- Web on TV -

Designing Web Content for Enhanced User Experience on an Internet-Connected Television Device

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by
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Abstract

The Internet is gradually expanding to many new devices, in addition to its original native environment that was the Personal Computer. This wave started with mobile devices and as we enter the Internet of Things era, connectivity is possible from cars to light switches. One of the first devices, to follow mobiles, is the Television. Connectivity and two-way interaction on the TV device has in fact started even in the first days of the medium, but had failed to make it widely available, due to technological limitations of the past. Now, this has changed, with the Smart TV devices that can utilize the fast internet connections that are available in most developed countries. However, even though the technology and devices are now widely available there are still challenges in order to make the vast Internet and web content available in the Smart TVs. These challenges, have a familiar resemblance to what happened a few years ago, when internet connectivity was introduced on the mobile phone. Although, it was "feasible" to access any webpage from your mobile device, the experience for the user was often very frustrating, due to many factors, that derived from the fact that the web was designed for large screens and mice of the desktop computers, not the small touch screens and limited hardware of the phone. Nonetheless, these obstacles were successfully overcome, by introducing techniques and methodologies (e.g. Responsive Web Design) to make the web more mobile-friendly and also work from the manufacturers to improve their devices to this direction as well. The success of these actions is now evident, since the access to the web from mobile devices has surpassed the PC, and it is now a standard practice for every new website to be mobile-friendly.

In this research work, we will attempt to do one very significant step towards this direction for the Smart TV. In other words, to discover what has to be done to make the web more TV-friendly. To do this, we explore many different TV devices from several manufacturers and see their similarities and differences. We explore numerous user studies and surveys to discover what is the problem in the Web experience on the TV, so that we can propose solutions to make web content TV-friendly. Based on these findings, we design prototypes and put them to the test on different devices and user-evaluation. Finally, we propose a set of guidelines, that web designers can apply on their websites to make them TV-friendly, in the hope to introduce the first step towards a friendlier internet era for the TV.

Acknowledgements

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List of Publications

The following papers have been published as a result of the research discussed in this thesis:

Journals

1. Perakakis, E., Ghinea, G. (2015). “HTML5 Technologies for Effective Cross-Platform Interactive/Smart TV Advertising“. IEEE Transactions on Human-Machine Systems vol. 45 no. 4 pp. 534-539. doi: 10.1109/THMS.2015.2401975

2. Perakakis, E. Ghinea G. (2017). “Smart Enough for the Web? A Responsive Web Design approach to enhancing the user Web Browsing Experience on Smart TVs”. IEEE Transactions on Human-Machine Systems vol. 47 no. 6 pp. 860-872. doi: 10.1109/THMS.2017.2726821

Peer-reviewed Conferences

1. Perakakis, E., Ghinea, G. (2015) "Responsive web design for the Internet connected TV: The answer to more Smart TV content?", IEEE 5th Internation Conference on Consumer Electronics – Berlin (ICCE-Berlin), 2015, pp. 38–42.

2. Perakakis, E., Ghinea, G. & Thanou, E. (2015). Are websites optimised for mobile devices and Smart TVs?. In Proceedings of the 8th IEEE International Conference on Human System Interactions (HSI), pp. 47-53.

3. Perakakis, E., Ghinea, G. (2015). A proposed model for cross-platform Web 3D applications on Smart TV systems. In Proceedings of the 20th International ACM Conference on 3D Web Technology, pp. 165-166.

4. Perakakis, E., Levinenko, A. & Ghinea, G. (2012). HTML5 and companion web technologies as a universal platform for interactive Internet TV advertising. In Proceedings of the IEEE International Conference on Telecommunications and Multimedia (TEMU), pp. 214-219.

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Chapter 1 - Introduction

1.1 Internet out of the PC and into the Devices

The Internet is gradually moving out of the typical desktop/laptop computers into every other device and the W3C has used the term "Multimodal technology" to describe the interfaces that will be used to access World Wide Web ('the web') through different devices (W3C, 2016). In the near future it seems that almost every device will be connected to the Internet, from our watches to our refrigerators, in order to exchange information through it. Traditional web-site design has matured a lot in recent years but over this course it was mainly targeted to the Desktop with only recently extending focus to include mobile phones and tablet devices. The year 2017 actually seems to shift the web design priorities for the first time from mobile-friendly to mobile-first after the massive popularization of these platforms (Shaoolian, 2017).

New devices need new user interfaces to efficiently interact with the users, and present information in the best possible and usable way. The W3C consortium, in recognition of the new needs that this situation arouses, has released the EMMA (Extensible MultiModal Annotation markup language) as a W3C recommendation (Johnston et al, 2009) for developing specifications for web interaction through other input devices, such as speech, touch, gestures etc.

The first new device to dynamically enter the web was the mobile phone, which, after the first discouraging attempts with WAP, finally became a mainstream web access device. Even more recently, a new market of bigger screen mobile devices has emerged: tablets. Again, after the failure on the market of the first tablet devices a few years ago, Apple with its iPad managed to convince the consumers that these are very useful devices, offering among other things a new very convenient way to access web content.

Web design used to be about making a web-site to be compatible with all desktop screen resolutions and web browsers. With the wide adoption of smart phones, it is now common practice to design a Mobile version of a website that must be viewable on the small screen of the device, and usable through the touch interface (W3C, 2016). Usually, this version will be very different from the desktop one as the screen resolution is much smaller and the input devices are totally different (e.g. touch, motion sensors, compass etc). "The widespread deployment of Web-enabled mobile devices (such as phones) make them a target of choice for content creators. Understanding their strengths and their limitations, and using technologies that fit these conditions are key to create successful mobile-friendly Web content" (W3C, 2016). For the same reason, a different version of the website should be made for tablets, taking advantage of their distinct characteristics. This of course, means a lot more work for a web designer and increased cost for the client, but if someone is really serious about his/her online presence, it is probably something s/he can't afford to ignore.

However, what about the one device that is far more popular than mobile phones, PCs and tablets combined: the television (TV)? The amount of people who can access the Internet is increasing constantly, but still is by no means close to the number of people who own or have access to a TV set. Considering this, Internet on TV might be the biggest step yet for the web to be truly available to virtually the whole world. Yet, there is another important factor that might even present a greater need for the TV to make a step towards the connected world: its very survival. Surveys show that Internet usage is constantly becoming much more popular than it has ever been, and, in a technologically advanced country such as the United States reaching the same time spent on it as on the TV. A Forrester Research study in the US for 2010 showed that North Americans spend 13 hours per week using the Internet and watching TV online, an increase of 121% for the Internet over the previous five years, compared to a 6% for the TV in the same time frame (Forrester Research, 2010). This trend has continued over the following years, and a 2017 report showed that TV, while still the main platform for media consumption is quickly losing ground to Internet (Figure 1-1). This is a direct threat for the TV and cannot be ignored, as seems inevitable that soon the TV will lose its spot as the top medium for media consumption very soon (Dunn, 2017).

1.2 Internet on the TV

Accessing the Internet on a TV is by no means a new idea. It is actually one that totally failed to capture the consumer's interest back when it was first introduced, around 1996, with the first generation of set-top boxes. One of the main problems was the content that was available at the time, which consisted mainly of text and simple-layout pages with limited graphics, shown on the low-resolution displays of the time. The bandwidth was also very limited. One of the first pioneers at the time was Microsoft with MSN TV but the system never quite delivered what it aimed for, probably because of technological limitations (Jones, 1997).

In 2011 a move had started by W3C, Google, Sony, other major hi-tech companies (like Apple, Samsung, Yahoo etc) and many smaller ones (Boxee, Kylo.tv, media center device manufacturers etc), some working together, some rivalling with competitive products, to re-introduce the web on the Television. This time around, the content was very different to what it was 10 years ago and had in many ways surpassed the TV in richness and diversity. Content is king, and since the appropriate multimedia content seems to exist on the web, it was probably time to break through to the Television. *"With the advent of IP-based devices, connected TVs are progressing at a fast pace and traditional TV broadcasting is quickly evolving into a more immersive experience where users can interact with rich applications that are at least partly based on Web technologies. There is strong growth in the deployment of devices that integrate regular Web technologies such as HTML, CSS, and SVG, coupled with various device APIs."* (W3C, 2011).

