Institut für Mensch-Computer-Interaktion
Universität Stuttgart
Pfaffenwaldring 5a
70569 Stuttgart
Germany

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Assessing the Impact of Interactivity on Recall and Recognition

Michael Girgis

Studiengang:	INFOTECH
Prüfer:	Prof. Dr. Albrecht Schmidt
Betreuer:	Dipl.-Medieninf. Florian Alt Stefan Schneegaß
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Abstract

The urban landscape is nowadays increasingly permeated with public displays. It is not only large outdoor advertisers that deploy them, but also smaller retailers set up displays in their shop windows. Advertising is currently the prevailing business model but the mere adaptation of traditional content (static text, images, or movies) makes displays hardly attractive to the passer-by. Consequently, new forms of more entertaining and engaging content is being developed and deployed, such as interactive games that promise a great user experience and are more likely to grasp a user's attention. However, it still remains a questionable challenge how advertisers can benefit from such content despite the increasing number of passers by starting to interact.

This thesis aims at understanding the effects that are caused by novel, interactive public display applications. This entails more specific questions such as whether people can better memorize the content on the screen if they interacted with it. Memorizing is measured by recall and recognition. Understanding the effect on recall and recognition would be of high interest to the advertiser as this could be a valuable measure for the success of future public display applications in combination with the advertising realm.

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Chapter 1

Introduction

With the ever growing population of retail and merchandise in the trade world nowadays, comes the advancing need to reach local community consumers in as attractive ways as possibly could be. Traditional public notice areas (PNAs) have lately become one of the most widespread communication and marketing media. They act as an attractive way to quickly exchange information with passers by. Consequently, their high usability has led to an extensive use in stores, cafes, supermarkets, and public institutions. Every day, the urban landscape is becoming increasingly permeated with public displays, not only confined to large outdoor advertisers but also smaller retailers have found marketing benefits in deploying displays in their shop windows. It is undeniable that public displays have become a main element for providing people with information, knowledge, news, offers and even advertisements for new products.

It is therefore evidential that advertising is currently the prevailing business marketing model. However, having said that, the counterpart must be considered: With the current flourish of interactive technology and media, the mere adaptation of traditional content (static text, images, or movies) makes displays hardly attractive to the passer by.

It is believed that, as with the majority of other forms of media, consumer interactivity via public displays will lead to a booming rise in marketing success. Hence, it becomes necessary to investigate the role of motion and physicality in drawing people to look and actively interact.

Consequently, new forms of more entertaining and engaging content is being developed and deployed, such as interactive games and trivia that promise a great user experience and are more likely to attract attention. It is undoubtedly true that a casual passer-by will stop to play around on an interactive touch screen game, as opposed to a static shop screen.

It can be successfully forseen that static PNAs will be replaced by their digital interactive counterparts in the future, hence contributing to making public displays a novel communication medium. However, the question still remains on the table. Despite the increasing number of passers by, this point still remains under thorough investigation: How can recall and recognition be assessed through consumer usability in such a way that marketing experts and advertisers can maximally benefit from deploying such interactive content?

1.1 Motivation

The above question is one worthy of thorough exploration. This thesis, along with its adjoining work, is dedicated to investigating and conceptually understanding the effects of human-computer interactivity impact caused by novel, interactive public display applications to the utmost. This entails both basic problems, such as how applications can be designed in such a way that users can easily recognize that they are interactive, as well as more specific questions such as whether people can better remember the content on the screen if they interacted with it. Understanding the human responses on recall and recognition would be of high interest to the advertiser as this could be a valuable measure for the success of public display applications.

In order to approach a solid conclusion in response to these questions, it must be necessary to establish an environment that contains an interactive system displaying some information opposed by a contradictory system that depicts the same information but with the use of static content. Of the many goals of this research, is the plan to build this system and run an interactive test-bed for its analysis in Stuttgart University. This study will essentially allow for a preliminary set of statistics that can act as a foundation for furtherly experimenting with the questioned hypothesis. It will then be possible to objectively validate or invalidate the given assumptions. Will user interactivity positively impact the recognition and recall of public displays?

The output of this study will undoubtedly act as a vital marketing competency for various stakeholders such as advertising agencies or information display owners. It is ambitiously hoped that it would provide knowledge that will guide them to alter their marketing strategies. For example: Should they upgrade their current methods and put the extra effort into integrating their content with an interactive environment or whether static content will remain the marketing superior with regard to recall and recognition?

1.2 Overview

Before commencing, a brief run-through of the chapters and sections provided in this paper will be offered in this section such that the readers can reference their readings to other parts of the text. Each chapter will also begin with an introductory paragraph to easily inform the reader about the main contents of the chapter.

The first chapter will initially provide the reader with an overview of the topic and the history behind public displays, including a section depicting the motivation behind this study. This part aims at shedding light on the importance of this research and how it can be made use of, especially in the advertising world, via future applications that can benefit from it once validating the truth of our research question.

Chapter two is a literature review, which explains terms that may not be familiar to the normal reader to allow better understanding to the material that will be discussed later on. Topics discussed will cover the definition of public displays, where they can be found, and elaborate on some specific topics like what makes consumers notice displays. Moreover, different methods of interactive public displays will be analyzed explicitly through their different types of interactivity. The literature review will move on to examine advertising techniques, especially Pervasive Advertising. Briefing on KPIs, the basic and future ones, especially recall and recognition will be provided too. Finally, the technologies used throughout the study in order to achieve the goal of this thesis were explained, especially the Kinect Software Development Kit (SDK), its architecture, and how does it work in reality.

Chapter three is fundamental as it is entirely focused on the exact problem behind the thesis, purposely discussing and searching for all possible solutions for the challenge at hand. It offers a detailed discussion about the different factors that were found to affect memorability and the ones chosen to be used in this study.

Chapter four is responsible for a total description of all that is related to the prototype created during this thesis in order to solve and validate the proposed research question. It will talk in details about the architecture and structure of the suggested prototype, mentioning all the components of it from the hardware prospective, as well as the software prospective. An overview about the implementation techniques used to achieve the prototype and finalize it will be included.

Chapter five will cover the evaluation of the study carried out focusing on evaluating the behaviour of people in response to the implemented prototype. A pre-study was held that took place before the prototype was complete, so the details of the pre-study are first explained, followed by an explicitly detailed analysis of the lab and field studies that were held. This section covers items such as the study arrangement, how the avenue was made ready for the study. It will then move on to mention the recruiting methods used to find people to come and participate in the study. The procedures of the study are then described in later sections within this chapter, including the exact scenario implemented with the participants to do the study. Finally, the experiment results will be shared accompanied by a set analysis of the acquired data.

Last but not least, the conclusion chapter will wrap up the thesis with an adequate summary of all the previous chapters, adding focused attention on possible forthcoming improvements and enhancement ideas through future developments.

Chapter 2

Background & Related Work

In order to get familiar with the task at hand, it will be necessary to establish some important terms and facts that will be applied through-out the rest of the research. Additionally, current state-of-the-art technologies and previous applications experimented in this same area will have to be reviewed thoroughly in order to investigate how the current techniques can be renovated.

The definition of public displays, discussion of the possible interaction techniques for public displays, and human analysis with regard to application interaction, are all issues that will need to be addressed in this research. Are interactive displays efficient and attractive enough to allow people to notice and hence interact with them? Moreover, how can passers by be encouraged to approach the interaction phase? These are but a few of the questions that this study desires to explore.

Throughout this research, different advertising and marketing techniques will be examined, especially those including pervasive advertising and its relation and impact on public displays. Another sector that will need to be discussed are the KPIs. It will be an asset to analyze the basic indicators as well as the cognitive ones, including recall and recognition. Measuring the KPIs will also be a focal point of the research, and consequently, the effect of engagement in other external stimuli on recall and recognition in public displays. Finally, the research will also inspect the technological background in this field, including the Kinect SDK that was used to achieve the prototype used to prove our hypothesis.

2.1 Public Displays

According to Moore's law, the number of transistors that can be integrated in an integrated circuit(IC) doubles approximately every 18 months and in consequence the price for the IC becomes cheaper [18]. This evidently results in the prices of displays continuously dropping. Accordingly, public displays have become widely used. Their popularity has led to their installation in various places, both indoor and outdoor, including open public places in the city or in private premises. Through the years, and especially with the development of technology and electronics, digital technology has lately teamed up with public display marketing to offer what is now known as digital signage. Digital signage excels in its presentation of dynamic multimedia content via electronic displays, targeting fields such as marketing, advertising, displaying restaurant menus and even television programming. When it comes to purposely focusing marketing and advertising on wide-area target audience, digital signage can play the best role in impacting content in the form of electronic displays in public areas such as train stations, universities and city centers [10].

It is predicted that paper signs will soon be replaced by digital public displays because of their various advantages over preliminary cardboard advertising material. Of its many pros, digital signage excels in its presentation of dynamic multimedia content. Not only does it give advertisers the tangibility to adapt to a variety of contexts, but it is also more cost-effective on the long run. Due to the fact that digital signage content offers the functionality of being both frequently and easily updated, saving printing and/or construction costs associated with static signage becomes an easily achievable bonus. Furthermore, because of the interactive abilities available through the accompanying employment of such real-world interfaces as embedded touch screens, movement detection and image capture devices, it has won wide acceptance in the marketplace.

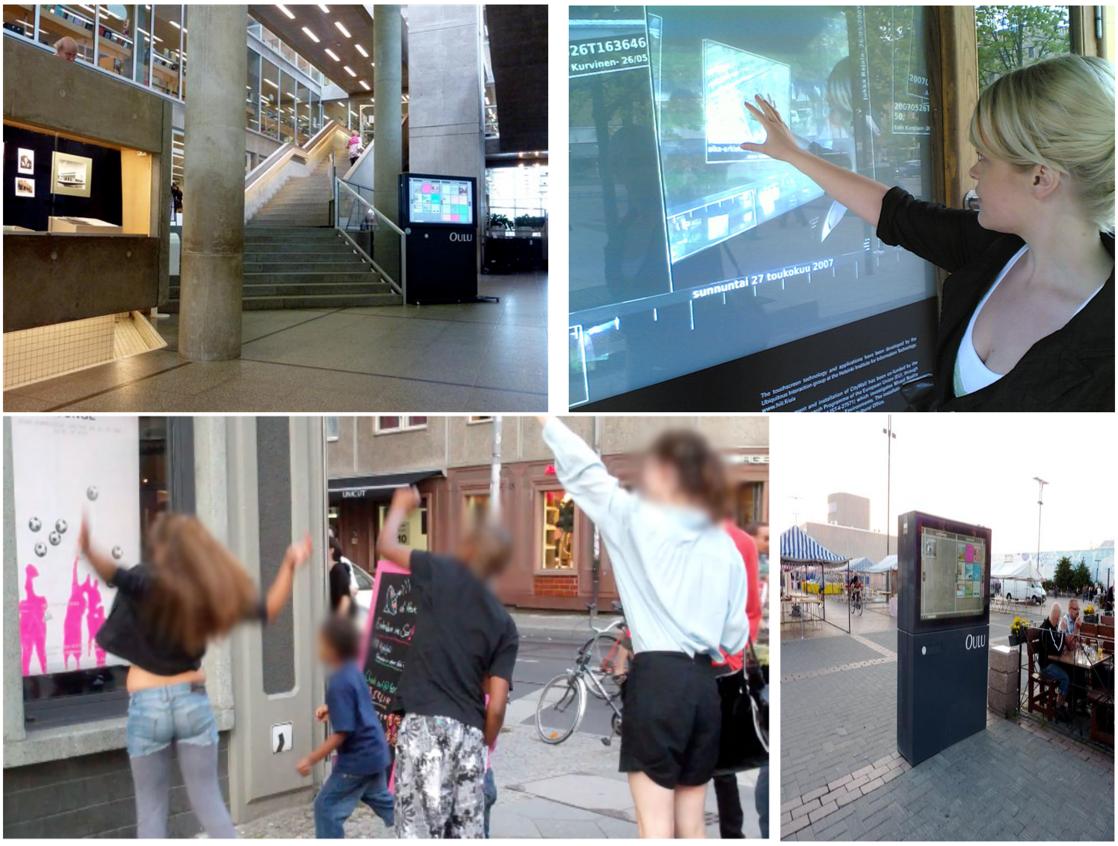

Figure 2.1: Picture 1: The Digifieds Public Display deployed in the public Library in Oulu[5]. Picture 2: Interactions at a large multi-touch display in the city center in Helsinki, Finalnd[26]. Picture 3: People interacting with the Looking Glass in front of a shop window in Berlin[23]. Picture 4: Deployment of the Digifieds in market square, Oulu[5].

Digital displays have many fields of application; they can be used for public advertising or for private information sharing within an institute among other applications. Public displays can either contain static or interactive data. The main concern with public display interaction is successfully attracting the attention of a busy passer-by to get the first click [17]. Figure 2.1 shows interactive public displays deployed in urban spaces.

2.1.1 Challenges

It is worth noting that not every public display is observed by passers by, which hence motivates the concept of display blindness. According to Müller et al., display blindness is the theory associated with the act of people failing to observe a certain public display although they pass by it. Deployers of this technology falsely assumed that all people observed all public displays and that by default, their attention was immediately attracted and caught. However, the challenge that has been realized, is that this is not entirely true [24].

