exceeded one hour time period. Participants' responses were submitted via paper-based questionnaires and organized in 32 separate folders to preserve all data.

One month after the completion of the experiment, we approached the participants with the request for a short phone interview regarding the study. Ten subjects, who agreed to participate, were asked to recall information about the stories.

3.6 Data analysis

Data from the study were obtained from printed questionnaires and transferred to an Excel spreadsheet. The data analysis was done with the Excel and the JMP 11 statistical software.

We analyzed scaling data in several ways. Firstly, we considered rating responses as ordered categories and used generalized linear model implemented in JMP to test the significance of the independent variables and their interaction.

Secondly, we applied Thurstone's law of categorical judgment (condition D) described in Torgerson (1958) to rescale our data from ordinal scale to interval scale. To this end, we calculated frequencies and cumulative frequencies of rating categories for every question across all participants, then cumulative proportions and corresponding the z scores. Subsequently, we computed scale values and category boundaries for every attribute.

Based on this analysis we were able to conclude that the "raw" data approximates interval scale very well. Figure 2 shows the linear relationship between scaled category boundaries and seven categories for overall experience attribute. Rescaled data for other attributes followed similar relationship. Our findings are in agreement with existing publications (e.g. Traylor, 1983) pointing out that Likert-type items perform closely to scales that are perceived as equal intervals, and can satisfy the equal distance assumption required for parametric statistical analysis.

Finally, following confirmation that the original rating categories are largely perceived as equal intervals, we applied ANOVA and multiple linear regression analysis to our data and compared the results of both approaches. There was a good agreement between two types of analyses. Since no discrepancy was found regarding the effects, we report the results obtained with parametric statistical analysis techniques.

Table 1: Comparison of stimulus presentation sequence for two experimental participants

Order	Participant #2		Participant #7	
	Story	**Publishing Method**	**Story**	**Publishing Method**
1	Lost and Found	Web/AR	The Way Back Home	Paper
2	The Incredible Boy Eating Books	Paper/AR	The Incredible Boy Eating Books	Web
3	Heart and Bottle	Paper	Lost and Found	Paper/AR
4	The Way Back Home	Web/Video	Heart and Bottle	Web/AR
5	How to Catch a Star	Web	How to Catch a Star	Web/Video

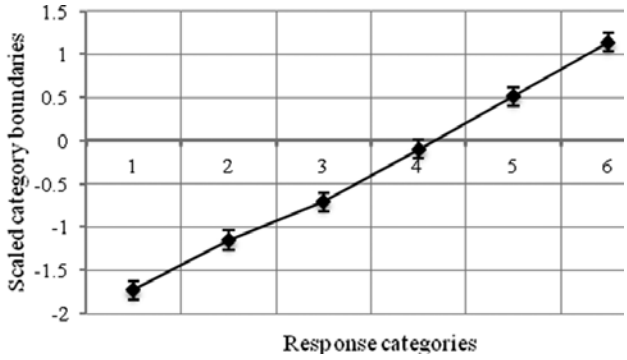


Figure 2: The relationship between response categories and scaled category boundaries using Overall Experience attribute data as an example

4. Results

We examined the main effects of the independent study variables, *Medium* and *AR*, and their interaction on all rated attributes using the two way ANOVA. There were no significant effects on understanding, readability, interestingness ratings, and on information retention score, calculated as a number of elements the subjects were able to correctly remember at the end of the experiment. The attributes, for which the significant effects were obtained, are described below.

4.1 Analysis of preferences for publishing methods

There was a statistically significant main effect of *AR* ($F = 13.15$, $p < 0.000$) and also a significant interaction effect of *Medium* versus *AR* ($F = 4.41$, $p = 0.037$) for the publishing platform liking question from the story questionnaire. The same significant effects were found for the post-test questionnaire, when the users had completed viewing all five stories: *AR* ($F = 9.98$, $p = 0.046$); *Medium* versus *AR* ($F = 5.06$, $p = 0.026$). The stories presented with AR were rated significantly higher than without AR. The interaction effect is demonstrated in Figure 3.

The fact that the analysis results were similar for the two instances of using the questionnaire, after each story, and after viewing all five stories, adds validity to the data. The significant interaction effect shows that the paper-based method gains the most from adding AR to the story content and is rated the highest. To directly compare all five versions of publishing, we ran the one way ANOVA, using the *Publishing Method* as an independent variable with five levels: *Paper; Paper/AR; Web; Web/AR; Web/Video.* The effect was significant ($F = 5.42$, $p < 0.000$). The *Paper/AR* condition had the highest score among all methods, significantly different from the *Web* ($p < 0.001$) and *Paper* ($p < 0.000$) conditions, with the latter having the lowest score (Figure 4). Other differences were insignificant, although preference for the *Paper/AR* condition in comparison with the *Web/Video* condition was close to the 5 % significance level ($p = 0.061$).