This approach for bringing Internet content to the TV was eventually branded under the "Smart TV" label. It is important to note that this is a Marketing tag not a

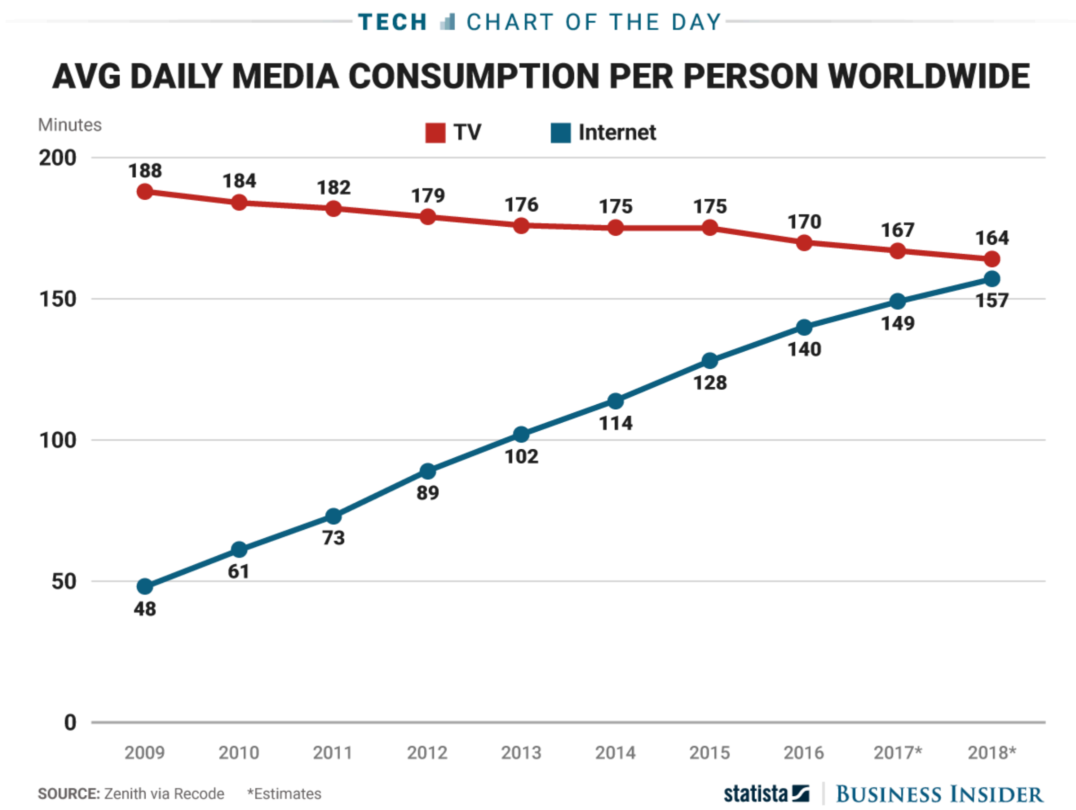

Figure 1-1 Internet as a platform of Media consumption is quickly closing the gap to TV (2017, Dunn)

specific technology, as Smart TVs by different manufacturers differ greatly in capabilities and technology standards. By 2017, Smart TV has become a standard component of most new TV devices, to enable some sort of Internet connectivity (Deloitte, 2015; 2016). Still, although the technology to connect to the Internet is so widely adopted on TVs, the expectations of the viewers in terms of content do not seem to have been met yet. This can be deducted by multiple surveys on Smart TV usage from owners of these devices that show a very limited use of its Internet capabilities (Nielsen, 2014; 2016; Bachelet, 2013).

1.3 Designing websites for the Television

As less technical people will be using these devices, simpler and more easy to use web-sites are needed for Internet TV users to be able to really use the web. As has happened for other devices, such as mobile phones or tablets, web designing for the TV is something totally different from designing for the PC and possibly even more so than the devices mentioned. All the aforementioned devices have in common that they are used almost exclusively by a single user (at least simultaneously), at a very short distance from his/her eyes and within reach from his/her hands. The 10-foot distance from the TV and the multiple-viewers model can have a lot of impact from an HCI prospective. Indeed, Google was the first to release a rough guide on web designing for its Google TV platform and the TV in general, focusing mainly on technical differences between the PC and the TV, such as resolution, ghosting etc (Ferrate et al, 2011). Prior to this, there have been academic studies (e.g. Bellekens et al, 2009; Chorianopoulos, 2008; Ahonen et al, 2008) but mostly focusing on the TV experience of interfaces (e.g. Interactive TV electronic program guides - EPGs), which of course share many things in common with web-sites but are not the same thing as explained in detail in the following chapters. In the following years many other technology providers as well as academic studies were published focusing on the TV experience, however most of these focused almost exclusively on TV Apps (Chorianopoulos and Geerts, 2011; LG Electronics, 2015; Samsung Electronics, 2016; Google, 2015).

Pemberton et al. (2003) argue that the differences between the PCs and the TV in a number of areas suggest than evaluating Internet-connected TV needs a different approach from desktop applications. Presenting new functionality on a device that the viewers are used to perform only the function of switching channels and watching, will possibly not have a very pleasing effect with too much interaction, but would prefer most things to occur with very little effort and not remain static for too long expecting the users to react. Also, the television content has many elements that don't normally exist in websites and vice-versa. It is probably not a good idea to just try to render the web content in the same way on the TV as on a PC (i.e. based on text), but probably adapt some elements of the standard TV content design, such as animation, storytelling, music, speech etc. As far back as in 2005, Nadamoto et al. proposed the Web2Talkshow system that transformed automatically web content to a TV-like talk-show (Nadamoto et al, 2005). An early adoption of course with many flaws due to the technology restrictions at the time ultimately failed to be transformed into an end-user product, but nevertheless constituted a worthwhile initiative.

Technologies such as HTML5 now allow for much richer, more TV-friendly web content, such as video, that can be embedded and controlled much more easily and without the need for any third-party components (Lawson and Shart, 2012). As this technology has matured and the TV devices now have more powerful hardware than ever, it could be the right timing for most Internet content to reach the TV devices, and not be limited only to specific content-consuming TV apps.

1.4 Research Questions

From many consumer surveys, as described in chapter 2 (section 2.6.1), it is clear that Smart TV users are not satisfied with the Internet capabilities of their TVs, which most of them do not use at all. The problems are identified on the hardware side, especially in respect of input/control devices, and on the software/content side, namely the lack of content, and the bad UX of existing content (Nielsen, 2013; 2016; Bachelet, 2013).

In this thesis, we explore ways to improve aspects of User Experience and Usability on the software side. As millions of TV devices are already owned by consumers, and even new devices that are sold have different software platforms, we try to find a way to address the problem given the hardware capabilities and limitations of the devices, thus focusing mostly on content. Given that most Smart TVs are connected to the Internet and have a web browser, practically the content available to these devices is the entire Web itself. However, as the content is not optimised for TV, it is no surprise that, although devices have a browser capable of displaying it, users are enstranged from accessing it through their TVs. Accordingly, the main research question we are addressing in this thesis is:

How should a website or web application design adapt to the Internet Television environment for enhanced User Experience while maintaining maximum compatibility with different Smart TV devices?

Moreover, we also explore if this can be achieved with minimum effort from content providers, i.e. without the need to develop new websites or TV Apps. In this way, the content available for Smart TVs could be expanded significantly; additionally, if the UX is improved, users are more likely to want to access it through their TVs.

1.5 Structure of the thesis

In chapter 2 we briefly outline the history of interactive TV to eventually becoming an internet-connected platform. Then, the current state of connected TV is outlined, including a disambiguation of related technologies and platforms. Following is a description of the user experience aspects of interactive TV and methodologies that can be used to measure them. At the end of this chapter we clearly describe the aims and objectives of this work, as well as the research questions.

Chapter 3 discusses in detail the research methodology that was used in the experiments carried out for this work.

The following chapters focus on three different areas of Smart TV applications and propose innovative methods for developing web-based TV applications.

Chapter 4 is focusing on interactive ads for Internet-conntected TV and proposes a system for developing web-based interactive ads that will be compatible with different TV platforms but will provide seamless viewer perception regardless of the capabilities of their device.

Chapter 5 explores the possibility of web-based applications that can exploit the 3D capabilities of the SmartTV systems. An evaluation was performed on the Web3D performance of Smart TV devices and a sample application was developed to validate the proposed guidelines for cross-platform Smart TV 3D apps.

In chapter 6 we studied the 50 most visited websites world-wide, according to Alexa research, to evaluate their compatibility with Mobile, Tablet and Smart TV devices. The findings of the study clearly showed that although the website designers give great importance to mobile user experience of their website, they ignore the Smart TV optimizations in most cases, leading to very bad usability on these devices.

Chapter 7 exploits the use of Responsive web design for the Smart TV. This technique is used widely in developing websites that have optimal user experience in different kind of devices such as desktop tablets and smartphones, but as we have seen in the previous chapter, it has not been adopted for TVs yet. The challenges for the best adoption of this model for the TV experience are explored and methodologies for the best application of this technique are outlined. The resulting prototype system has been tested for compatibility across different TV platforms to make sure it is cross-platform as intended. Then, a user study was performed to put it to the test against the normal non-optimized website on a Smart TV. The results are explicitly outlined, showing the aspects in which, the experience of the users was enhanced.

The key output of this work is a set of Guidelines for developing websites for the Smart TV environment, which can be adopted in the future by web designers and developers for practicing in their projects. Our ultimate goal is that by adopting these techniques, it will be a first important step in more accessible web content from Smart TV users and it will significantly contribute in the evolution of Smart TV as web access devices. These guidelines are described in Chapter 8.

The last chapter (9) discusses the overall conclusion of this research work, including the contributions and the research findings. Finally, it proposes ways in which this work could be continued in the future.