In the busy fast-paced world we are living in, ensuring that people can notice and perceive public displays is certainly not an effortless task. While roaming the busy streets, most people, be they everyday consumers, students, business men or even workers, are presumably immensely pre-occupied. They are usually walking with a focus on their destination, with no room for any extra side time to even glance at nearby window displays as they pass. All this obviously leads to the ultimatum challenge of exploring how to make displays attractive enough to grasp a busy individuals attention despite the opposing worldly factors that burden them every day and hence make their awareness of the presence of public displays quite low.

Huang et al. conducted an experiment consisting of deploying and observing how noticeable large displays can be, located in three different cities in Europe. The main scope of their study was concerned with displays that generally provide non-urgent content. They examined commercial LCDs, plasma at panel displays, front and rear projected displays, and one large electronic billboard. The focus of the study was to observe only pre-deployed displays without deploying any new ones. They monitored the activity on displays set up in various places like train stations, bookstores and many other arenas.

The study they conducted provides us with a basic overview concerning people's attention to public displays[15]:

- People subconsciously do not spend more than a few seconds to determine whether a public display is attracting their interest or not. The display should show all the necessary data in just two or three seconds so the user can perceive the information intention and benefit from it in the fastest way possible. Furthermore, it should not contain a lot of text in order to be easily apprehended and catchy.
- Displays located on eye level are more likely to be noticed. Accordingly, displays located above or below eye level tend to go unnoticed or even ignored.
- Dynamic content draws the users'attention for a longer time duration.
- Displays are more likely to be perceived and noticed when situated in the passer-by's walking direction and also when engaging it with other media objects such as posters.

Churchill et al. developed plasma posters to share information. They concentrated in their design on some more factors that they concluded would help the user to perceive the presence of the display like making the content visually attractive, and choosing display colors that can be noticed in all lighting conditions. Also, they employed large font to ensure that the display is more readable from large distances[11].

2.1.2 Interaction Techniques

Interactive public displays can be found in many shapes and forms. You can find public displays in train stations that offer attractive usability through electronic booking. Needless to say, the advertising market definitely offers the highest usage of interactive public displays that aim at adapting the content according to the targeted consumer segment. They differ from one to another in their type of interaction technique; for example: touch, voice, or mobile phone technology.

Müller et al. describe ten types of factors that affect interactivity between the user and the public display [21]:

1. Presence: The interaction depends on the extent of the users presence within the vicinity of the display. The system uses a set of sensors like cameras and microphones to collect information about the location of the user within the vicinity. An example of this experiment is the Hello.Wall [28], which is a display reacting with passer-bys by using RFID-based ViewPorts carried by the users.

2. Body Position: Body position works the same way as presence but with more precision regarding defining the exact position of the person. It also uses cameras and pressure sensors but with the aim of identifying the exact position not only the presence of the user. According to this information the system can interact with the user in a more developed manner such as controlling the information showed on the screen based on how close or far the user is to the system. For example, the system can make the font larger when the user is far from the screen and smaller when the user gets close to the screen. Beyer et al. [7] used a camera to get the exact position of the user around the cylindrical screen and hence following the user to entice him to interact with the display.

3. Body Posture: This technique intends to detect the body orientation and position as well as the way the user approaches the display and whether the user stands and faces the display or just passes by. This can be implemented by motion tracking techniques and 3D cameras. Vogel et al. presented a version of a public interactive display [33], where the study concentrated in the transition between implicit interaction such as body orientation and user proximity to the display, and explicit interaction such as hand gestures and touch screen input.

4. Facial Expression: To monitor the facial expression of the users, the installation of cameras, sensors and software within the vicinity of the display would be an asset to allow the system to detect the users psychological responses to the interactive experience. Exeler et al. deployed the eMir system whose goal was to acquire achievable standards of facial expression classification as

well identification of the users gender [13].

5. Gaze: Using an eye-tracking technique with the help of a simple webcam, it is possible to identify the direction in which the user is gazing or looking. ReflectiveSigns[22] uses the gaze detection scheme to get the preferences of the user for content in different situations.

6. Speech: Microphones are installed to record the spoken words upon the users trial and also to estimate the number of people in the vicinity of the display. Installing speech recognition systems within the public display can offer an appealing option for the user to control the content on the display using some voice commands.

7. Gesture: Experimentation with both facial and bodily gestures in response to public displays can be achieved using accelerometers, touch sensors or gaze-tracking cameras. It is possible also to use hand gestures for explicit interaction like manipulating objects and controlling the screen. The Pendle [32] is a wearable device that translates the human gestures to the system under study.

8. Remote Control: Interaction with displays does not have to be done directly especially if the display is not near the user. Remote interaction makes it possible to control the display and navigate through the system by the manipulation of a remote control. This can be achieved using mobile phones connected to the display via Bluetooth. Boring et al. developed the Touch Projector [8], which allows users to interact with it remotely through a live video image displayed on their cell phones, all the while making user accessibility a very attractive option.

9. Keys: Of the most simple and accessible methods of interaction between the user and the display can be achieved through a standard keyboard or mouse. Brignull et al. presented the Opinionizer [9] to investigate how people socialize around public displays using a standard keyboard as an interaction technique.

10. Touch: Interacting with public displays can be achieved easily through touch screens. Touch screens are from the most paramount appealing display techniques that have strong luring effects on beckoning the user to approach and get closer to try out the screen. CityWall [26] is a very well-designed example of touch interaction with public displays which not only tests the users response to touch methods, but also enticingly allows many users to interact simultaneously on a large screen.

2.1.3 Interaction Encouraging

Needless to say, nowadays people do not go out, spread through the streets and stroll the sidewalks rummaging for a public display to interact with and use. The story is of course, the other way around. The user, rather, comes across a public display during his/her daily routines. It is then the purpose of that display to steer their focus away from their usual directive routes, and motivate them, by a combination of some or all of the above mentioned external factors, to approach the display and use it [21].

Many people are held back or are cautious enough to not want to interact with public displays. They are somewhat shy to start the interaction because they feel self conscious and embarrassed, especially if there is no crowd and they will be the first to attempt the process [9]. In most cases, the situation unquestionably requires a motivator, whether it is someone or something, to encourage them to start the interaction. When people notice something new, they usually find an internal urge of curiosity to drive them to try it out, but at the same time they are too hesitant to initiate the interplay. Therefore, a motivator is needed to bootstrap the action. Once someone has already taken a step forth and attempted to try out the display, more and more people will be encouraged to engage in the interaction afterwards. It is only the phenomenon of human nature to realize that the more there are people already interacting with the public display, the more enthusiastic the other observers will be, motivated enough to take a step and attempt the same experience too. Also at the beginning of the interaction trial, people do not understand exactly what the system is about and how it works so the motivator guides the people to understand the system and demonstrates to them how they can interact with it. Upon doing that, the motivator disappears to allow the natural use of the display to take over as per the phenomenon of the honeypot effect [9].

The honeypot effect as described by Hornecker et al. [14] is a metaphorical term describing something with attractive features that grasps peoples attention and draws them towards it hence allowing them to congregate and socialize in its vicinity. Observers senses are stimulated when they see others interacting with the system and once that happens they gradually pass through a set of stages that build up their eagerness from simple attraction level to the point of taking the decision of interaction. Observing the current participants already engaging in the activity also makes it easier for observers to understand and anticipate how the system works and how can they engage with it easily without feeling too anxious to approach a trial.

Interaction with public displays occurs in many steps starting by first noticing the presence of the display, then monitoring other peoples interactivity around the vicinity of the device. Following that, the user then gets encouraged to proceed and interact with it as shown in Figure 2.2.

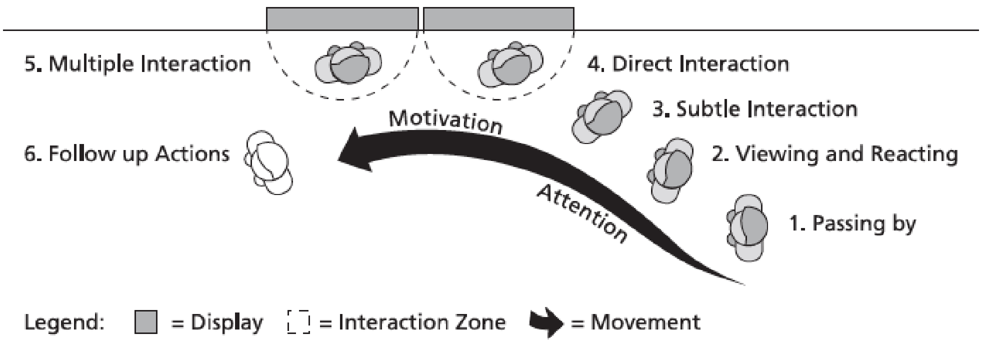

Figure 2.2: The passer-by passes by many steps from noticing the display till he interacts with it[21]

Lidwell et al. think that progressive lures can entice people incrementally to approach, enter and move through the system [19]. Progressive lures also may help in creating the honeypot effect but the success of the phenomenon also highly depends on the physical setup of the system. If there is enough space around the system for participants and observers, without hindering its accessibility, then it will consequently be much easier to create the effect [14].

One more factor to encourage people to interact with public displays is by decreasing the barriers on how to use the system. The use of public display should be made efficient and users should be able to use it successfully with minimal effort. Huang et al. perceive that creating a system with a user-friendly accessible manner will definitely make it more likely to be used in daily life. If the system is complicated, time-consuming or if its functionalities are not evident, users will not feel encouraged to use it or interact with it [16].

The simple notion of shops making advantage of digital interactivity can also be successfully applied in the shop window displays, by presenting the popular and attractive products at the entrance which would therefore attract people to enter the premises. The same theory should be also be adapted in public displays by displaying attractive content that may attract the user to engage more with the display [14].

Müller et al. conducted a study [24] in which they discovered that the directed advertisement in the web applies the same for digital signage and public displays. Many people tend to expect that the content of the display would be uninteresting and, hence, ignore it.

Having discussed the different interaction techniques and previously conducted studies, it can be undoubtedly stated that people take the decision whether to interact with the system or not according to a combination or set of factors. According to Brignull and Rogers [9], they considered the main factors that affect people's decision about engaging in the interaction or not to be the following:

- The duration of their time that the process will consume.
- The benefit the user will get from the interaction.
- The steps that the user has to follow in order to interact.
- If the experience will be comfortable for the user or not.
- If the user has the ability to stop the interaction easily and quickly without disturbance to anyone.

2.1.4 Examples

Brignull and Rogers created in [9] a system called Opinionizer which consists of a big public shared display on which participants can share their opinions. They can input their comments by simply typing them up on a keyboard, and these comments are then projected later on a wall display. The main objective of the Opinionizer is to function as a public opinion sharing system and to enable strangers to mingle and socialize together by breaking the ice between them as they interact to use the device. For instance, in a welcome party where, naturally, there will be a large crowd with a lot of unfamiliar faces, this type of system would work perfectly to allow the newcomers to exchange opinions and talk to each other immediately, hence minimizing awkwardness. The design included a laptop for participants to input their opinions about a question which was projected on a big wall in user-friendly and appealing colors.

To make the whole system enthusiastic enough to urge interaction, participants are provided with a collection of small cartoon avatars and speech bubbles in order to add some personality to their opinions. To add more personalization to the process, they are also given the option of choosing nicknames to label their opinions. The screen was divided into four sections according to the background of the participants and they can then enter their avatar in the respective section whether student, designer, softie or techie as shown in Figure 2.3. For extra guidance, the application was also accompanied by an assistant who stood next to the laptop in order to explain to the users how the system works, answer any of their queries, as well as to encourage them to interact. The system was tested in two different events, a book launch party and a welcome party for postgraduates entering a school at a university.

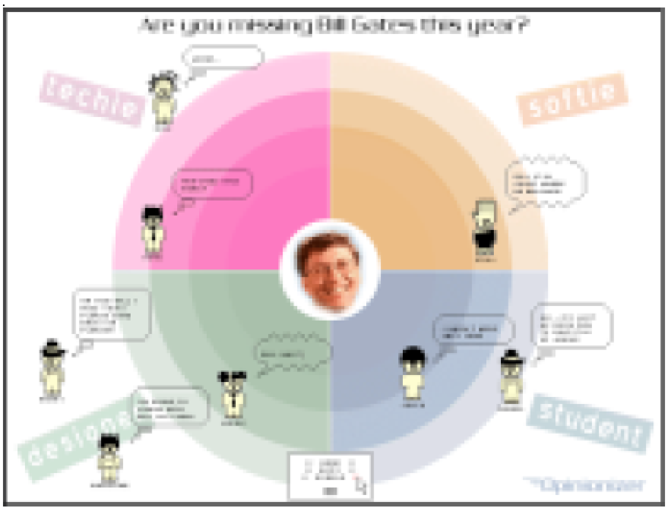

Figure 2.3: Screen shot from the the Opinionizer System[9]

Another presentation of an interactively experimented public display application is the Plasma Poster, developed by Churchill et al. in [12]. This conducted study is, essentially, a plasma display with interactive overlays in portrait orientation that support interaction through touch technology. The arrangement was set up and tested in public areas to enhance and simplify multimedia information sharing. Underlying the Plasma Posters is the Plasma Poster Network which is a client-server system that provides content parsing, management, hosting and distribution. From the conducted investigation it was clearly observed that another main concerning factor for user interaction with the screen is allowing easy content authoring, publishing and modification on the application.