4.2 Analysis of overall experience ratings

None of the main effects, neither *Medium* nor *AR*, were statistically significant for the overall experience ratings. There was, however, a statistically significant interaction effect of *Medium* versus *AR* ($F = 6.93$, $p < 0.009$), demonstrating the same behavior as was found for the platform liking data. Namely, adding AR changed the paper-based version from the least preferred to one the most preferred making it equal with electronic publishing methods in terms of overall experience. The one way

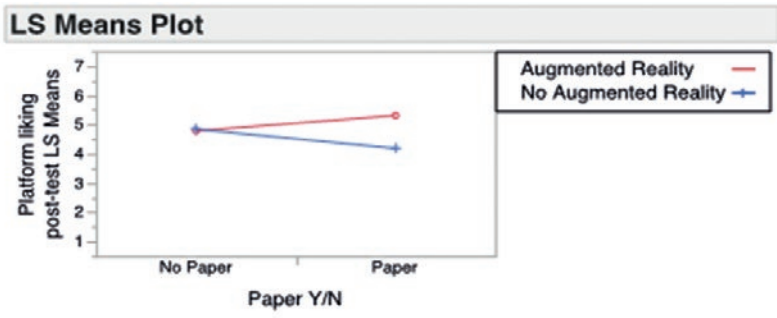


Figure 3: Interaction effect of Medium versus AR on publishing platform liking

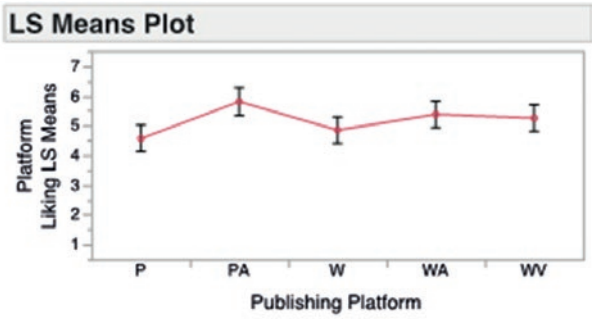


Figure 4: The effect of publishing method on platform liking (P – Paper, PA – Paper/AR, W – Web, WA – Web/AR, WV – Web/Video)

ANOVA showed a significant effect for the *Publishing Method* variable ($F = 2.68$, $p = 0.034$), with the *Paper* condition being substantially lower rated (Figure 5).

The absence of the main effects led us to test the influence of the story-related attributes, including interestingness, understanding, readability, story liking, as well as platform liking, using multiple regression analysis. The effects for all these variables were significant ($p = 0.04$, $R^2 = 0.62$) showing the importance of other attributes on the overall experience, particularly associated with the story content. We did not find any gender differences, or significant differences between the participants.

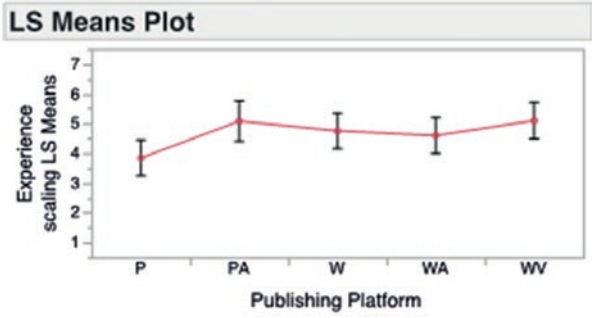


Figure 5: The effect of publishing method on the overall experience rating

5. Discussion

Our data demonstrate the statistically significant influence of AR on the users preferences for different publishing methods. Specifically, adding AR enhanced users' experience with printed publications and made this method of publishing as one of the most preferred ways to read the content. Moreover, without AR, print publications were evaluated as the least preferred by the group of young college students, which are reading electronic media on a regular basis. This result is novel and points toward advantages that can be gained by incorporating AR to interactive print publications. The consistent substantial interaction effect of combining the publication medium and AR on the users' preferences and experience speaks about qualitative change of media integration and potential direction that can be explored for various applications in graphic communications and publishing.

We did not identify any significant effects of AR and or medium on the reading performance, possibly because of the story types we have chosen for the experiment. Our stories were short and easy to read and remember without any difficulty. It would be interesting to conduct a study with more challenging content, such as for example scientific publications.

6. Conclusions

Our study demonstrates that augmented reality significantly affects preferences for the publishing format of short stories, providing a particularly strong influence for the stories printed on paper. Overall experience ratings reveal a similar trend, where we found a significant medium–AR interaction effect. The study results are consistent with the findings from research in advertising and education that show positive effects of AR on

the user experience with the material at hand. However, our study has a relatively small sample of participants and is confined to the lab settings. In order to prove the real-life utility of AR in publishing, a larger study, beyond the lab experiment, is necessary. This will help to address concerns about novelty factor playing a major role in AR preferences, as well as to understand how to properly design interaction experience to justify additional efforts on the consumers' side associated with using AR.

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Appendix

Questionnaire (For each story)

What is the topic of this story?

_____

What is the main character in this story?

_____

How easy was for you to understand the story?

Extremely easy			Neutral			Extremely difficult
1	2	3	4	5	6	7

How easy was for you to read the story?

Extremely easy			Neutral			Extremely difficult
1	2	3	4	5	6	7

How interesting do you find the story you just viewed?

Not at all			Neutral			Extremely
1	2	3	4	5	6	7

How much do you like the story?

Not at all			Neutral			Extremely
1	2	3	4	5	6	7

How much do you like the way the story was published/presented?

Not at all			Neutral			Extremely
1	2	3	4	5	6	7

If the story includes an interactive publishing part, how do you like the interactive part?
(If no, please skip this question)

Not at all			Neutral			Extremely
1	2	3	4	5	6	7

Please circle three most important features in this story
□ Layout Design
□ Content
□ Readability
□ Interactivity
□ Color
□ Video clips
□ Illustrations
□ Other _____

Please circle three most enjoyable features in this story
□ Layout Design
□ Content
□ Readability
□ Interactivity
□ Color
□ Video clips
□ Illustrations
□ Other _____

Please write down any comments and observations you may have.