Chapter 2 - Internet and the TV

2.1 Introduction

The Internet and the TV had very different beginnings and uses. While the Internet focused on interactivity from day one, the TV was mostly a one-way communication. While TV was used to transfer video and audio, the Internet was initially used for textual data. However, these two channels shared many things in common. In essence, their purpose was to transfer information. Unsurprisingly, as the technology was advancing in both these mediums, the common features these shared were increasing, reaching to a point where one of the main types of information shared through the Internet is video and audio, while the TV implemented interactivity with the viewers in many ways. So, the convergence of these two mediums is not a surprise, but probably was inevitable to happen.

In this chapter we initially go through the early history of TV and the various attempts to add interactive features, which led to Interactive and Internet TV. In section 2.3 there is a detailed review of the current state of Internet Connected TV or Smart TV, including technologies, devices and platforms, as well as standards and capabilities. In section 2.4 we describe the applications of Smart TV, so there is a detailed account of the most popular uses of these platforms. Section 2.5 explores the aspects of User Experience and Usability, and how these are important for the Smart TV users and applications. In section 2.6, the main research question for this work is presented, followed by a detailed account of the aims and objectives of the research.

2.2 Brief History of Internet on the TV

2.2.1 Analogue TV

TV is short for Television, a word made up by the combination of the Greek word ”Tele” (“τηλέ”) which is a prefix to circumscribe distance and the English word Vision. As in many other complex technologies, the TV device was not invented by a single creator, but several pioneers took the idea one step further, in order to become what we now have as a standard compartment of modern life. In order to have a better understanding of the medium, a brief history of the TV will be outlined, referring to the most important individuals, companies and technologies in the short time the TV has existed.

Figure 2-1 This is the first known photograph of a moving image, produced by Baird's "televisor" in 1926

In 1884, the German inventor Paul Nipkow proposed and patented a rotating disk that would allow images to be transmitted over wire. This disk would rotate at a fast pace, while the light passing through the holes would form a picture on a glass screen. (Shiers et al., 1997). Nipkow’s efforts were directed towards a mechanical television. The term Television was actually introduced by Constantin Perskyi in a paper reviewing existing electromechanical technologies, such as Nipkow’s disk (Perskyi, 1900). On March 25, 1925, Scottish inventor and TV pioneer John Logie Baird gave the first public demonstration of televised silhouette images in motion, in London’s Selfridges department store. He had built a prototype Television based on the Nipkow disk. A year later, he demonstrated the transmission of an image of a face in motion by radio (Figure 2-1). Baird's disk had 30 holes, producing an image with 30 scan lines, a very limited resolution but enough to make out a human face (Baird, 1932). In 1927, Baird transmitted a signal through a telephone line between London and Glasgow.

In 1897, physicist Karl Ferdinanand Braun build the first cathode-ray-tube (CRT) oscilloscope (*Braun tube),* which lights up a phosphor-coated screen when hit by electrons (Figure 2-2). In 1907, the Russian scientist and electronic TV pioneer Boris Rosing used the CRT to form a picture from an experimental video signal and succeeded to display crude geometric patterns onto a television screen. He was referring to this technology as Electrical Telescopy and filed a patent in Russia and later in USA (Rosing, 1911). This was the first effort towards an electrical television, as the mechanical television (based on Nipkow's disk) had already shown its limitations.

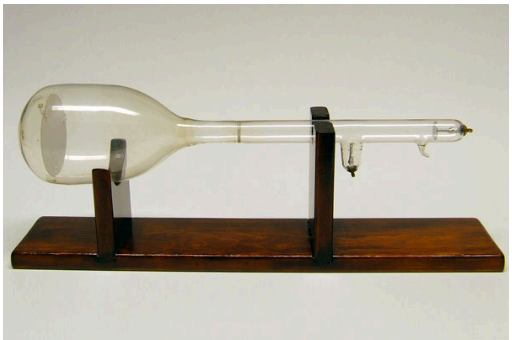

Figure 2-2 The Braun Tube

In 1928, television pioneer Philo Farnsworth demonstrated a complete system of electronic TV. The image dissector camera tube breaks a single image into 60 lines of light, transmits them as electrons, and then reassembles the original image on a screen. This is widely regarded as the first electronic television demonstration. RCA agreed to pay Farnsworth US$1 million over a ten-year period, in addition to license payments, to use Farnsworth's patents (Schatzkin, 2002). With this historic agreement in place, RCA integrated much of what was best about the Farnsworth Technology into their systems. In 1941, the United States implemented the 525-line television standard (New York Times, 1941) while 3 years later the Soviet Union standardized the 625-line standard, which was adopted in Europe as CCIR. Up till then, the Television was in black and white, although inventors had already started experimenting with colour as soon as the first monochrome prototypes. Whilst John Logie Baird had demonstrated the world's first colour transmission in 1928, using three spirals of apertures, each one with filters to a different primary colour, he also made the

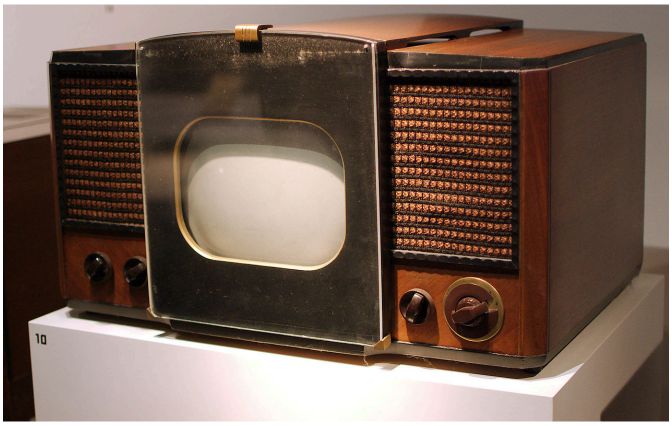

Figure 2-3 RCA 630-TS, the first mass-produced TV (1946)

world's first colour broadcast 10 years later, sending a 120-line colour image from his studios to London's Dominion Theatre.

Initially, monochrome and colour TV were not compatible, so you could not use a colour TV to watch a black and white (BW) broadcast, which was a great limitation as most programs were BW. RCA researched and developed a compatible colour system, which encoded the colour information separately from the brightness information, thus reducing colour information to preserve bandwidth. So, the brightness image was compatible with existing monochrome TV devices and this, in 1941, was the first widely widely adopted broadcast colour system, named NTSC after the National Television System Committee (1953). Colour broadcasting in Europe was also not standardized on the PAL format until the 1960s. Analogue TV stations were broadcasting their programs in UHF, in the same fashion as the radio, and most of them had switched to colour signal from BW by 1984 (2017, Wikipedia).

Up till recently, UHF was the main method for transmitting TV programs, but this has gradually changed in late 2000s with Digital Television. Digital television (DTV) is the transmission of audio and video by digitally processed and multiplexed signal, in contrast to the totally analogue and channel separated signals used by analogue television. Digital TV can support more than one program in the same channel bandwidth (Benoit, 2008). However, it is important to point out that digital TV is only referring to the transmission, which does not include any means of two-way communication or interactivity.

2.2.2 Interactive TV

Traditional TV used to limit its interactivity to the ability of user to switch between different channels, alter the sound volume and, of course, switch the device on and off. Originally, this required the user to go to the TV device and use a radio-like tuner to find the appropriate frequency. The first remote controls, introduced as early as 1950, made this functionality much easier with the user being able to do these basic functions from his/her couch (Figure 2-4).

Figure 2-4 An ad for the Zenith "Lazy Bones". The first TV remote control (1950)

2.2.2.1 Teletext

A more complex form of TV interactivity came in the form of Teletext, a television information retrieval service created in the UK in the early 1970s by John Adams (Adams and Adams, 1982). Teletext is a means of sending pages of text and simple blocked graphics to a TV with the appropriate decoder, by use of a number of reserved vertical blanking interval lines that together form the dark band dividing pictures horizontally on the television screen. It offers text-based information, such as news, weather, business catalogues and TV schedules (Briscoe, 1979). However, Teletext did not technically offer two-way communication between the viewer and the broadcaster but the whole information is transmitted one way, indexed in pages, and the viewer can form the page number on the remote control to view the desired page. The original

Figure 2-5 BBC CEEFAX, the original Teletext service (1974)

specification for teletext were defined by the BBC, IBA and BREMA in 1976 and included 40 x 24 rows of text and blocks.

2.2.2.2 Analogue Interactive TV

While Teletext was a rather successful service, real Interactive TV (with actual two-way communication), could still be regarded, to much extent, as an experimental technology. Indeed, through its history there have been many experiments, trials and many real-market products that had seen limited success or, more often, failed.

In 1977, Time Warner (then called Warner-Amex) launched a trial system named QUBE in Colombus, Ohio, which was the first commercial interactive TV service. QUBE was a cable television system which provided 10 normal broadcast channels, 10 pay-per-view channels, and 10 channels with original, interactive services (Forth, 2009). The system was equipped with a narrow-band upstream return channel to allow direct interactivity of the viewers. Via this they could participate in game shows, choose sports events, order pay-tv, participate in opinion polls and voting, etc. The viewers pushed the buttons on the box, the selections were processed by a computer, and later the result was announced on the screen (Jensen, 2008). Due to its innovative character, press coverage was very big and many households subscribed to the service. The use of the interactivity provided however was low, and users were mostly using the ability to interact with TV games and some polls. It was finally decided to never go on full scale in the US market and in 1984 the system was quietly closed down.