Moving on to yet another observational study, it can be said that CityWall, made by Peltonen et al. [26], is undoubtedly another innovation that fits the criteria. CityWall is a large multitouch screen installed amidst the bustling city center of Helsinki in Finland. It allowed identification of as many hands and fingers as can possibly fit the screen at any time instant. It has a high-resolution and high frequency camera that can process up to 60 frames per second. Moreover, a computer-vision-based tracking is found to be embedded in the system. The appealing quality found in this type of tracking technique is that it works in such a way that is adaptable to changing light conditions. The CityWall experiment aimed to support interaction of all types of users and age groups including children and seniors. It was suitable for navigation of media in general and in particular photos. It was observed that a very significant motivation for users to interact with the system is the ability of the system to have multiple users interacting with it at the same time, which was one of the vital reasons yielding to the success of the CityWall. Users generally consider it to be far more fun and engaging to use an application with the ability of sharing with their friends and other users. Moreover, this also helps in decreasing the feeling of awkwardness or embarrassment since it avoids having one user at the center of attention while others are just standing around watching the procedure.

Last but not least, Müller et al. created the ReflectiveSigns mentioned and discussed in [22]. It is a context-aware public display that adapts to the attention of the audience in different contexts. It consists of four displays and was deployed and studied in a university department for a duration of two months. The system consists of four components: face detection software, MySQL database, Java-based content scheduler and a Java-based content player. Videos, images and mixed content from various genres and categories were shown on the display. Initially, all content was displayed in a randomly equal manner. Installed cameras and the face detection algorithms were implemented to detect whether someone was watching the screen at any particular moment. The view time duration, date and time stamp, and screen location corresponding to specific displayed content are stored in the database. According to this acquired and stored information, content is displayed again in a non-random pattern, and with varying time duration corresponding to the detected user reaction patterns. Hence, through this procedure, the screen learns how to better grab the attention of the user by displaying the relevant data that he/she wants to retrieve and has interested him/her in the first place. The most important observation made from this experiment was that it is more about where the display is situated rather than the contained information itself.

2.2 Advertising

Advertising is all about delivering the informative message desired in such a way that will grasp the audiences senses and hence attract their attention in the fastest way possible. Consequently, ensuring that the purpose has been delivered and settled in the users mind [29] should not be a dilemma. A long-lasting impact is hence, undoubtedly guaranteed.

The advertisements delivered to the users should be tailored according to their needs and wants. When conveying a certain message, it is necessary to purposefully customize it in order to suit the target audience in such a way that they perceive it in the way that would entice them most. Another element to put into consideration is ensuring that the advertisement does not portray any content that will be apprehended negatively by the audience or provoke them and thus cause an adverse reaction on the marketed product. On the one hand the target and purpose of the advertising company and corresponding product must be met, but on the other hand it goes without saying that living up to the expectations of the consumers and their needs is an asset to any promotion design or marketing campaign. The perfect scenario would be to match the promotion content to the style and environment that would maximally attract the customers needs, while altogether ensuring that this happens in the appropriate environment and the proper timing that will yield the ultimate impact. In addition, providing the user with an appropriate user-friendly way to interact back and respond to the advertisement is one of the critical challenges to consider.

2.2.1 Pervasive Advertising

Since computers first appeared, three phases have been passed throughout their evolution. The first phase is known as the Main Frame, which is when only one computer was shared by many users. Following that came the Personal Computing phase, named after the individual computing space given to each person working at a separate computer station. Third and last came what is known as the Pervasive Computing phase [34] in which every user can use as many computer and devices as required.

Nowadays, almost any device, from tools to appliances to home equipment to cars, can be embedded with chips to connect it to a network of other devices. Pervasive advertising is the concept of using pervasive, or in other words widespread, computing technologies in advertising purposes. Currently, social networking platforms like Facebook, MySpace, Google+ and LinkedIn have become extremely widespread globally. With the evolution of such social networking media, people are daily encouraged to share a lot of personal data such as their biographical information and personal preferences that include favorite movies, interests, groups they belong to and associate with. Moreover, career information is also exchanged, for instance their curriculum vitae and professional interests. The personal data that such sites hold goes far beyond the age, sex, and location of their users [30].

Such a wealth of personal information encouraged companies and advertisers to profusely consider the prospect of pervasive advertising. Interested companies can easily contact Pervasive Service Providers which run many advertising environments like TV, Internet and newspaper media. They also hold plenty of information about the users that they acquire through their running social network. Their role then, simply becomes to present the appropriate advertisement to the right audience in the right time via the right device (e.g., TV, radio or mobile, etc.) and to consequently support their customers with an efficient manageable way to follow up the advertisement and its impact. In the past, advertisers had to contact each advertising media like TV or radio separately which was an inconvenient hassle in terms of monitoring [29]. Therefore the penetration of pervasive advertising into the marketing undeniably offered a much more adequate way of information sharing and widespread media marketing.

Having discussed the elements of pervasive advertising, it assuredly goes without saying that this new technique has many advantages over traditional advertising. Müller et al. listed these advantages [20], and the following list includes some of them:

1. *Power to the people*: In traditional advertising, advertisers offer their promotion to the customers making the customers only given privilege is to choose to ignore it. The power is concentrated in one hand, as it is only the advertising agency which has the upper hand in decision making, hence rather than serving the customer first and foremost, they cause consumer demotivation by making them feel that theyre under the mercy and control of the advertisers. Thanks to the interactivity in pervasive advertising, now people have the power to communicate their ideas to the advertisers and respond to advertisements in the way that best serves their desires and needs. The relationship has now become mutual and interaction has developed into a two-way street rather than just a one way road. This is an improvement for both parties involved because the communication channel offered has built a more trustful relationship between advertiser and customer as well as a richer exchange of information.

2. *Me, Too*: Pervasive advertising is an automated process, in which the individuals' contributions are a very significant element without which the purpose would fail. This evidently puts smaller companies in a more advantageous position because they have the ability to design their own campaigns with less time, effort and money.

3. *The Wow effect*: Because pervasive advertising is more like an experience

and not just an advertisement and because it benefits from the accessibility of reaching the customer anywhere they are, it offers the attractive option of surprising the user new and unexpected things, such as offers and promotions, at unexpected timing. Displaying an advertisement that is related to what the user is thinking of or interested in would surprise and interest the user far more than a generic random advertisement would.

4. *Just for Me, Just for Now*: One big advantage in pervasive advertising over traditional advertising is its very user-personalized nature. In traditional advertising, there were only few factors in which context can be user-adapted, e.g., demographics. However, with pervasive advertising advertisements can be personalized and the gradually the system learns to understand the users patterns and gathers information about their preferences, thus making the whole process acquire more intelligent skills with time.

5. *Did You See Me?*: It is very important to measure how the audience interacts with the advertisement because with the results of the acquired measurements, adaptations and modifications can be developed to improve the quality and content of advertisements to ensure that they are more effective and specifically customized for the user. In traditional advertising, the measurement tools were not very effective like Google Analytics, but with pervasive advertising more measurements can be captured and analyzed such as where the user is looking and when did his eyes and attention drift from the advertisement by using Computer Vision and other audio-visual techniques.

2.2.2 Public Displays and Pervasive Advertising

As discussed earlier, Public Displays have presently become widely adapted to, used, and deployed in many areas. They have become popularly booming in the market, similar to the entrance and evolution of mobile phones in the telecommunication field. The main challenge with public displays is how they can be designed and deployed to be smartly cost-effectively funded. Of the topmost applications that can gain high revenue from public displays is using them for advertisements and marketing. Logically, if public display interactive promotions were designed successfully, high consumer interest would be triggered and therefore a tremendous flourish in the associated product sales. However, the problem that is currently being met, is that the advertisements are all static which doesnt lead to the revenues hoped for. Static advertising lacks the spark that interactive marketing ignites in the customer. Studying the customers pattern makes it more than obvious to conclude that user always desires the element that will grasp his sense and attention, leading him to stay for the advertisement and enjoy the process. This is the main motive behind the desire to start eliminating unattractive static displays and exploring new interactive methods as the ideal solution for the problem at hand.

To conclude the discussed discoveries, it can be confidently stated that Public Displays can be an integral component of the Pervasive Advertisement methodology. When public display are connected to the Pervasive Service Provider, presenting the appropriate advertisement in perfect timing should not be any longer a challenge. Interacting Advertisements are one of the vital techniques that can be employed in the Pervasive Advertising process [29]. Müller et al. discovered that the selection of the right location of the display is more important than displaying the right content and that this is one of the most critical elements to study when it comes to Pervasive Advertising [22]. With public displays located in many places it is undoubtedly easier to show people the desired content in the most convenient places.

2.3 Key Performance Indicators

The term Key Performance Indicators (KPIs), is used to define the standard set of measurements that help people set a benchmark to monitor the progress rate and success of their goal achievement. It is the unit used to measure the advancement towards specific set targets for any given projects. When it comes to the marketing field, KPIs acts as one of the strongest set of criteria that can be meticulously used to measure the success of advertisements. Some of them are just simple and basic indicators, however, the future indicators are predicted to focus on measurements regarding the mental attention that the promotion or marketing projects succeeds to attract.

2.3.1 Traditional Indicators

Traditional basic indicators are a set of factors that already exist and are easy to observe, monitor and measure. Listed below is a briefing about some of these basic indicators:

- Clicks: This indicator is used in measuring website and Internet advertisements to get the number of clicks that correspond to the acknowledgement of a certain online advertisement.
- Lead: Similar to the 'Click', it is also used in Internet advertisements. This indicator aims at getting the number of mouse clicks it takes to lead the user to reach the desired website or online advertisement.
- Conversion Rate: This method is used to calculate the percentage of persons that stopped by the advertisement to the total number of persons that originally passed by it.
- Sales: An indicator used to measure the sales of a product and/or organization achieved via a certain marketing campaign.

2.3.2 Cognitive Indicators

Cognitive indicators are concerned with the mental processes that take place in the users mind when he/she notices the advertisement. Such mental stimuli involve measures such as how his emotions moved towards the advertisement or what was his attitude towards the brand upon catching sight of the advertisement.

The fundamental cognitive indicator that concerns our study is known as recall and recognition. Recall and recognition are two indicators widely known to measure the awareness of and interaction with an advertisement or a specific product. Recognition is the ability to recognize previously known things and it is perceived as a direct technique while recalls needs to access the memory for information retrieval [27].

Recognition involves tasks like figuring out the correct answer given a set of possibilities in a multiple-choice test. Such a measure of recognition is evidentially perceived easier by users than having to pull out answers out of their head in a fill-in-the-blanks test. The latter is the case with 'recall'. It is therefore asserted that recognition is a much easier comparative indicator than recall.

Recall and recognition are both important properties of an advertisement campaign since they reflect the interactivity of pervasive advertising. If public displays cannot communicate this interactivity, they will lose their purpose of acting as an appealing media and will fail to fulfill their intended marketing goal [23].

The effect of engagement in other external stimuli on recall and recognition of public displays

When it comes to questionably investigating the wether engagement in other external stimuli has an effect on hindering the recall and recognition process of public displays, Norris and Colman took the initiative. According to the reference, an experiment was conducted to inspect the relation between recall and recognition on one hand versus the preoccupation of the person on the other hand [25].

According to the hypothesis of Soldow and Principe [31]:

> *"When an absorbing article in a magazine is read, it is unlikely that ads separating parts of that article will be noticed when the reader flips through the pages to find various points of continuation of the article. On the other hand, when a magazine is casually glanced throughe.g., in*

> *a waiting roomadvertising that separates editorial parts is much more likely to be attended to. It could be said that in the former situation the reader is highly involved in the editorial content, and in the latter situation the reader is uninvolved in the editorial content" (p. 59)*

Norris and Colman proved the validity of the hypothesis by conducting an experiment in Leicester University. The participants were 73 undergraduate psychology students. To start off, each were given copies of a magazine to read and this magazine included six advertisements. Upon reading the magazines, the participants were questioned about the advertisements that were featured in the magazine. It was concluded that the higher the involvement rate in the topic the less the concentration in the advertisements which are in between. When the topic is boring and not of interest to the reader, higher concentration in the advertisements is noted [25].

The same theory would logically apply to public displays in the streets: Whether the person passing by is in a hurry and wants to catch a bus or is busy with reading a message on their cell phone or preoccupied with thinking over a problem or concern, the end result is more or less the same. The advertisement will fail to catch the users attention and their pre-occupation will obstruct their concentration on the public displays, all leading to the advertisement passing by unnoticed. One additional observation is that in the cases that the public display's existence is noted, the content of the display will not be recognized and remembered.

Measuring Recall and Recognition

Alt et al. reported that the following three types of studies can be conducted in order to evaluate user recall and recognition [6]: descriptive, relational and experimental studies. The main goal for descriptive studies is to describe what is going on in a certain situation, like CityWall by Peltonen et al. [26], while not necessarily providing any hypotheses for a predicted pattern.

The second type of analysis is the relational studies, which aims to explore the relation between some factors and their effect on the associated experiment. Last but not least are the experimental investigations that function by depending on a base hypothesis and always tend to include more than one prototype and a comparison between them. Müller et al. offer an example of an experimental study referenced in [23].

With recall and recognition being the main performance indicator concern, Norris and Colman created a set of measures to test and verify the degree to which users could remember the content of the advertisement in a given magazine [25].

1. *Free Recall*: The participants were asked to write down what they remember about the brand names, product types and advertisements.

2. *Recognition of Product types*: The participants were shown a list of 48 product types and were asked to choose the six products featured in the advertisements.