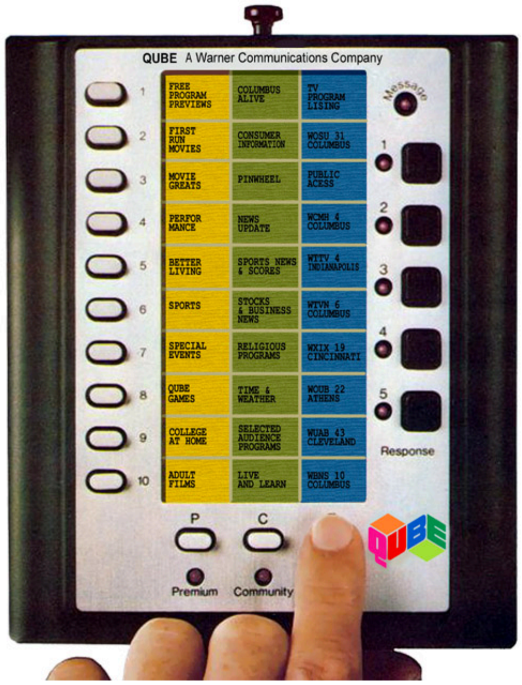

Figure 2-6 The QUBE Interactive TV remote control from 1977 (Forth, 2009)

In the 1980s, the TV device had seen some interactive elements being added to it: The Video Cassette Recorders (VCR) and the Game Consoles. These cannot be regarded as pure Interactive TV, but the ability to watch films a user could choose at any time (provided one had the video tape) and play games on the TV screen are two of the most common interactive elements that can be seen in today's devices and interactive services. So, this has certainly familiarised a much wider audience with the concepts and capabilities of TV as a more interactive device.

2.2.2.3 Digital Interactive TV

A great technical problem problem with Interactive TV has been the need for two-way communication, between the broadcaster and the receiver. This was not possible in most cases, as TV programs were received through radio waves. This "return path" could utilise a telephone line or even the cable TV line, as these were the only available options in the 90s. Digital TV services sometimes "fake" Interactive TV, by utilizing their ability to transfer easily large amounts of content. So, for example, a Digital TV provider could transmit several angles of a football game to all the receivers, so this data is downloaded to their set-top box, but the viewers can interact with their device and switch between different angles. An example of this kind of service is Freeview in the UK.

Figure 2-7 The Full Service Network from 1994 (Time Warner Cable History)

Figure 2-8 The box for FSN costed $4500 and was the size of a small refrigerator (Time Warner Cable History)

The Full-Service Network (FSN) by Time-Warner cable, initiated the first wave of experimental interactive TV systems, launched in 1994. It was available in 4000 households in Orlando, Florida and allowed viewers to do things like order from Pizza Hut or buy sports highlights from recent games (Rosoff, 2011). The FSN pioneered many features we see on today's interactive TV services. The return path for two-way communication was done through the cable. Although truly novel, one of the major drawbacks of this system was its cost, which was extremely high for the time, as each set-top box costed $4,500 for each of the 4000 subscribers. The service was cancelled in 1997 (Time Warner Cable History).

2.2.3 Computers, Internet and the TV

Many projects in the 90s attempted to exploit the convergence of Computers, Internet and interactive TV. Unfortunately, all of these projects ultimately experienced a complete failure in the market. This does not come as surprise, as it was obvious that the technology was not ready for many reasons: data transmission speeds were very low, connection through telephone lines was problematic and not always on (it was also usually charged per minute); moreover, computer's graphical and audio capabilities were also very limited. So, in many ways it was a convergence without a specific meaning, just a soup of technologies that were hype at the time. An example of this kind was the "Macintosh TV" (1993), in which Apple combined a Macintosh computer with a Sony TV instead of a screen. There was no actual combination of the Macintosh OS and the TV, just the ability to switch between the OS and the TV tuner on the screen (everymac.com).

Figure 2-9 Macintosh TV (everymac.com)

Another important device, which was the first to promise access to the Web on a TV, was the WebTV box launched in 1996 (Rosoff, 2011). The set-top boxes were manufactured by Sony and Philips and one of its stronger aspects was its low-cost ($300), which was much cheaper than the only alternative at the time to access the web, the Personal Computer. Of course, the hardware capabilities were very basic in order to keep cost at the lowest possible level, and included a RISC processor at 112Mhz, 2MB of RAM and 2 MB of ROM plus 1MB of Flash memory for storage. The device included an IR keyboard and a remote control. Microsoft actually bought the company in 1997 for $425 million and the subscribers

Figure 2-10 The WebTV set-top box (later MSN TV)

reached almost 1 million. It was renamed by Microsoft as MSN TV and updated versions of the device were released. The primary uses of the WebTV were web browsing and e-mail. The setup included a web browser, a corded or wireless keyboard and a connection to the Internet using a modem. A more advanced model was introduced a year after the original release and included a TV tuner to allow PIP (picture-in-picture) TV window while browsing the web and even allowed one to capture video stills from a camera, VCR or broadcast TV as a JPG.

The Internet connected TV landscape was greatly improved in the 1990s with the wider adoption of the Internet and got even better in the 2000s with the wide availability of Broadband, which meant much higher data speed and full two-way communication 24/7. It was an obvious opportunity for Interactive TV, to many considered as a failed project, to ride the wave of the Internet and go along, thus Smart TV was born.

2.3 Current State of Connected TVs

2.3.1 What is an "Internet-connected TV" anyway?

Probably the first challenge someone will face when researching the field of Internet connected TVs is that there is no clear definition for it. Many technologies with similar names or functionality have been around for the past 15 years. The most common term for a TV device with Internet capabilities as of 2018 is "Smart TV" (Figure 2-11). Indeed, when a consumer seeks to buy a Smart TV, that usually means a TV with built-in Internet connectivity (Plummer, 2017). This will also mean that the TV device will have some basic computing capabilities, such as an Operating System, and the ability to download and run Applications (TV-Apps). It will also usually mean that there will be a full web browser to browse any web page.

However, it is also possible to upgrade a TV that does not have these capabilities, into a fully capable Smart TV system by connecting an external device to it. These external devices come in many forms and is sometimes difficult to draw the line into which ones can be considered to make your TV, "Smart". The most obvious solutions are "upgrade" devices from TV manufacturers such as the LG Smart TV upgrader (LG USA, 2016) , or DVD/Blu-ray player devices that include Smart TV upgrader software on them, such as the Samsung Blu-ray Player (Figure 2-12).

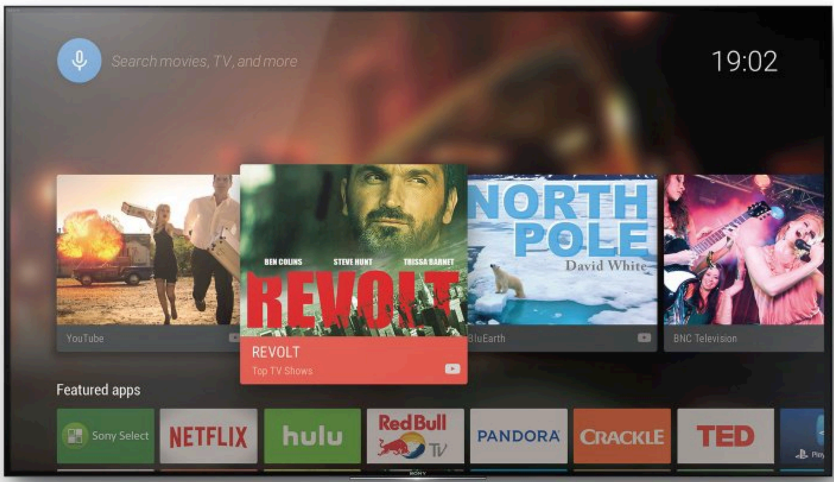

Figure 2-11 A Sony Smart TV (Sony.com, 2016)

There are devices to add Smart capabilities to a TV from hundreds of vendors. Apple has a popular device (**Apple TV**) and Google has tried twice to enter the market with **Google TV** and **Android TV**. The first time it flopped both on reviews and sales and the product was discontinued (Bonnington, 2011). Now it is rebranded as Android TV with upgraded software and capabilities. Other than that, other popular devices include: Amazon Fire TV, ROKU and many Android-based devices from Chinese manufacturers.

Another type of popular category of devices that enable Internet capabilities for a TV are **game consoles**. Devices such as PlayStation 4 (Figure 2-14), Xbox One, Nintendo Wii etc all include Web browsers that you can use to access the Internet through your TV. These even include popular Apps such as YouTube and Netflix to play videos and films on the TV screen.

Figure 2-12 The Samsung Blu-ray set-top box with Smart TV software (Samsung Electronics America, 2017)

There are also some simpler devices, such as the **Google Chromecast** (Figure 2-13)**,** that will convert a TV into a screen that a user can "cast" videos or even duplicate what is being displayed on another device (e.g. the contents of the web browser, an app, even a game), usually a tablet, a mobile phone or even a PC. These would move a little further out from the standard field of Smart TV as the TV will only act as a screen while all functionality and user input would come from other devices. Apple TV allows this kind of functionality as well through its own technology, **Airplay**.