3. *Cued recall of brand names*: The product types were written down and the participants were asked to recall their corresponding brand names.

4. *Recognition of brand names*: For each product type, five possible brand names were listed randomly including the right one and participants were requested to choose the right one.

5. *Recognition of advertisements*: The participants had to pick out the six featured advertisements from a set of 18 various adverts showing similar product types with unfamiliar brand names.

The measure mentioned above perform much validating results when implemented in the same order presented above because the latter measures offer solutions to former ones.

2.4 Kinect Software Development Kit

Kinect is the motion sensor of the Xbox 360 created by Microsoft to be used in the game console. It allows the interaction between players and the Xbox 360 without touching or using any devices, but it uses body motion and gestures instead. The innovation was released in the beginning of November 2010 and by mid June 2011, Microsoft released the Kinect for windows, which allowed users to use the Kinect to program applications for windows systems. The current version of Kinect SDK is version 1.5 which was released earlier this year starting May 2012. Of its attractive advantages, Kinect SDK allows developers to create applications in C#, C++ and Visual Basic.

2.4.1 Kinect Architecture

The component architecture of Kinect consists of camera and a microphone array accompanied with software for processing color, depth and skeleton data. Figure 2.4 illustrates the architecture of the Kinect for windows.

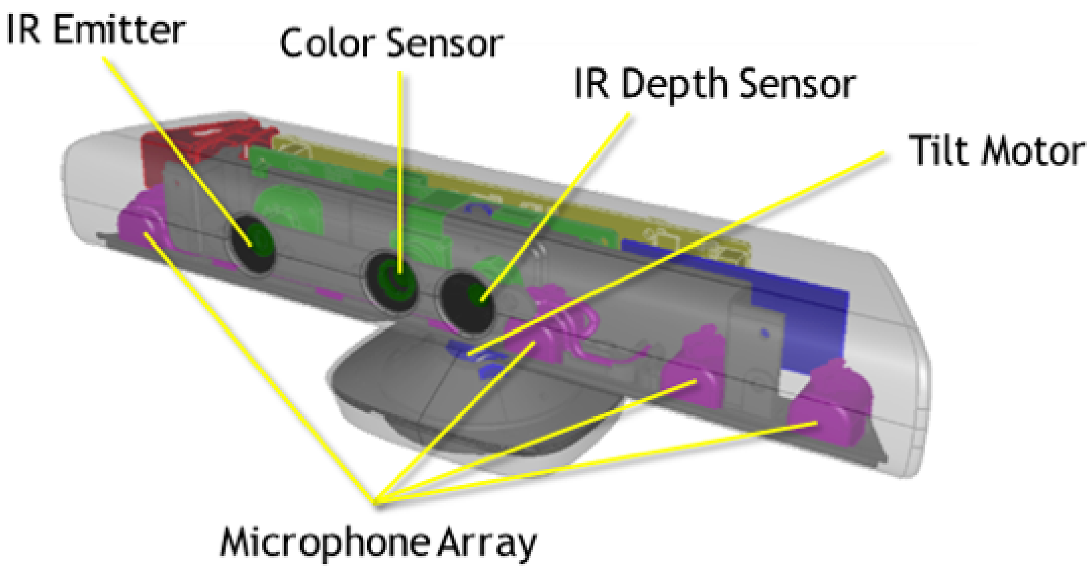

Figure 2.4: Kinect for windows contains IR Emitter, IR Depth Sensor, Color Sensor, Tilt Motor and a Microphone Array[3]

It can be seen to have three lenses, from left to right: IR Emitter, Color Sensor and IR Depth Sensor respectively.

- IR Emitter: This device emits infrared rays in front of it, which are reflected off of objects in its path.

- IR Depth Sensor: The infrared rays are transmitted back from the objects to a sensor which calculates information regarding depth.

- Color Sensor: It is a color camera, which can record with 15 frame per second at resolution 1280x1024, or 30 frame per second at resolution 640x480.

Kinect can currently only work with standing players. It has still not yet been developed to work with seated players, or if attempted, does not live up to the expectations of the awaited results and performance. Moreover, the Kinect can work in two modes, the default mode and the near mode. The tracked distance and unknown are shown in Figure 2.5.

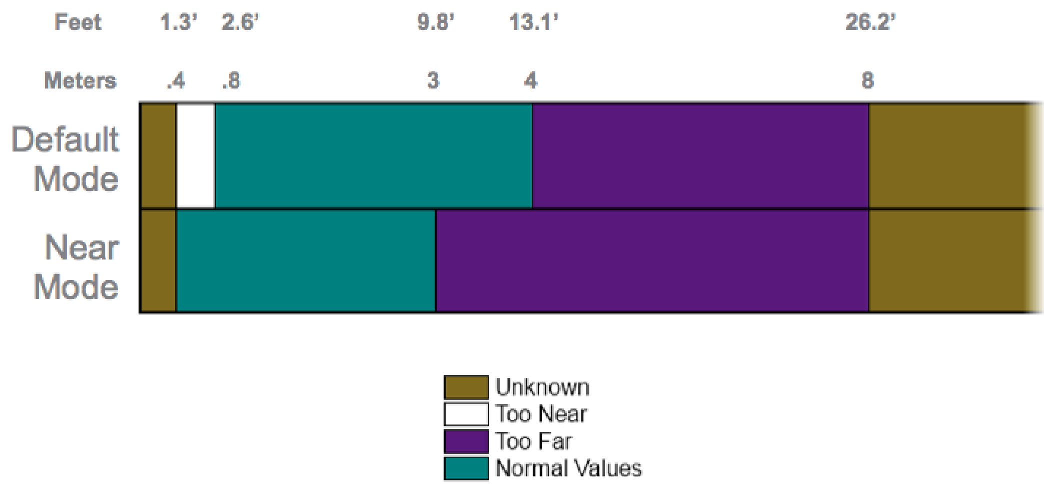

Figure 2.5: Kinect can work in the default and near modes, but with different distances[2]

2.4.2 The way Kinect works

The IR Depth Sensor returns the distance and player information for each pixel. Which means if we are using resolution 320x240; so we have 76,800 pixels, each one with distance and player information. The distances are returned in millimeters. Kinect can detect up to 6 players as a maximum. In order to receive the player information the skeletal tracking must be enabled. For each pixel we have 16 bits of data, 13 bits for the distance information and 3 bits for the player information. In order to extract the depth information and the player information we use the following formulas.

Listing 2.1: Getting depth & player information

```
int depth = depthPoint >>
                DepthImageFrame.PlayerIndexBitmaskWidth;
int player = depthPoint &
                DepthImageFrame.PlayerIndexBitmask;
```

The skeletal tracking can track maximum two skeletons. There are 20 joints that are tracked per tracked player in the default mode, while in the near mode not all the 20 joints are tracked. By tracking the joints it is then possible to acquire knowledge about the exact position of each of these 20 joints in addition to the depth information.

It cannot be forgotten to mention that the tilt motor in Kinect gives the user more freedom for the interaction space, as it can tilt ±27 degrees in addition to the 43 degrees range that is initially the normal coverage area for the sensors as is illustrated in Figure 2.6.

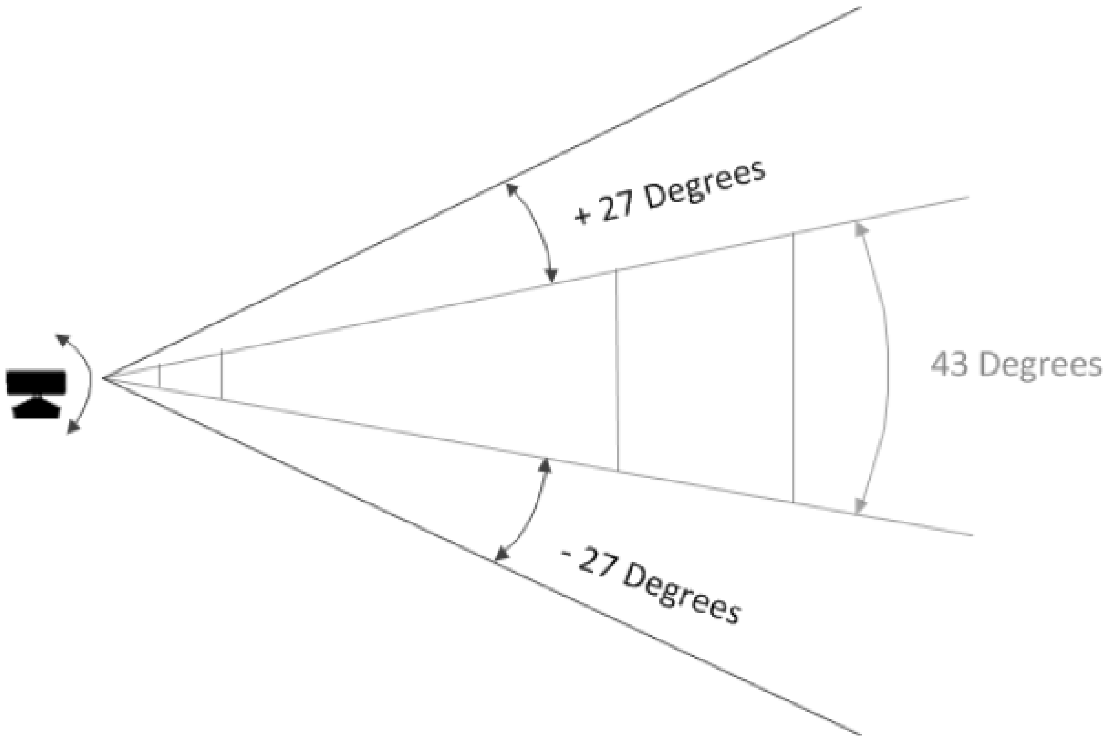

Figure 2.6: Kinect covers 43 degrees and can tilt up to 27 degrees in both direction[1]

Chapter 3

Concept

This work aims to investigate and understand the effect of using interactive public displays. The main question of research is whether the people will better remember the content displayed on the screen if they interacted with it. The main KPIs to evaluate this were the cognitive indicators, especially *Recall* and *Recognition*. Hence, the purpose of this thesis is to investigate the effect of interactivity in public displays on the recall and recognition of people.

3.1 Todays solution of Public Display

You can find the public displays of today located in many places, such as in airports, train stations, downtown, city malls, food courts, shops, exhibitions, and many other places and for various purposes, as demonstrated in Figure 3.1. Public displays are now becoming more commonly used and deployed for a wide variety of purposes. They are deployed for advertisements, information displays, and recreational purposes, among other things. However, currently popular public displays are mostly static and their content is text, images, or a video. Since they are mostly static, user interaction is not supported and is still a research question being investigated.

Figure 3.1: A public display that represents the current solution of public displays [4]

3.1.1 Problems and Pitfalls

The major problems of current displays are their limitations. In other words, the user is only limited to look at what is already displayed. However, the user wants to feel that he is in control of the display and can interact with its content, but current static displays do not offer such privileges for the user. The user is obliged to only watch the displayed content, which is a drawback and a limitation, and will result in the user getting bored and uninterested faster in the display.

Static displays are limited to only display some advertisements, information and news, and this stays the same for all the users irrespective of their interest. That may be a major drawback in static displays as the interests of different people vary; some people would be interested in certain content and others in other content. Such user customization is not possible since we do not have a technique deployed to inform us about the user in front of the display and his/her interests and what would be interesting to him/her and what would not be.

3.2 Factors

Interactivity in public displays can be affected by so many factors; some of which have a major impact, while others have a less significant impact. These factors or dimensions should be observed and considered due to the impact they have. The dimensions will affect recalling and recognizing the contents of the display. We will investigate some of the more important factors that are considered relevant, as we cannot discuss all the known factors in detail and depth.

3.2.1 Interaction Technique

As discussed in Chapter two, many interaction techniques exist between the user and the public display. The interaction technique deployed may help in recall and recognition but also may have no effect whatsoever. Some interactions such as presence may not assist in recalling the content on the display, as it depends on the presence of the user in the vicinity of the display and by the aid of some sensors or cameras it can chose the content to be displayed on the screen. The user may not be able to relate his presence to the customized change of content on the screen. Hence, it may be of no significant impact. Other techniques similar to presence are body position and body posture. These are more advanced than presence because they measure other factors in depth like the orientation of body and how the body approaches the screen and so on.

Facial expression, gaze, speech, gesture, remote control, keys, and touch can be of more impactful use as interaction techniques for public displays. With such techniques, the user can easily identify or relate his movement or speech to the change that occurred on the screen. Hence, this would in turn more likely increase the chances of the user recalling the displayed content. Discussed below are some interaction techniques that are usually used in public displays.

Non-interactive

Non-interactive screens are the basic trivial ones which do not allow any possible interaction and are the ones used normally nowadays. With such screens, the user is obliged to watch whatever is displayed to him whether that is video, text, or picture. He can only watch the content displayed on the screen but cannot adjust its content according to his needs or interests. Moreover, no information can be collected either about the user experience, interests, or satisfaction.

Touch-based input

Touch-based input screens are of more importance than basic static ones as they empower the user with some control over what is displayed on the screen as shown in Figure 3.2. This may encourage the user to interact with the screen and increase his level of interest. The screen and its content are more engaging for the user as the user is now capable of controlling its content and changing it to another with more interest for him. Such screens are widely spread now in some domains such as in airports to present dynamic information for passengers and so on. The limitation of such technique is that these displays must be equipped with sensors to be able to collect the input of the user: the user touching the screen. An advantage of the touch screen is how it increases the intelligence of the system, since it can now collect more information about the user who already interacted with the screen and can easily provide numeric information on the number of people who are interested and interact with the screen. Information about how they interact with the screen and in which categories, and hence information on their interests can also be collected using such technique.

Gesture

Using gestures as the interactivity technique is a new trend that is becoming more commonly used in many devices like in Xbox[1], but is not yet widely used in public displays since it is still a relatively new approach. Gestures can be tracked through

[1]Xbox is a video game console manufactured by Microsoft

Figure 3.2: Touch screen deployed in Hard Rock Cafe in Barcelona, Spain

several techniques; maybe through optical flow or using the Kinect device. The advantage of such technique is that it enables the user to interact with the public display naturally just with his movements and gestures, and without using any devices or touching any screens. This makes such a technique more natural and interesting for more users and makes the display more easily accessible.

3.2.2 Interactive Items

The degree of engagement of the user in the interaction with the public display should assist in better remembering the content or not. Hence, if the screen is totally interactive this implies that the user may be engaged more, while if not all the items are interactive this may reduce the degree of interactivity and therefore the engagement level of the user.

All items are interactive

Having the system fully interactive may present the user with a better experience and may lead him to be more engaged with the screen. Consequently, this may result in a longer time of interaction. The longer the user interacts with the screen, the more likely he can remember the content on the screen.

Only some of the items are interactive

Having only a few of the items interactive may lead to less interaction. Therefore, this may reduce the interaction duration and that may negatively affect how the user will recall or recognize the items that were shown on the public display.

3.2.3 Previous Knowledge of Content

A further factor, that may affect the recall and recognition in public displays, is whether the user already has previous knowledge of what is displayed on the screen or whether it is entirely new content for the user. It is simply easier for users to remember the things they already know. While sometimes it is easier to remember new or previously unknown information because it is new for the user and may catch the attention of the user so he will be able to remember it more easily.

3.2.4 User Situation

User can encounter public displays in many places, may be in metro stations or in the streets. That makes another factor which is the user's situation, whether he is in a waiting situation or he is just passing by the display. In the waiting situation the user may want to kill the time so he may engage more with the display. While passer-by's are in a mission and have a target that they are going to, so they may ignore and do not even interact with the display, and if they did interacted they will only interact for a few seconds and then, they will go on and complete their trip.

3.3 Research Question

This thesis aims to identify the impact of the interactivity on the recall and recognition for public displays. Some factors may affect the ability of the users to remember the displayed content better while others may make no difference. There is certainty regarding which may increase the users ability to remember more of what is displayed on the screen and hence the need for an investigative study. Some factors may make the user more engaged and interactive with the screen while others might result in less engagement, and others might make no significant difference. For such purposes, a study has been conducted to investigate this more thoroughly.

3.3.1 Hypotheses

According to the dimensions previously mentioned, three hypotheses are presented concerning recall and recognition. We are aiming to investigate these hypotheses with the study presented later.

Hypothesis 1: Interactivity increases memorability

The first hypothesis (H1) presented is that interactivity increases memorability, because interactivity makes the user more engaged with the display. Therefore, the user will invest more time and attention to it so he is more likely to remember what was shown on the screen. By assessing how much the user remembers the screen content, we are targeting how much the content is recalled and recognized.

Hypothesis 2: Interactivity with an item itself increases the memorability

The second hypothesis (H2) presented concerns partial interactivity of the screen (only some of the items are interactive). The interactive items are more likely to be remembered than the non-interactive items. This is because the user has interacted with them so the user may remember them more significantly while the user did not care too much about the static items on the screen because they are of less interest to him.

Hypothesis 3: Waiting situations have more influence on memorability than passing-by situations

The third hypothesis (H3) presented is that waiting situations, when user has nothing to do and just want to kill time, have more influence on memorability than other situations when the user is just passing on front of the display. That happens because usually people do not like to wait for anything, so they have nothing to do than interacting with the display may be even if it does not attract them. While, its more unlikely that people will stop by a public display to interact with it if they are on their way to work or to a shop or any other trip they may be doing.

Chapter 4

Prototype

This chapter is dedicated to the description and discussion of the prototype that was made in order to tackle the previously raised research question. The prototype that suits well was the implementation of an interactive game using c#. The interaction technique had to have the ability to capture colored video frames, depth videos, had to extract players from the surrounding scene and most importantly track the movement of those players. Thus, the Kinect was found very suitable; especially that it can track up to 20 different joints of the human body.

In order for this prototype to fulfill its purpose, it had to be simple and user friendly to hereby encourage user interaction without the need of any external helper. So the prototype was implemented with the least possible complexity. The user should be able to discover the interactivity without help.

In the following there is an illustration of the structure of the prototype. The main parts are listed and their connection to each other is explained. Furthermore, there is a discussion of the used implementation methods and techniques. Finally, an explanation of how the data were logged and stored was presented.

The prototype is called Bubble Game, shown in Figure 4.1. It is a game in full screen mode. Initially, Bubbles are generated at the bottom of the screen in random x-positions. In each bubble, there is a figure of either a fruit or animal that seems to be inside that bubble. Basically, the bubbles fly vertically from the bottom to the top of the screen and eventually they disappear from the top edge of the screen. They randomly fly at different speeds and in different directions, to the right or left or straight ahead. There is also a certain depth value to the position of each bubble which enables bubbles to overtake and/or pass behind each other.

4.1 Architecture

Kinect is connected to the game and the color camera, depth camera and skeleton tracking are all enabled and started. Using Kinect a depth image is generated. Its a transparent image with the silhouette of the extracted players. There is always one silhouette in black while the rest of the extracted silhouettes are green. The player in black is the active player and gets tracked using the skeleton tracking functionality as seen in Figure 4.1. The player should pop the bubbles seen all around the silhouette. This is achieved by moving any of the two hands and/or the feet to the position of the bubbles.

Three actions take place as soon as a signal is sent to a bubble to be popped. The bubble stops in its position and it fades out till it disappears. Meanwhile, the fruit or animal that was previously inside the bubble falls down at an accelerated speed, whereas the acceleration increases the more the fruit or animal gets closer to the bottom of the screen. Additionally, the sound of popping is played each time a bubble is popped.

Kinect can capture up to 30 frames per second. Each captured frames carries a lot of data regarding the players that are detected in the scene as well as the depth distance to all the points in the frame. Linking the detected player in a frame to that same player being detected in the following frame was a bit challenging. To solve that problem a variable was added. This variable acts like a clock; it keeps

Figure 4.1: Screenshot of the Bubble Game in action, a player is popping the bubbles on the display

getting incremented as long as no player is detected. If the value of this variable exceeds a fixed, given value then the player to be detected next is regarded as a new player otherwise the player is assumed to be the same player that was detected in the previous frame. Based on experiments, the time buffer of three seconds was found most accurate in switching to another player.

A class called *Bubble* was implemented to hold all the information about each bubble. The class includes an ellipse with the bubble picture as a texture, another ellipse with the picture of a fruit or an animal also as a texture, but with a transparent background. Other attributes of the class are the moving direction of the bubble, the timestamp of the generation of the bubble, the timestamp of its popping and of its total disappearance, an ID in addition to the ID of the picture it includes. Figure 4.2 shows an example of how a bubble looks like.

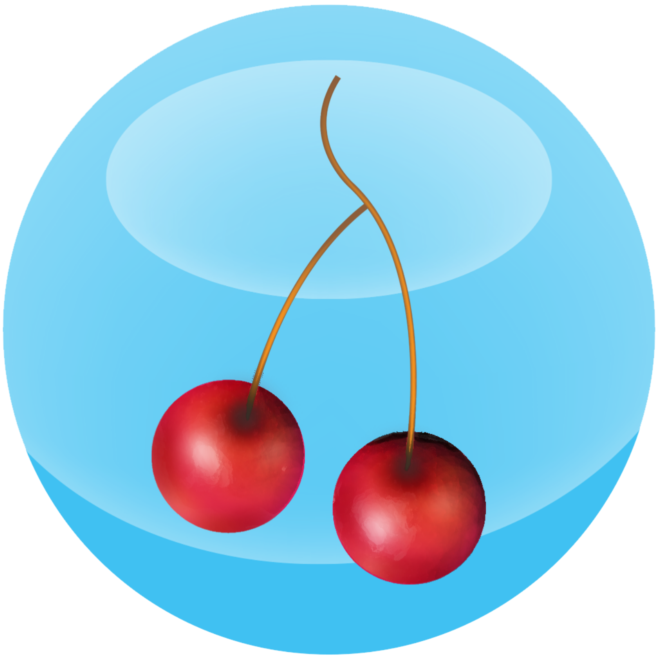

Figure 4.2: A bubble picture with a cherry as an item inside it

Another important class is the mClick class. This class simulate a mouse click. So any movement in the display using the Kinect is transformed to an mClick. This class contains the x and y positions of the click and a Boolean flag. If the Boolean flag is true the click is treated as a true click and if the Boolean flag is false then the click is not regarded as a real click and is not to be treated like a mouse click. The flag is set in a special method that tests the click. So each movement is checked using that method and accordingly the Boolean flag is set or reset.

A third class is the Player class. It holds all the information about each player, the players ID, the time of interaction for that player, the start and the end of the interaction, how many bubbles were popped by this player, the types of the popped bubbles, how many bubbles were already generated when the player got active, the distance between the player and the display and finally the total duration for that player to notice each bubble.

The player class was essential for the creation of the Log file. A vector of players was generated and at the end of each session all the data and attributes of each player are written into a file.

Simply, there is a Canvas as the container and everything is added to it. The canvas adjusts its height and width dynamically as to be of the same dimensions as those of the screen. A Kinect sensor chooser is added to the Canvas. Its task is to choose the available Kinect device and upon completion of its task, this sensor chooser goes invisible. Finally a frame containing the depth image is added to the screen.

Additional hidden components were added to the application for testing purposes. These include a color viewer for the Kinect and a skeleton viewer. Also, three hidden sliders were added to the application to enable the adjustment of the maximum number of bubbles that can be displayed on the screen, the angle of the Kinect and the scaling ratio of the depth image shown on the screen.

4.2 Implementation

After the initialization and after all parts are loaded the application prepares for the session. Each session has a unique session identifier. The application keeps track of that number by writing it into a file. At the beginning of a session the number of the previous session is read off the file, incremented, set to be the session identifier of the current session and written into the file.

A StreamWriter is created to hold the log file of the session; its identified by the session identification number, time, and date of creation. Furthermore, the application keeps track of the time of start of the session for calculations like the duration of the session. Finally, the background texture is initialized and added to the Canvas.

For the creation and movement of the bubbles on the screen a DispatcherTimer is used. That is a timer with a predefined interval. Accompanying the DispatcherTimer there is a method that specifies what is to be done when the timer is set. The application creates two DispatcherTimers, the first one generates bubbles at random interval that varies between one and two seconds and the second one moves the bubbles that are on the screen at an interval of 150 milliseconds. At the beginning of a session both timers are started.

The last part in the loading process of the session is to call the Kinect sensor chooser to start scanning for connected and active Kinect devices. This is done by specifying an event method that changes the Kinect sensor used. In the occurring case that no Kinect is connected and then a Kinect gets connected, the Kinect sensor will change from null to the new sensor that was detected, which will then call the mentioned event method.

When the DispatcherTimer that is responsible for the generation of the bubbles starts, the program invokes the handler on the timer. The handler then starts to generate bubbles under the condition that the total number of bubbles on the screen doesnt exceed the maximum number of bubbles allowed to simultaneously be on the screen. As mentioned earlier, this upper limit can be set through the sliding bar.

The handler then creates an ellipse with fixed height and width and includes the texture of the bubble. It also creates another ellipse with the same dimensions but fills it with the texture of either a fruit or an animal; this will be explained in more detail further on. Each bubble is given an identification number. The initial position of the bubble is determined as follows: the y-position is fixed to be the bottom of the screen and the x-position is generated randomly. The depth of the bubbles position, the z-index, is also generated randomly. The ellipse with the texture of the bubble is set to always have a z-index deeper inside then its corresponding ellipse textured with the fruit or animal. After the creation of the bubble, it is added, in the form of two child Canvas to the main Canvas.

A HashTable of type Bubble is created in order to keep track of the bubbles that are active. Each created bubble is added to the HashTable. And when a bubble is popped or gets out of the top of the screen, it is then deleted from the HashTable. So the total number of bubbles on the screen is retrievable at any time simply by getting the size of the HashTable.

Finally, the DispatcherTimer is stopped. The interval for it to start again gets randomly redefined to continue creating more bubbles. So a number between 3000 and 6000 milliseconds is randomly chosen. Then the timer is started. This means that after 3 to 6 seconds the timers clock will start ticking again and thus the generating bubbles method will be invoked.

Each bubble carries either a fruit or an animal. The choice of texture each bubble gets cant be random because there is a probability that not all textures will be chosen. So to solve this problem, an array with all the possible textures was created. This array is shuffled, and then the textures in it are chosen one by one. Whenever the array is empty, it gets refilled again with the textures that then get shuffled to be taken one after the other. By using this algorithm it is ensured that all the texture will appear and it is a random order as well.