Figure 2-13 Google Chromecast (Google Store, 2015)

For this research work we consider a Smart TV any Web-Enabled Internet Connected Television. This would be any TV that can connect to the Internet and access the Web through it, either through embedded hardware and software or by enabling this connectivity with an external device, such as a set-top box.

Figure 2-14 The PS4 Web Browser (Davison, 2017)

2.3.2 Related Technologies

As highlighted in the previous section, the most common term to describe a TV that can connect to the Internet as of 2017 is **Smart TV** (Deloitte, 2015). However, there are many similar terms that have been used in the past, while some are still being used today, that can be confusing as these seem to describe the same thing. Below we provide some of these terms with brief descriptions and the connection of these terms with Smart TV:

- **Interactive Television (ITV):** Interactive TV refers to any TV device that the user can interact with it in some way (besides switching channels and altering the sound volume), thus changing the content or the linear flow of the program. Smart TV has Interactive TV functionality, but an Interactive TV can be something else as well, as Internet connectivity is not required. It normally requires two-way communication between the viewer and the broadcaster (Chorianopoulos and Spinelis, 2006).
- **Internet TV or WebTV or Online TV**: Refers to distribution of television content through the Internet. The device that consumes the content does not necessarily need to be a TV, but it could be a Personal Computer or a mobile device (Nielsen, 2013). It does not refer to a particular software, and usually every channel has its own App or website to view its content, which sometimes is subscription-based and open only to subscribers. It is also common to have geographic restrictions to what content can a user view, according to the country s/he is in. A Smart TV certainly has WebTV capabilities as there are numerous TV Apps from TV channels to view their content. Also, it is a very common use of the TV browser to view the website of TV broadcasters in order to watch their shows that are available online.
- **Internet@TV**: Not to be confused with the generic term "Internet TV", this is a platform for Internet Connected TVs developed by Samsung and is embedded in some of its early TV models. It allowed for a TV to be connected to the Internet and access data from it through TV-Apps developed for this particular platform (Samsung, 2011). The platform is not supported anymore, and was succeeded by the Samsung Smart Hub.
- **Internet Protocol TV (IPTV)**: This technology refers to the delivery of Video content to subscribers over IP-based networks. These are usually closed networks of a service provider and not public Internet. In contrast to video over the public Internet, with IPTV deployments, network security and performance are tightly managed to ensure a superior entertainment experience, resulting in

a compelling business environment for content providers, advertisers and customers alike (ATIS, 2006). This technology is unrelated to Smart TV.

- **Digital TV (DTV):** Describes the transmission of TV programs through UHF channels, but digitally encoded and compressed so that much more data can be transmitted on a frequency compared to the traditional analogue TV transmission. It provides a one-way communication but can contain pseudo-interactive elements by transmitting more data to the viewer's set-top box and then allowing him to activate it (Benoit, 2008). Most traditional TV and Smart TV devices include Digital TV receivers nowadays, but this functionality is unrelated to their Smart TV capabilities.
- **Connected TV**: Connected TV describes any TV device that has the ability to connect to the Internet. It was an early term to describe Smart TVs but is less commonly used after 2014, in favour of Smart TV. Connected TV is interactive and supports two-way communication between the viewers and the broadcaster, where this is achieved through a standard broadband Internet connection. It actually means the same thing as Smart TV and was renamed for marketing purposes (Pereira, 2012). It is most frequently used as a term to describe Smart TVs in research papers.

2.3.3 Smart TV Platforms

Smart TV is the new kind of device that is growing in popularity over the past few years, following the rise of smartphones and tablets. Sales of Smart TVs reached 90 million units worldwide in 2013 and were estimated to grow at 21% CAGR (Compound annual growth rate) to reach 228 million in 2018, according to a report (Futuresource Consulting, 2014). More recent reports, showed that this forecast was surpassed already in 2015, with 220 million connected TV devices (Smart TVs, game consoles, media streamers etc) sold throughout the year worldwide (O'Halloran, 2016) However, even today, content for these devices is limited and consumers are slow to utilize the device's full potential, with using it most exclusively to stream video, TV shows and movies (Nielsen, 2014). One of the problems for Smart TV content developers is the fragmentation of the market, with many companies with incompatible platforms trying to gain market share. This is a very different landscape compared to mobile phones and tablets, where iOS and Android platforms are clear market leaders. However, Samsung has a clear advantage on worldwide market share with 26.4% of devices sold, while LG and Sony share the second place with significantly lower shares of 14.3% and 14.4% respectively (Strategy Analytics, 2013). It is also interesting to point out that in addition to pure Smart TV devices, there are also some other methods for having Internet on the TV. These devices include set-top boxes (e.g. AndroidTV, Boxee, AppleTV), BlueRay/DVD (by Sony, Samsung, LG etc) and even game consoles (Sony PS4, Nintendo Wii, Microsoft XBOX One etc.). More recent reports show that Samsung maintains the larger market share for Smart TVs (28%) with LG managing to narrow the gap (17%) compared to Sony (13%) while Vizio is following with 11% (Kosir, 2016). These reports also indicate that Roku is the leader in streaming media devices in the US while AppleTV and Chromecast are leaders in worldwide sales worldwide.

2.3.4 HbbTV and Standards

Currently, there are no standards that all manufacturers and content providers follow. An initiative named HbbTV[1] aims at the use of web standard technologies combined with TV content (HbbTV, 2016), but has not yet been adopted by the industry at large. It is noteworthy, however, that while all these platforms have their own Operating Systems and APIs, a common development ground can be found in that most devices provide an HTML5 web-browser App to freely browse the web.

2.3.5 3D capabilities of Smart TVs

Another common feature of the Smart TV devices is that they often come with 3D glasses, so that the viewers can watch stereoscopic videos. Three-dimensional content however, is currently very limited, with few movies, and even fewer TV shows, being produced in 3D, as this requires different cameras and equipment. Most 3DTVs have an option to automatically convert 2D content to 3D, but this does not have the quality results of a real 3D-made production.

On the other hand, real-time 3D content is extremely rare on Smart TV platforms right now. There are a few 3D games on newer systems, especially by LG and the Samsung

[1] https://www.hbbtv.org/

TIZEN 2015 platforms, and a trend is appearing in this direction, although it is very early to draw any safe conclusions.

Previous studies on 3DTV remarked the interest of Smart TVs Web3D capabilities but focus mostly on delivering content that is pre-rendered on a server (remote rendering) and then sent to the TV (Zorilla et al., 2012). This is no surprise, as Web3D capabilities on TVs have only appeared in 2013. This approach however can suffer from network delays and requires heavy server resources, if it is to allow the users for real-time interaction with 3D objects. In a more recent study, Olaizola et al. (2013) propose a model where a hybrid system is used, blending Web3D objects and 3D video stream, that is combined either on the server or on the client's Smart TV, provided that in the future there will be such capabilities. Other studies propose the automatic conversion of current 2D web content to 3D stereoscopic content by placing the objects of a web page in 3D space (Yim, 2014).

2.3.5.1 Web 3D on Mobile devices and Smart TVs

The mobile device landscape, which includes smart phones and tablets, is clearly a more evolved market compared to Smart TVs. This is not a surprise, as these devices been around longer than Smart TVs. It is also much less fragmented, with only two major platforms (Google's Android and Apple's iOS), owning the largest part of the market, with billions of units being sold, creating a large user base. Also, in marked difference to Smart TVs, mobile users use their devices to browse the Internet very often, as numerous surveys and website statistics show. For instance, according to StatCounter.com[2], worldwide mobile browsing has reached 32.12% as of December 2014, increasing from 22.16% a year earlier, figures that are even more dramatic given that in 2008 the proportion was close to 0%. Additionally, WebGL support is clearly flourishing on mobile devices according to webGL Stats (Figure 2-15), with more than 75% of visitors having mobile devices that support WebGL in 2015 (an enormous improvement over 25% in 2014) which eventually reached an impressive 97% by 2017.

[2] StatCounter Global Stats: Platform Comparison (Dec 2008 to Dec 2014) http://gs.statcounter.com/#all-comparison-ww-monthly-200812-201412

Web 3D support was initially absent from Smart TV capabilities, contrary to other HTML5 features such as <video> and <canvas> that were partly supported even in earlier models. This, however, finally seems to have changed since 2014 where new models feature more powerful hardware and better HTML5 web browsers.

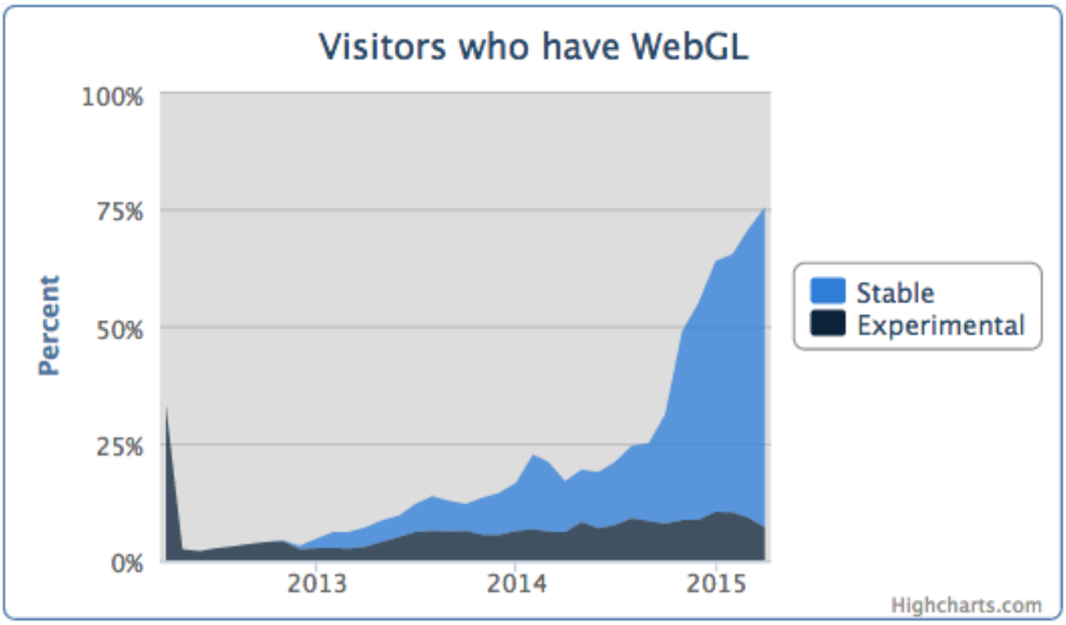

Figure 2-15 Percent of mobile visitors on websites that use the webglstats.com stat tracker, with WebGL capable phones

2.4 The Smart TV Experience

Even in the first days of TV, interactivity and two-way communication between the broadcaster and the viewers was something that many pioneers dared to dream (see section 2.2.2). The limitation of technology had made it impossible to materialise this vision at the time especially on a large scale, but experimenting was persistent while failures did not prevent its continuation.

Now, widely available Broadband Internet and affordable computing power, make these features easily available on new TV devices. The Smart TV has come to finally deliver the dreamed of interactivity to millions of users, and it is now mostly a matter of applications to utilise the technology to make a valuable service for the viewers which have now become users. In this section, we will explore the Smart TV experience, its current uses and how this is different from existing Internet experiences on Smartphones and Personal Computers.

2.4.1 Uses and Applications of Internet on the TV

It is no secret that Smart TVs have yet to find the so-called "killer app". This is a popular tech term for an application of a device that will attract millions of users to that device, in order to be able to use it (Investopedia). Regardless, the hardware cost drop allowed Smart TV features to be included in most new TV sets so, even without the killer app moment, the Smart TV user-base is constantly increasing (Figure 2-16).

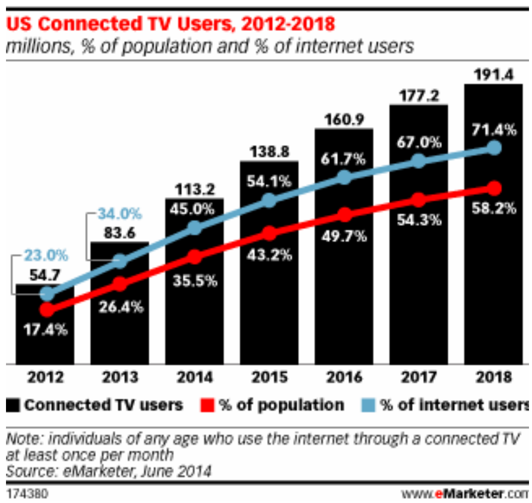

Figure 2-16 Projected increase of Connected TV users in US (eMarketer Inc, 2015)

2.4.2 Smart TVs: New uses, applications and research issues

The connected TV devices' interactivity and computing power have allowed a new breed of services on the television. Some of these are extending traditional TV programs with new functionality, some are direct transitions from services existing in Personal

Computers and mobile phones. In the following section, we describe some of these new uses of Smart TVs.

2.4.2.1 TV Apps

One of the most important features of Smartphones, which contributed in the popularisation of these devices, was the ability to download and run Mobile Apps, thus extending their capabilities. It also allowed for a healthy profitable ecosystem where developers provided useful Apps and users could instantly purchase them at a small cost. It was natural for TV devices, as soon as they got the computing power to be able to have some similar feature for downloading Apps. Much research has been done on the nature and usability aspects of TV Apps (e.g. Chorianopoulos and Geerts, 2011; LG Electronics, 2015; Samsung Electronics, 2016; Google, 2015). According to a Tomorrow Focus Media survey (2014), "almost one in two people use Smart TV Apps". The functionality of these Apps includes:

- watching web videos (e.g. YouTube, Vimeo etc),
- TV channel Apps, that allow to stream of watch videos from libraries of TV channels
- Music listening (e.g. Spotify)
- Web browsers
- Games
- Video chat (e.g. Skype)
- Social Media Services

Moreover, according to the same survey the most popular Apps for the Smart TV users where the ones used for watching videos (51.1%) and TV channel Apps (44.8%) while the least popular were for video chat (7.5%) and social media (8.2%).

All SmartTV manufacturers have some sort of App Store to download Apps and also maintain developer websites with instructions on how to design and develop TV Apps for their ecosystem (LG Electronics, 2015, Samsung, 2016, Google, 2015). TV App design and usability have also been studied academically, but this is not exactly a new field, as TV Apps generally share the same principles to Interactive TV Applications which have been studied extensively (Chorianopoulos and Geerts, 2011).

Most TV Apps run on full-screen mode, so the live TV content is hidden from view, but there are also Apps that only take a segment of the TV screen while the live TV content is displayed simultaneously. In general TV Apps run asynchronously and are agnostic of the live TV content being displayed on the TV set. However, research is being done for synchronizations between live TV content and TV Apps. For example, Strzebkowski et al (2014), propose a system where TV app content augments TV content and overlays relevant information either on the TV screen or a second-screen display, such as tablets and mobile phones (2014).

2.4.2.2 Electronic Program Guides (EPG)

Traditional TV has always been organised in a linear schedule, with predefined times when each show starts and ends. This is still common in TV channels, despite the fact that Internet bandwidth allows the asynchronous playing of videos. These TV station programs used to be printed in magazines but later appeared on News websites and the TV station's web pages. One of the popular uses of Teletext was also to display the TV schedule (Tanton, 1979). So, naturally one of the first uses of Interactive TV was the

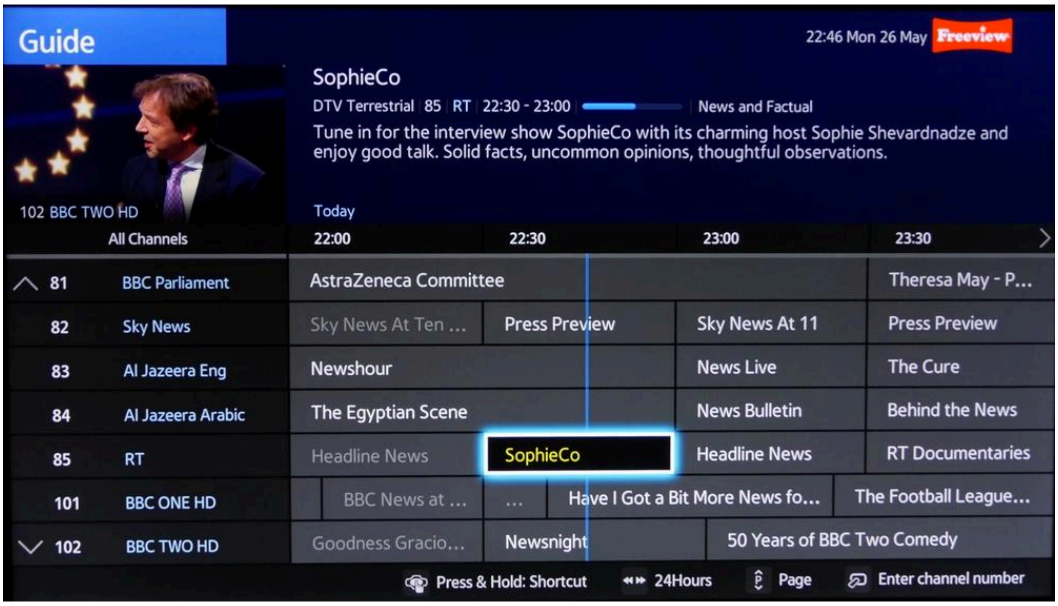

Figure 2-17 The Samsung Smart TV EPG (Hodgkinson, 2014)

Electronic Program Guides (EPGs), where TV programs are displayed directly on the TV. The vast increase in the number of channels with digital TV made EPGs a necessity. In many cases the specification of service information which could be used to render an EPG was built into the new broadcasting standards, such as the European Telecommunications Standard (ETSI, 2011). So, the pseudo-interactive capabilities of the Digital TV allowed the display of the EPG on demand. EPGs also allowed for the ability to schedule recordings of shows and display additional information about a film. It was obvious that the new Smart TV capabilities, with real interactivity through two-way communication and retrieval of data through the web, could enhance the functionality of EPGs even further, enabling non-linear play of shows, recommendation of shows, display even more information about a film, and more experimentally find relevant information to the show from web sources. A personalised EPG can therefore be created, by using web content such as the web's new semantic capabilities. In an example application of this, Stoneroos, a Dutch DTV company, developed a personalised program guide that uses XML TV (Bellekens et al., 2009). Indeed, most Smart TV vendors provide an EPG system on their Smart TVs which usually provides recording functionality (Figure 2-17).