The second DispatcherTimer is the one responsible for moving the bubbles from bottom to top. In this part each time the handler is invoked all the bubbles have to move upwards. This is done by looping over the HashTable containing all the bubbles. As previously the bubbles move upwards but also in any direction left, right or straight ahead. To compute the new x-position of the bubble the number one or two is randomly picked and multiplied by one, zero or negative one according to the direction of the bubble, right, center or left respectively. Finally the computed value is added to the current x-position of the bubble resulting in the new x-position.

Before moving a bubble in the y-direction it must be checked whether the bubble is still on the screen. If its already outside the screen then there is no need to update the y-position. If the bubble is found within the dimensions of the screen, then the bubble is just moved six pixels upwards. By moving a bubble it is meant that the ellipses of which the bubble consists, the ellipse with the bubble texture and the ellipse with the fruit or animal texture. If on the other hand the bubble needs to be removed both child Canvas, both ellipses are removed and finally, the bubbles identifier number from the HashTable.

The second timer is not stopped as the previous one was. Instead it will keep repeating with the same interval till the timer starts ticking again and herewith the corresponding handler is called and the whole algorithm goes on.

The game is ready to run smoothly after the timers are activated. At this point all that is missing is the interaction. As soon as the Kinect sensor changes, as previously mentioned, and a valid Kinect sensor is detected, then adjustments are made as follows: the color stream and the depth streams are enabled, and they are adjusted to operate at 30 frames per second with a resolution of 640 pixels horizontally and 480 pixels vertically. When the sensor is started and handler names *AllFramesReady* is adjusted and invoked whenever a frame is received with all the data (color stream, depth stream and skeleton stream).

The *AllFramesReady* handler is the core method for transferring data from the Kinect to the game. It is responsible for creating the depth image of the player as would be shown on the screen. It also gets the skeleton that is to be tracked and if none exists then it returns null, concluding that there are no skeletons to be tracked. In the case that null is returned the time of the last detected skeleton is checked and the duration calculated. If the duration exceeds the time buffer that was agreed upon, 3 seconds, then it is interpreted that the previous player had done this interaction and that if a skeleton gets detected it should be added to a new player.

In the case that a skeleton was tracked then a player has to be detected and the application needs to distinguish whether it is a player from previous frames or a new player. Whenever a player is detected a Boolean flag is set to true. So the flag is checked and if it is true then the detected skeleton belongs to the same previous player otherwise it belongs to a new player, which would need to be initialized and added to the vector of players. Hereafter, a method that deals with the skeletal data is called.

The method *ProcessSkeletalData* takes the tracked skeleton as an input argument and processes its data to result in getting different positions of the joints. In this game only the position of four joints is of concern, the two hands and the two feet. For all four joints of interest the following is done: When the x and y positions of the joint and the depth are available, they are passed along with the x and y positions and the depth of that same joint in the previous frame to the method *isAClick*. This method determines if the data can be considered as a mouse click or not. Then the new positions are saved instead of the previous ones.

Then we check for the four created mClicks whether any of them have a flag that is set to true indicating that this mClick should be treated as a mouse click. As soon as an mClick with a flag set true is found the *popBubblesInLocation* method is called. As their name suggests, this method pops the bubbles by checking the given mouse location on the screen for any bubbles and pops them.

To check whether a movement is to be considered a click or not there is the method *isAClick*. It takes as input arguments two 3D positions of the same joint, the one of the current frame and the one of the previous frame. By computing the distance moved by that joint and using hereby 40 pixels as a threshold it is determined whether that movement is a click or not. So basically, if the result of subtracting the x positions and the y positions to get the distance is greater than 40 pixels then it is a click. Initially this calculation was also performed on the Z dimension as well but it was removed due to its excessive and unnecessary complexity. After calculating the method returns an mClick that has its Boolean flag set wither to true or to false according to the results of the calculations.

popBubblesInLocation is the method that is responsible for taking the position of the mClick and checking the whole screen for bubbles at that same position to then pop them. Firstly, the method loops over the HashTable that contains all the bubbles that are shown the screen. For each bubble it is checked whether it intersect the click position. If any bubble is found to intersect the click position then it should be popped. To check whether a bubble intersects a specific position or not a method called *intersectionBubblePoint* is used. It returns a Boolean indicating the results. As previously mentioned popping bubbles happens in three stages and the method *myellipse_MouseDown* is responsible for this task.

intersectionBubblePoint goes as follows: The x and y positions of the bubble and its radius are brought. Then the distance between the bubble and the point are computed using the equation:

$$d_{BubbleToPoint} = \sqrt{(x_{bubble} - x_{click})^2 + (y_{bubble} - y_{click})^2}$$

If the distance calculated is less than the radius, then the point intersects the bubble, so the method returns true.

myellipse_MouseDown is one of the most vital methods in the program because it is the one responsible for popping the bubbles and issuing the accompanying effects. It starts an animation that makes the bubble fade out. This animation is applied onto the opacity property of the bubble and makes it transparent. Then the bubble popping sound is played. A DispatcherTimer with the same interval as that of the animation and whenever it clock ticks bubbles are removed from the screen, practically by removing them from the Canvas. After that another DispatcherTimer is started to make the fruit or animal that was in the popped bubble fall downwards.

When the handler that makes the fruit or animal fall down is invoked it first checks the y-position of the ellipse containing the texture of the fruit or animal. If the y-position lies within the range of the screen, then the textured bubble is moved downwards with the fall speed attribute of the bubble. This speed is accelerated by one pixel, which means that each time the textured bubble falls a bigger distance hereby giving the feeling of an accelerated speed due to gravity. Then the timer is started again. This sequence of accelerated falls keeps getting repeated till the ellipse is out of the screen. Then the timer is stopped and the ellipse is removed from the Canvas.

4.3 Logging the data

In order to keep track of each session and of all that takes place a log file is created after a session is terminated. It contains all the information and data alteration that happened during the session. After the method *Window_Closing* is closes the session the log file writing starts. All important information is written: the sessions start time, the session end time and the total number of detected players interacting during the session. Then all the log data concerning each detected player is written; the data is extracted by looping over the vector of detected players.

For each player, the program keeps track of the player number, the time the interaction started and the time it ended. Then the total duration of the interaction, measured in seconds, is calculated and written into the log file. The total number of bubbles on the screen at the time when the user started interaction is kept track of and it is also written how many bubbles of each type were shown.

The application does not only keep track of the total number of generated bubbles while a player was interacting but also distinguishes between the different types of bubbles. Also the total number of bubbles that werent popped is written into the log file as well as the total number of popped bubbles and the total number of popped bubbles grouped according to the different types.

Furthermore, the log file saves the distance between the Kinect and the player in millimeters. This distance is measured for each frame and all the measurements are written into the file. Finally, the total time in which each bubble was shown on the screen is written down, this applies for the popped bubbles as well as the bubbles that were not popped.

Chapter 5

Evaluation

In the following chapter, evaluations for the different approaches that were used to test our hypotheses will be discussed. In order to be able to evaluate the different hypotheses discussed in Chapter 3, various number of experiments in their corresponding appropriate environments have to be conducted. The following chapter will mainly discuss the different experimental approaches followed, and how they correlate to the suggested hypotheses, and how the environment could be adjusted to accommodate the corresponding user and study requirements. Each subsection will present a separate experiment with its different goals and results, and will contain the following:

- Hypothesis: The assumption being currently investigated.
- Participants: A brief description of participants demographics' and the selection criteria.
- Procedure & Apparatus: Methodology and tools utilized for gathering the desired information.
- Results: Statistical inferences and descriptive analysis for the experiment outcomes.

The section is then concluded with a discussion that summarizes the findings, and connects the results of the different experiments, as well as relating them to the main research question.

5.1 Pre-Study

Experiment Question

The pre-study experiment could be classified more as an exploratory experiment rather than a confirmatory one. The goal of this experiment was to get a first user-acceptance feedback, as well as exploring obvious shortcomings regarding experiment set-up or software functionality.

Participants

As the experiment was hosted by the Tag der Wissenschaft[1], its participants mainly consisted of the fair visitors. In total, we welcomed 65 visitors that interacted with our system. And as the all-day long fair was mainly targeting younger audience, mainly children and teenagers, we had a very broad range of visitors on the age dimension. Participants' ages ranged from 6 years to 40 years (Parents also felt the desire to give the new technology a try). The ethnicity dimension was not very much explored by this experiment since it was only limited to the fair visitors who, more or less, live in the Stuttgart area.

Procedure & Apparatus

The system consisted of a big vertical display screen connected to a laptop on which the source code was running as in Figure 5.1. Connection wires between laptop and the screen that served for audio and video output were still visible to the end user. The system was present in the main hall where similar projects were presented as well. Another Kinect project, in which users wrote letters on screen

[1] A day held at Univeresität Stuttgart to show children the new technology

using only body gestures, and a Microsoft Surface Touchscreen demo, were the two neighboring projects. Having such similar projects in the same hall helped the users become quickly familiar with the system, as well as to have close expectations to what the system should deliver.

Figure 5.1: The setup of the system in the Pre-Study

The Software system presented was an advanced prototype to the proposed original version. We decided to test user's recognition and recall ability through a game scenario. The basic idea behind the system is very simple. Soap bubbles with different images displayed on each bubble pop up from the bottom of the display screen and float till they disappear when they reach the top of the screen.

The Kinect motion sensor is responsible for detecting the user hand motion, and delivering its coordinates to the implemented logic to compute the intersection points with the bubble's current position on the screen. In order to pop a bubble, a hand movement in the z-direction was required which was complex, so it was removed in the later version. Images displayed on the bubble were for six different fruit types and one animal, and a label displayed on the top of the screen was asking users to only pop bubbles with fruit images.

All participants were observed and a paper and pencil approach was followed to record their interactions. After participants tried out the system they were encouraged through some sweets (as most of them were children) to take part in a quick, informal and friendly interview that lasted 3-5 minutes to gather their initial feedback.

Results

On average, participants interacted for duration of 3.9 minutes. They were asked to name the fruits and animals displayed on the screen and they could recall on average 3-4 items.

Most of the results of this experiment were concerning technical problems with the systems rather than problems with people's interactivity. People really demonstrated great affection to the project, and some of them even returned in the afternoon to play a second round of the bubble game. One major bug in the system's implementation was discovered, which involved some bubbles freezing on the screen and did not float upwards, and it did not provide interactivity for the user to pop it; it just stuck on the screen. As the number of those buggy bubbles increased, the system had to be restarted so it does not bother the user. It was discovered also that the z-direction movement makes it really hard for the user to interact with the application, and having all players in the same color was really confusing for the participants as well, because they do not know which one is the active one and can interact. Another major point that caught our attention was that most of the participants paid low or no attention to the label indicating that only fruit bubbles need to be popped.

These shortcomings were fixed in later versions of the prototype leading to the final version as described in the following sections.

5.2 Lab Study

Examined Hypothesis

H1 is the main hypothesis under the loop here to investigate the effect of interactivity on recall and recognition. We assume that interactivity increases remembering the content.

Participants

In order to recruit participants we used university mailing lists and social media like Facebook and Twitter. Some other ways were used for recruiting participants too which are shown below.

In total 37 participants (22 male and 15 female) aged between 18 and 29 years, with mean = 23.216 and standard deviation = 2.983, were recruited for this experiment. Independent measure/between-groups design was used here, in which the participants were divided into two groups. Each group was subjected to the same experiment but with different conditions. One group was subjected to interactive bubbles on the screen (experiment condition), and the second group was subjected to static bubbles on the screen (control condition).

We held the study simultaneously with other studies, which were conducted simultaneously in the same lab environment. We asked the participants coming for the other study to wait in the waiting area till the person conducting this study comes to pick them up.

We posted advertisements on the pages of the study programs of Stuttgart University. A doodle link was created so that all interested participants can write down their names and select the appropriate times that suit them the best.

Each participant in the study was paid five Euros for participating in the study. The funding for the study was provided by the European Union as part of the pd-net fonds[2].

Procedure & Apparatus

The conditions to be investigated in the study were the full interactive condition versus the static condition. The static condition was achieved by showing a video of a silhouette of someone interacting with the system. The setup was closely similar to the pre-study. However, some modifications to the software were done beforehand. Most importantly, the frozen bubbles bug mentioned above was fixed. Moreover, we allowed the interaction to be done using the feet as well; previously interaction was only allowed with the hands. The label which stated that only fruits are to be collected was removed. A background that fits well with the bubbles, fruits and animals was added to the screen. We updated the log and enhanced it so it can measure and record anything. Photo streams of players detected were recorded as well. We designed the interacting player to appear in the black color, while all the other non-interacting players to appear in green. The most important modification was in the technique of the randomness of choosing the fruit or animal to fill the bubble. Previously it was a completely random method, which implies that some fruits or animals may not appear at all. We changed this to use a new technique, which is performed by shuffling the list of fruits or animals and then using them one by one till they are all consumed. Then, the file is re-shuffled and all the fruits and animals are used again and so on.

The study primarily depended on achieving a waiting situation, so participants were brought to the venue of the study, and were told to wait for two minutes, while someone will come and pick them up to start the study. Hence, all participants

[2] `http://pd-net.org`

were not aware that they were in a current study while they were participating in it.

According to the previous situation in the study conducted, we utilized a big area in front of the labs, which has a door leading to the labs from a side, and from the other side, a small entrance. In other words, when someone enters the building, he walks through a small hallway, and then he can enter that area in which the study is conducted.