2.4.2.3 Content Streaming & Video on Demand (VOD)

Video on Demand refers to the capability of viewing a video (i.e. a show or a film) when the user wants it, and not in the linear fashion of the traditional TV program. This usually comes at a cost, charged to the user per film. It was one of the most popular services of IPTV, streaming films on-demand from closed networks. Popular services like iTunes, Roku, BBC player allowed for this functionality through the Internet, thus bringing it to Smart TVs. Recently, content provider Netflix (Figure 2-18) has dramatically changed the VOD area, by allowing the viewer to watch any video s/he

Figure 2-18 Netflix on Smart TV (Nel, 2013)

wants without any extra charge, but with a fixed monthly subscription. This path was soon followed by other providers, such as Amazon Prime Video and Hulu. As this type of service was massively popular with users, even more traditional TV networks are introducing their versions (for example HBO Go).

Another popular VOD-style service is the streaming of YouTube and other online video content on Smart TV devices. This remains to this day, arguably the most popular use of Smart TVs, as several studies reveal (Nielsen, 2013; Tomorrow Focus Media, 2014; Deloitte, 2016). It is not, however, the typical VOD service as most videos are uploaded by users and are free to watch without any subscriptions but usually described as streaming. Streaming commonly utilizes a second device, in which the user finds the content that s/he is interested in (e.g. a mobile phone or tablet) and streams it via Bluetooth to his Smart TV device. The reason that a second device is utilized arguably has to do with the difficulty of use of the TV interface to actually find the content in the first place, a topic thoroughly analysed in many other parts of this thesis.

2.4.2.4 News & Sports

One of the most popular traditional uses of TV is to watch the news. This area has changed dramatically over the past few years as new Interactive Media and the Internet have altered the landscape significantly. The dominance of print and TV has decreased as Web media have taken over. According to Deloitte Media Consumer Survey in the

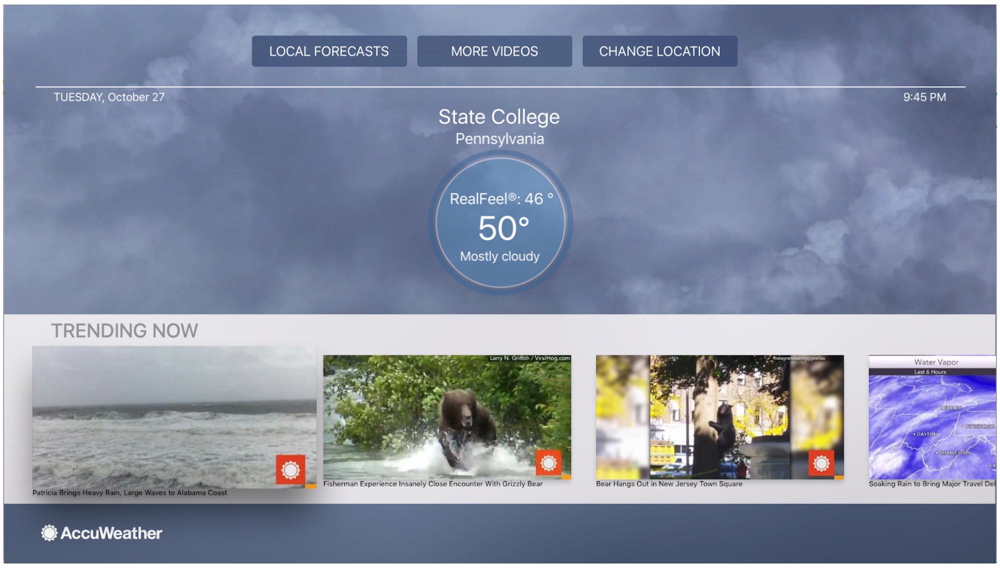

Figure 2-19 The AccuWeather app for Apple TV

UK (2013), "*PCs are now the favourite way to read news with only 39% preferring print, a staggering reduction from 75%*". New Smart TV capabilities can offer many Interactive Features to enhance the traditional TV news, and also provide more timely services, bypassing one of the major limitations of the TV news, which is the specific show times. Most news providers offer TV Apps for users to consume their content through them. According to the Tomorrow Focus Media Smart-TV Effects survey (2014): "*News and weather apps are the most commonly used apps*". Also, popular apps include information for sports such as MLB.tv for baseball and NBA Game Time. Figure 2-19 shows the AccuWeather app on an Apple TV device.

2.4.2.5 Social Media & Social TV

Smart TV vendors very often advertise the Social capabilities of Smart TVs. These allow Social Media content to be viewed from these devices and also perform actions such as Like, Share or even commenting based on the program being watched. Several social media research has taken place on an interactive TV domain with researchers trying to provide a more socialised experience for the Smart TV (Mate et al., 2010; Nathan et al., 2008). For instance, Park et al. (2011) created an application which captured a user's interactions during live game events, e.g. during a baseball game, while Viegas et al. (2012) propose a Multiplatform Social TV prototype where viewers can use emoticons to express their feelings towards what they are watching, and share

Figure 2-20 Samsung Social TV app showing relevant tweets to the US elections (Samsung,

this with their friends through social media. In another study, You et al. (2013) proposed a system which aims to offer strengthened EPG services such as EPG navigation, EPG recommendation, and EPG searching, all based on users' virtual social relationships. There were also commercial apps available that made Social TV available to TV viewers, for example Samsung Social TV (Figure 2-20).

Social TV capabilities however never seemed to capture the interest of the users (e.g. Tomorrow Focus Media, 2013:16). The reasons for this are numerous, but mostly have to do with the personal character of a Social Media account in contrast to the shared character of the TV device. As it is very common for many people on the same house to share a TV device, it is usually unwanted for others to be able to use one's social media account. Another problem is posed by the usability issues of the input devices, discussed elsewhere in this document, that make it very difficult for users to input text.

2.4.2.6 Games

Although the hardware of most Smart TV devices is not very powerful, especially compared to game consoles, this does not mean that is not enough for basic gaming Apps. So, even the most basic models include the ability to play games on the TV. As the hardware is getting more powerful, more demanding games are available on Smart TV devices. For example, PlayStation Now is a gaming app by Sony, which allows Samsung Smart TV owners to play classic PlayStation Games without needing a PlayStation device (Figure 2-21). Gaming has been a popular use of the large TV screen for quite a while, starting as early as the Atari set-top box back in the 1970s. A Smart

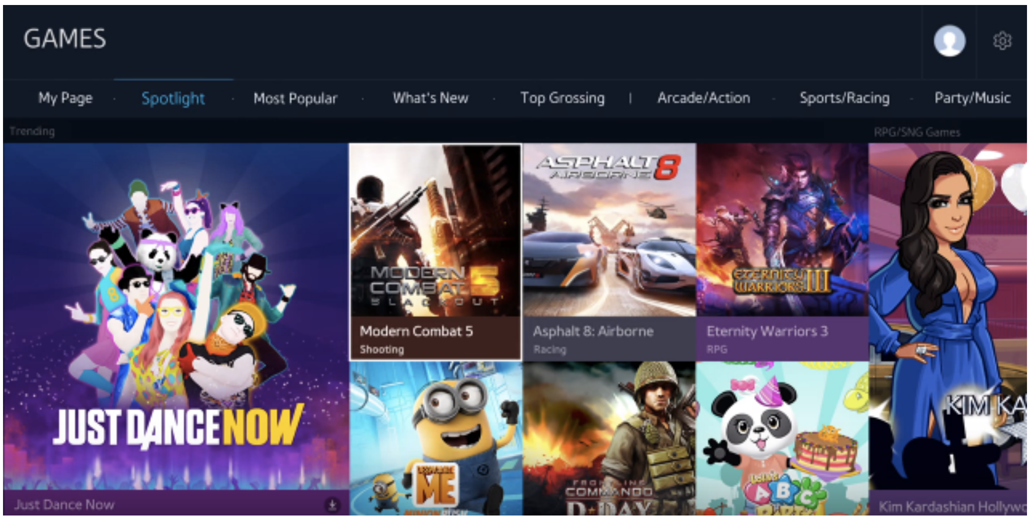

Figure 2-21 The Playstation Now gaming App on Samsung TV (Connolly, 2015)

TV is a great chance for some relaxing gaming time for the occasional gamer (Montejo, 2016), although more devoted gamers prefer more dedicated hardware connected to their TV screen, such as the latest gaming consoles.