In order to separate the waiting area from the hallway, we hung up a white board that states that no one is allowed to enter except the participants of the study, which was not seen by the participants. Otherwise, they would know that they are taking part in a study at the moment. There was also another sign, that participants can see when they enter the waiting area next to the door leading to the labs, that asked people to wait in this area and do not interrupt current studies.

When participants enter, they find on the other side next to the door leading to the labs, a big vertical 42" screen which was used as the public display. Next to it there was a table, on which the laptop was placed. We connected the video output of the laptop to the screen through an HDMI connection.

We had to come up with a good way to locate the Kinect just below the screen. We tried using a camera tripod but could not fix the Kinect to the tripod head. Hence, we brought a wall hanger for the tripod and we used tape to fix the hanger on the screen itself. We wrapped the tape around the screen holding the Kinect holder, and attached it to the display. The Kinect was put on that holder and connected to the laptop through a USB connection. The whole system is demonstrated in Figure 5.2, in which this photograph is taken from the back camera.

Two cameras were added to the venue to record the study. One internet camera was fixed on front of the screen at the other side. In other words, it is located behind the participants when they watch the display. We tried to conceal it, so we

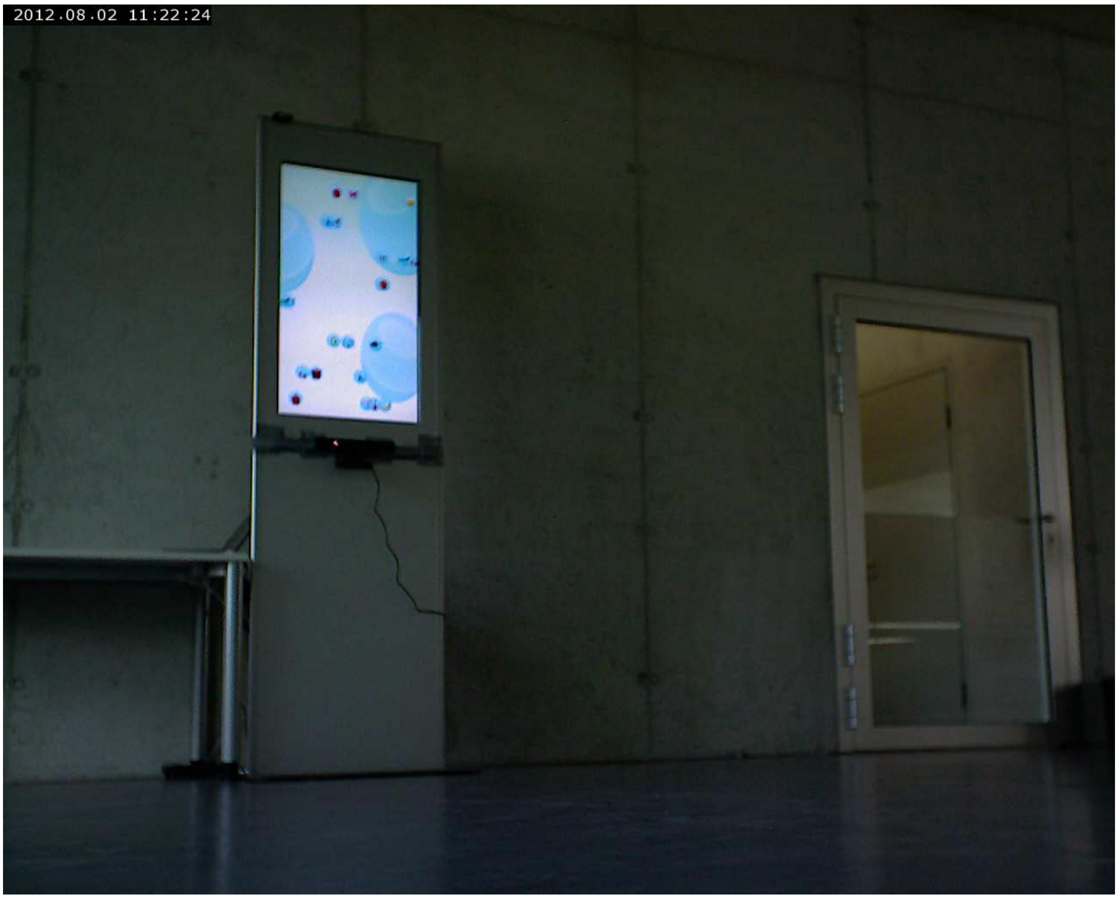

Figure 5.2: The setup of the system in the Lab Study, photo is taken from the back camera

placed it between a locker and a trash can on the floor. The camera was connected wirelessly to the laptop, we could access it from another laptop to view what is happening outside. The other camera was a bit obvious, and was fixed above the display in order to record how the user was interacting, and to also cover the other part of the area which was not covered by the other camera. It was connected directly to the laptop through USB connection. Both cameras had time stamps with the date and the time, and they were synchronized with the clock of the laptop which ensures they are both synchronized together. A paper sign was hung up in the waiting area which stated that the area is under video surveillance.

The study began on the 30th of July and it lasted for about two weeks. The usual scenario for the study was that someone would be waiting for the participant to arrive. When the participant comes to the building, we ask him to wait for two minutes in this waiting area until someone comes to pick the user up for the study he intended to participate in.

The camera would be already recording and the software running during the waiting time. The participant waits in the waiting area, and we leave him alone for five minutes and the participant is observed using the internet camera. We also make sure that no one passes through that area, in order not to interrupt the ongoing study.

After the five minutes pass, someone goes and picks up the participant and brings him to a room, where we can ask the participant if he would like to participate in a study regarding the screen he saw in the waiting area. The participant is informed that he can abort the study at anytime he wants and that he will be rewarded with five Euros.

The participant then fills out the questionnaire, which begins by asking some demographic questions like age, sex, and profession. Then he/she is asked to list down all the items that he/she remember from the screen. Afterwards, he/she have to go through another paper listing a lot of items: 24 food items and 24 animal items and he/she should choose on a scale from one to five, if he/she has seen that item or not.

Then, we ask him/her about his/her knowledge of the Public Displays in general and Kinect and how good they are in remembering content, to assess their memory in general. Finally, he/she has to sign a statement that states their acceptance of the study and using their data and videos and all the information.

Recall must be tested before recognition, and that is why we asked the participant to list all the items he/she remembers firstly; and that represents the recall part, and then he/she is asked to choose on the scale the items that he/she thinks he has already seen on the screen. Hence, we manage to achieve the condition of measuring the recall before the recognition.

Results

As mentioned previously (H1), we hypothesize that interactivity increases the memorability, hence we will investigate it first. The non-interactive (static) system is compared with the interactive system, which is achieved in the first study.

Recall was calculated by counting the items that he/she remembered. In the interactive condition they remembered an average of 4.867 items with standard deviation 2.295. In the non-interactive condition; they remembered an average of 3.118 items with standard deviation 2.118. After applying the independent t test, it shows that the difference in the number of recalled items is statistically significant, $t(30) = -2.242, p < .05, r = .375$.

To assess recognition, we calculate the score for each participant by summing up the ratings (scale from 1 to 5, 1 = I did not see the item, 5 = I saw the item). The sum varies between 24 and 120 points; higher scores signify that the participant recognized more items. In the interactive condition, a score of 71.333 with standard deviation 17.695 is achieved, while in the non-interactive condition, a score of 62.941 with standard deviation 19.851is achieved. After applying the independent t test, it shows that the difference in the score of recognized items is statistically insignificant, $t(30) = -1.470, p = .152, r = .259$.

Following the test, we can accept H1, as the results demonstrate significant difference in recall but no significant difference in recognition. Therefore, interactivity increases memorability. Figure 5.3 visualize the results of the test.

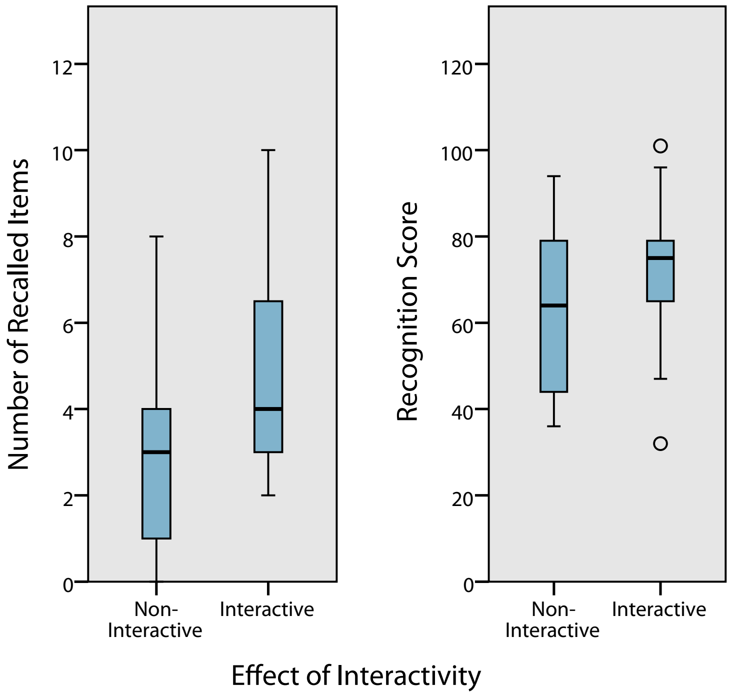

Figure 5.3: Boxplots of recall (left) and recognition (right) for the effect of interactivity. Participants can recall statistical significantly more items in the interactive than in the non-interactive condition. The difference in recognition is not statistically significant

5.3 Field Study

Examined Hypothesis

The field study was conducted to measure the validity of (H2) the ability to remember depending on the interaction scheme. It was assumed that interacting with an item makes it more likely to be remembered.

(H3) was also investigated after this experiment to examine whether the context in which the system is present plays a role in the participant's memorability. It was assumed that a waiting situation should be more encouraging for memorability.

Participants

For the second study we had 52 participants (41 male and 11 female) aged between 18 and 43 years, with mean = 24.962 and standard deviation = 5.235.

Field study is not like the lab study, so we did not need to recruit or bring participants. The display is located in the way of the students entering or leaving the building which makes it accessible to any one who wants to try it.

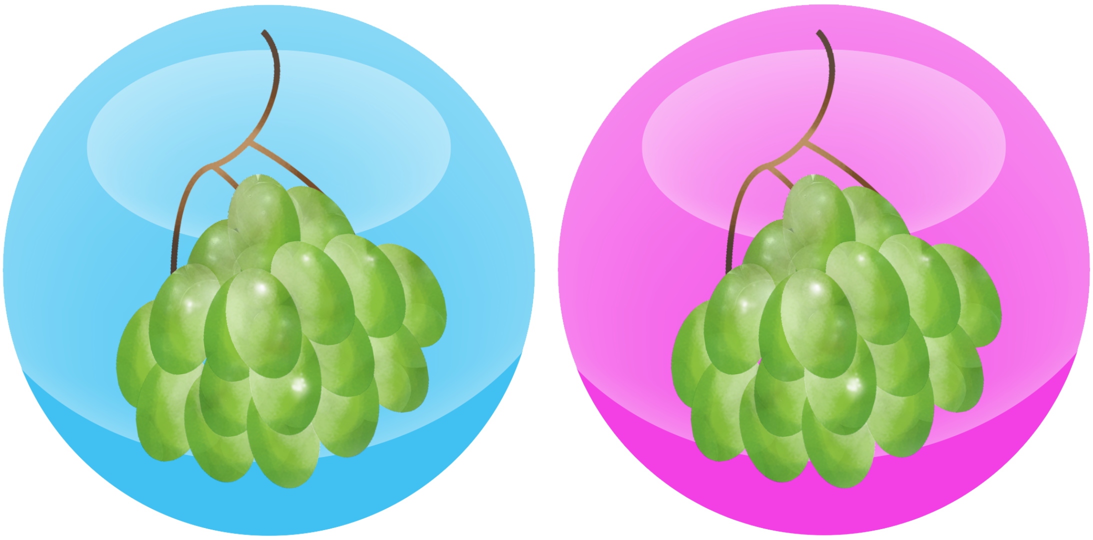

Figure 5.4: The blue bubble on the left is interactive and can be popped, while the bubble on the right, the red one, is not interactive and can not be popped

Procedure & Apparatus

Here, we are experimenting the second hypothesis, to know whether the interactivity with the items itself makes a difference in remembering. The software was modified slightly adjust it to testing that condition. We wanted to design the software such that half of the bubbles on the screen can be popped while the other half cannot be popped. Hence, we selected 50% of the items randomly to be possible to be popped. We chose randomly half of the fruits and half of the animals. We added two flags in the code in order to manipulate this. The first one can invert the items that can be popped with the items that cannot be popped. The second flag is to choose between the two conditions, whether 100% of the items are interactive and can be popped or only 50% of them are interactive and the others cannot be popped.

We had to come up with a way to differentiate between the two types of bubbles. The proposed solution here was to designate a different color for the bubbles that are not interactive. Hence, we designed the non-interactive bubbles to use a bubble texture in light red and not in blue as in the interactive items, and Figure 5.4 shows the difference.

Instead of applying the waiting situation as we did in the lab study, we created another situation. We placed the display in the way of the passer-by, so it is noticed whenever someone passes. People could accidentally pop bubbles while passing by and the accompanied sound is played so the participant can notice that. We placed the display in the building of computer science in the university, so anyone entering or leaving the building can see it. On front of the screen there was a room that belongs to the student union, and our representatives were waiting there for anyone who interacts, so they conduct the study. Figure 5.5 shows the setup of the study.

The procedure here is simpler and less complicated than it was in the lab study. We were just waiting for any students that pass by the screen and interact with it. After they finish interacting, we go and ask them if they would like to participate in a study regarding the display they just interacted with, and that they can abort the study at anytime, and we asked them to fill in a questionnaire.

Resultls

In H2, we hypothesized that interactivity with an item itself increases memorability. In order to investigate it here, we collected the data from 27 participants who interacted with the semi-interactive condition. We summed up the

Figure 5.5: The setup of the field study, the display is on the way of the students entering or leaving the building

remembered items that were interactive and the others that were not interactive. The results showed that participants recalled more interactive items than non-interactive items. They recalled an average of 1.593 interactive items with standard deviation 1.152, while they recalled on average of 1.185 non-interactive items with standard deviation .962. After applying the dependent t test, it shows that the difference in the number of recalled items is statistically insignificant, $t(26) = 1.388, p = .177, r = .263$.

For recognition, we calculate the scores the same way we did before. The interactive items were recognized with mean 30.444 and standard deviation 7.261, while the non-interactive items were recognized with mean equals 28.704 and standard deviation 10.410. After applying the dependent t test, it demonstrates that the difference in the recognized items is statistically insignificant, $t(26) = 1.417, p = .168, r = .268$.

Following the test and its results, we reject H2, as the results have no significance difference in both recall and recognition. Hence, interactivity with an item itself is not a factor in increasing memorability. Figure 5.6 visualize the results of the test.

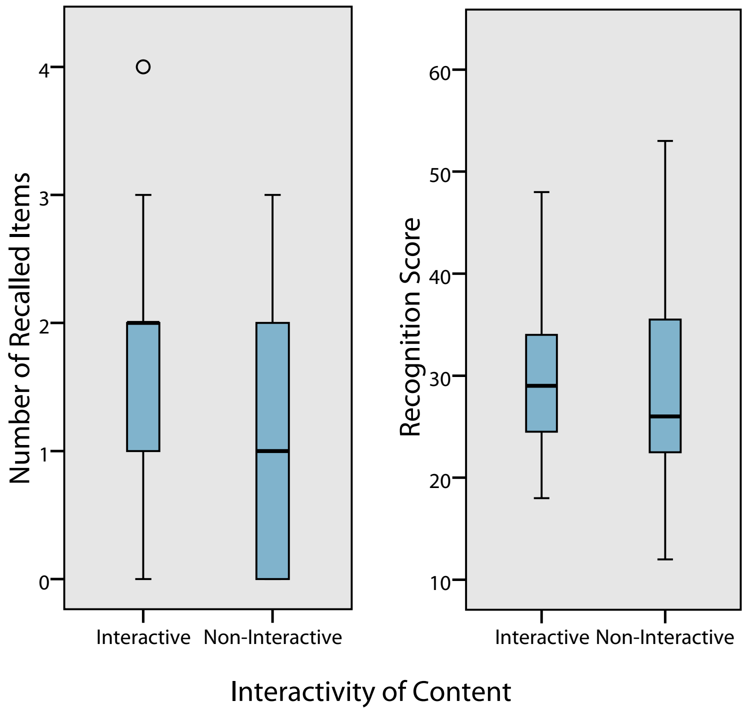

Figure 5.6: Boxplots of recall (left) and recognition (right) for interactive content. Participants can recall and recognize more interactive items than non-interactive items. The difference is not statistically significant.

We argued in H3, that people in a waiting situation have more time and are somehow not occupied and 'waiting', so they will interact more and therefore remember more what was on the display. For investigating H3, we considered only the totally interactive conditions in both situations (waiting and passing by). This resulted in a sample size of 40 participants, 15 in the waiting situation and 25 in the passing by situation. Due to the difference in setup of experiment in both studies, and in order to minimize the resulting effect of having different users with different skills, we checked the users' ability to remember things and to recognize details. All participants were asked to rate their mental abilities of how good they are in remembering content from one to five, and the same for recognizing the details (1 = very easy, 5 = not at all). A Mann-Whitney test demonstrates that there is no difference between the participants in both groups for remembering items ($U = 767.000, z = -0.478$) and for recognizing the details ($U = 807.500, z = -0.082$).

The results showed that participants in the waiting situation recalled an average of 4.867 items with standard deviation 2.295 which is higher than what they remembered in the passing by situation, as they remembered on average 3.680 items with standard deviation 2.295. After applying the independent t test, it shows that the difference in the recalled items is statistically insignificant, $t(38) = 1.506, p = .140, r = .237$.

For the recognition test, participants acquired a recognition score of 71.333 with standard deviation 81.343 in the waiting situation, while in the passing by situation they acquired a recognition score of 67.458 with standard deviation 16.122. After applying the independent t test, it shows that the difference in the recognition scores is statistically insignificant, $t(37) = 0.704, p = .486$.

In consequence of the test and its results, we reject H3, as the results have no significant difference in both recall and recognition. Hence, the situation in which the user interacts with the display has no significant influence on recall and recognition. Figure 5.7 visualize the results of the test.

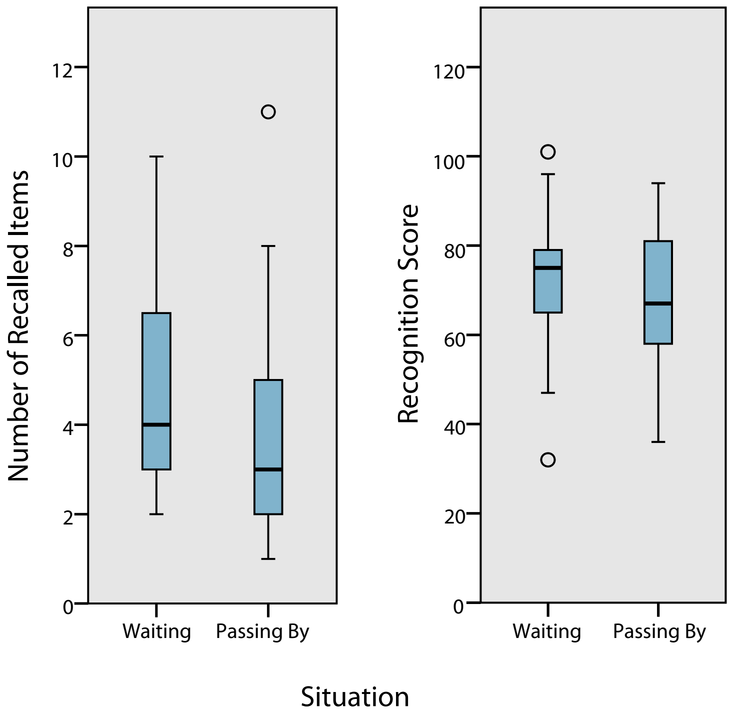

Figure 5.7: Boxplots of recall (left) and recognition (right) for user situations. Participants could remember items in the waiting situation more. The difference is not significance.

Chapter 6

Conclusion

"Creative without strategy is called 'art.' Creative with strategy is called 'advertising.'"

This very profound statement, quoted by Jef I. Richards, the American professor, purposefully reflects the vitality in integrating creativity with advertising. Advertising is all about being creative. Creativity comes in many mediums and forms and has no limits. It can be as out-of-the-box and eccentric as can possibly be needed. Public displays have always been a field of innovation and novelty. They pave ways for creative-born designers to adopt different color schemes and fonts to decorate them as well as accommodating 3D objects and animation to make the displays more attractive and eye-catching for users and passers by. It is optimistically aspired, that future technological realms and advertising breakthroughs will adequately change and modify current methodologies to allow for the integration of technological interaction into public displays in such a way that yields a mutual benefit, in terms of users attraction and product revenues, on both the customer and the advertiser respectively.

Having said that, it is still under investigation, whether the technological advancement of interactivity in public displays will widen the media channels that advertisers seek to communicate their content to the users. The essential purpose of this work was to explore and analyze the effect of interactive public displays on consumers, and whether interactivity would help the users to more efficiently recall and recognize the content advertised on the presented media. Examining the memorability of the content with respect to the user, studied under the context of 'recall and recognition', was implemented by observing the user scenario upon seeing the display whether in a waiting or passing-by situation. Another questionable criteria that called for experimentation was whether the main reason for enhanced content memorability was the interactivity with the items itself or the interaction with the system as a whole.

Before approaching the core foundation question of this thesis, a comprehensive review of the main global interactive display studies that have previously been implemented was carried out, with specific attention to how researchers tried to benefit from the interactivity applied in the various discussed public display trials. Exploring interaction techniques applicable to public displays and methods of encouragement and enthrallment to initiate the users approach and interaction towards the screen, were also investigated. Another factor put under observation was the analysis of the strength of the link between the interactivity of public displays and advertising. This particular hypothesis was accompanied by a set of measures known as the cognitive Key Performance Indicators that can quantify the mental ability of a user to benefit from displayed content and recall the information conveyed. Recalling and recognizing specific items from a list of many are the two indicators we thought may be of importance regarding assessing public displays.

Some deterministic aspects that are believed to affect the interactivity on public displays were discussed. They include elements such as the user situation and its effect on memorability, whether in a waiting situation or in a passing by situation as well as the interaction techniques explored, be they through total or partial interactivity. Finally, the previous knowledge of content that may affect the users memorability of the perceived content was considered.

In order to test the founding hypotheses of this thesis, an interactive application named 'bubble game' was built. The game consisted of bubbles moving randomly on a screen containing items, animals and fruits, where the bubbles can be hit by the user and hence 'popped'. Upon the user action of 'popping' the bubble, it fades out and the item inside it falls down accompanied by a popping sound effect 'plop'. The application supported two methods of interaction technologies: Kinect and touch. The application also provided two options, either to make all the items on the screen interactive or only half of them. The differentiation between interactive and non-interactive bubbles was made by having the interactive ones in blue semi-transparent bubbles and the non-interactive ones in red semi-transparent bubbles. The latter arrangement can be inverted in such a way that the previously non-interactive items switch to become the interactive ones and vice versa. The game was designed to work on a big vertical screen.

A set of carefully planned studies was carried out using the previously mentioned applications to investigate and analyze the hypotheses under inquiry. The studies were supported by two environments, a lab study and field study. The main focus in mind was to prove the validity or invalidity of the hypotheses. In both studies, investigations were conducted by collecting questionnaires from 89 participants. The first study, the lab study, was designed as a waiting situation where the participants were shown one of two conditions, the Kinect interactive game and a non-interactive version of the game by showing a video recorded from the screen of a player previously using the application. The second study, the field study, was designed as a passing-by situation where the participants were shown one of two conditions, the fully interactive version of the game where the participant can pop all the bubbles and a semi-interactive version where the participant can pop only half of the bubbles, as mentioned above.

After conducting the two studies followed by careful analysis and evaluation, the fundamental results listed below can be concluded:

- Interactivity with the public displays increases the user ability to remember the intended content.

- It is not a must that people will remember more the items they interacted with in a display that originally shows both interactive and non-interactive content.

- The way the user encounters the display, whether in waiting or passing-by situations, does not remarkably affect the extent of their memorability.

6.1 Limitations

Having discussed the positive breakthroughs and outcomes of this work, it cannot be overlooked that some limitations were encountered while validating the core hypotheses. Mentioned below is a briefing of these restrains, which will, without a doubt, act as foundation pillars for forth coming research and modifications of this work:

- Content such as graphics of animals and fruits were used in the interactive trials rather than considering real life data that may be interesting for the advertisers such as company names and logos.

- Due to field inaccessibility, there was unfortunately no opportunity to carry out the experimented applications in the 'wild', such as in local area streets where a wide genre of people, such as students, adults and children can see and interact with it. This restricted the studied operation to be limited to the grounds of a university environment only and especially to computer science students.

- Another criteria of investigation that fell short of this study was observing group interaction situations. Whether in the waiting or passing-by situations, only single interactions were focused on.

6.2 Future Work

For future work, many other factors will need to be considered and dug in deeper into. Such questionable theories include items such as checking the previous knowledge of content as well as other hypothesis that were possibly not mentioned in this thesis. Conducting and observing the application in the wild in a more general area like the downtown would be of high interest, as it is the realistic grounds relevant to an advertising application that targets a wide genre of residents. Moreover, the group interaction is of crucial interest as well, because it not common to find a single user interaction, as it is likely that people tend to interact in groups. Group interaction provides a scenario that decreases social embarrassment and allows interaction in a less formal, but rather more fun attire.

Finally, it is of great importance to investigate the effect of interactivity with regard to digital signing. For example, it would be worthwhile to assess whether the interactive applications of digital signage in common areas such as hospitals will enhance the patients' ability to recall directions and locations around the premises.

As exciting a breakthrough as interactivity in advertising has come to be, it is undeniably true that careful attention and adequate studies have to be paid in order to benefit from this new unexplored field and to start deploying and sustaining such marketing interactive applications on the long run. It can only be hoped that in a few years time, interactive public advertising will be the norm, rather than unexplored territory.

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Erklärung

Hiermit versichere ich, diese Arbeit selbstständig verfasst und nur die angegebenen Quellen benutzt zu haben. Wörtliche und sinngemäße Übernahmen aus anderen Quellen habe ich nach bestem Wissen und Gewissen als solche kenntlich gemacht.

Stuttgart, den 02. November 2012 ______________________