2.4.2.7 Interactive Advertising

Unsurprisingly, one of the first fields of experimenting with Interactive TV was Interactive TV Advertising (iTV Ads). Content networks have been experimenting in this field, long before Smart TV devices hit the market and as soon as interactivity could be applied to Television. All iTV ad solutions allow for a more immersive advertising experience than a traditional :15 or :30 advertisement (IAB, 2011). The general form of an iTV ad contains an entry point and a micro-site/app. The entry point can be a banner placed somewhere in the Smart TV content (e.g. a menu, an app, a website) or a video in which the user can click a button during its playtime to enter the interactive content, i.e. the micro-site/app. This looks like a branded app where the user can learn more about the product for as long as s/he wishes and then s/he can exit and return to normal program flow. Companies are very interested in iTV advertising as it is likely to provide a new marketing tool to promote their products and services, so experimenting in the field is incessant. By 2017, with the video streaming quickly advancing to become the top source of video consumption, advertisers create interactive and targeted advertising for the audience to keep them engaged (AdWeek, 2017). Figure 2-22 shows a interactive TV ad from BrightLine.

Figure 2-22 An interactive TV ad from BrightLine (AdWeek, 2017)

2.4.2.8 Web browsing

As a fundamental capability of a Smart TV device is the connectivity to the Internet, it would be obvious that web browsing should be one of the vital functionalities of the device. As with any new platform, an initial caveat has to do with the limited availability of content. It is true that a web browser (Figure 2-23) is available on most Smart TV and Connected TV platforms, however, studies show that users do not use this feature very often (NPD, 2012; Nielsen, 2014). Given the fact that a full web browser gives the ability for users to browse the massive content on the entire web, this thesis explores thoroughly on the caveats that prevent them from using this and aims at providing guidelines for better TV web browsing experience.

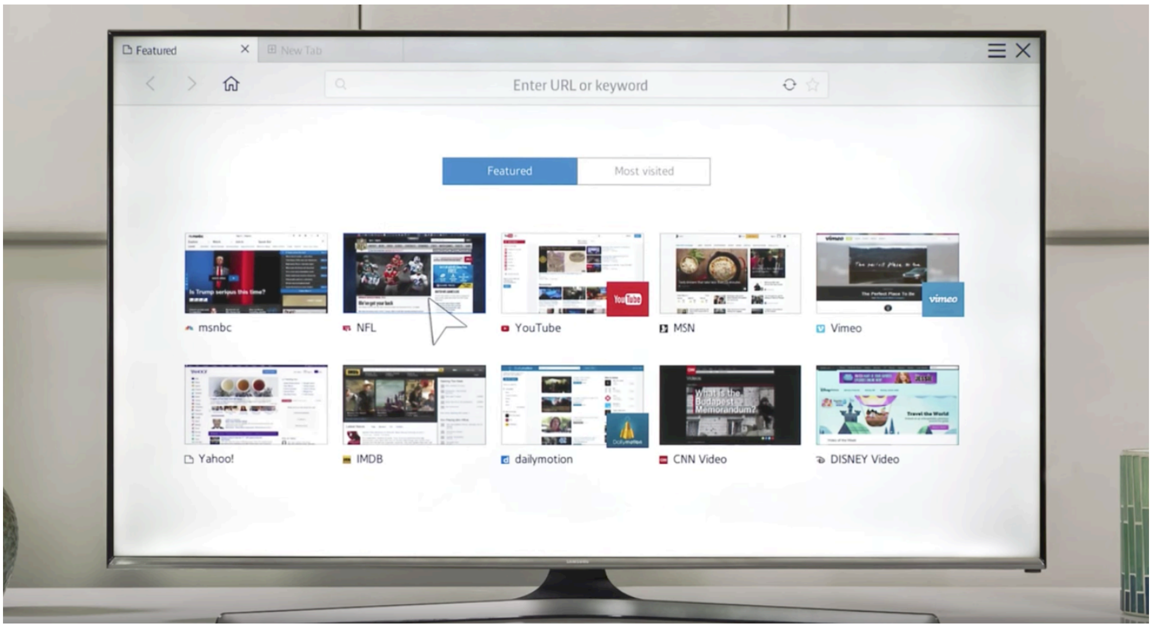

Figure 2-23 The web browser App on a Samsung Smart TV (Samsung SPSN, 2015)

2.5 TV Usability and User Experience

2.5.1 What is User Experience (UX)

In the field of Human-Computer Interaction, or better, Human-Device Interaction, as more computer-based devices are coming along, User Experience is a term that is getting increasingly popular with time. The previously most popular term in HCI was Usability, a much easier to describe and measure metric, as it could be evaluated with a series of relatively simple task-based actions by the users, and therefore find out the effectiveness of the User Interface Design of the system. Usability has an international standard definition in ISO 9241 (1998:11), which defines usability as the extent to which "*a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use*". There are many tests and methodologies available to evaluate the usability of computer-based systems, from software to websites to mobile applications, many options for measuring effectiveness and use the results for improvement.

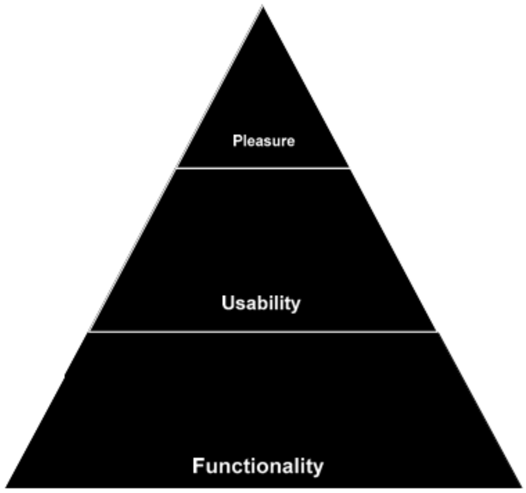

Figure 2-24 Hierarchical structure of UX qualities (Jordan and Persson, 2000)

UX on the other hand, is a more complicated concept as it includes usability but is affected by many other factors as well, while some of those are quite difficult to measure accurately. These factors can include **Functional Use Qualities**, which mean that the product offers beneficial value to the user, **Hedonic Use Qualities**, which describes the pleasure that the user feels when using the product, and also **Superfunctional Use Qualities**, such as aesthetics and semantics, that do not have an immediate instrumental value, nor are the primary goal of use, but do influence the UX (Knight, 2006). Jordan and Persson (2000) suggested a hierarchical structure of qualities that contribute to positive experience, with Functionality as the base followed by Usability and topped by Pleasure (Figure 2-24). Additionally, Karapanos et al. (2008) argued that there should be an additional factor of Time, pointing out that most UX studies evaluate the user's **First** experiences, while these change over time, as they get more used to the products.

Conclusively, UX is a broad term, that includes everything Usability is about as well as more, often more subjective, factors such as aesthetics, semantics, engageability etc. and refers to all aspects of someone's interaction with a product. *"Many people seem to think of the user experience as some nebulous quality that can't be measured or quantified".* (Tullis and Albert, 2008). There are however methodologies for evaluating User Experience, which will be presented later in this document.

2.5.2 Factors of User Experience

As discussed above, UX is affected by numerous factors, and, in this section, there will be an explanation of these and their effects on UX.

2.5.2.1 Usability

Most software is designed to be used by humans that interact with it through a User Interface, to aid them in the completion of some tasks. Usability of a software product has to do with the easiness that its users can complete their tasks.

2.5.2.2 Aesthetics

Looking up the word in the Oxford Dictionary it reads "*concerned with beauty or the appreciation of beauty*" and also "*giving or designed to give pleasure through beauty*". Aesthetic is derived from the Greek world *aisthētikos* which comes from *aisthesthai* meaning to *perceive. "The sense 'concerned with beauty' was coined in German in the mid 18th century and adopted into English in the early 19th century, but its use was controversial until much later in the century"* (Oxford Dictionaries, 2010).

Looking back in the early days of computing, beauty was definitely not an important concern for software design. One reason for that was that this was not even possible, since the graphical capabilities of computers were extremely limited. Even recently, and sometimes even today, there are developers that will argue about the importance of aesthetics in a computer application and it is a common anecdote about the limited aesthetics of computer programmers. The aesthetic issues of computer software however have been rapidly changing in the later years, as both scientific studies and market success has outlined the importance of aesthetically pleasure in both hardware and software products. **Apple Computers** is probably the most well-known pioneer in the creation of beautiful computer products, a trademark for the brand. The company actually was one of the first to release an HCI guide in 1987 (Apple Human Interface Guidelines), containing many of the principles used in computer interfaces for the following years, and even an early web design guide in 1996 (Apple Web Design Guide). Numerous scientific studies have also outlined the importance of Aesthetics in UX (Coursaris & Kripintris, 2012; Tuch et al., 2012; SEO et al., 2014).

2.5.2.3 Engageability

Engageability is also an interesting UX factor beyond usability, meaning that the user of the system has "engaged" his/her attention to the system, sometimes in such amounts that s/he becomes ignorant of the actual location s/he is in, and the sense of time is also becoming distorted. This notion is usually true, and sought after, in certain applications, such as Computer Games. Many researchers argue for design to go beyond usability and there is a consensus to move to hedonic use qualities. Csikszentmihalyi (1991:71) describes qualities of optimal experience and flow: "*A sense that one's skills are adequate to cope with the challenges at hand, in a goal-directed, rule-bound action system that provides clear rules as to how well one is performing. Concentration is so intense that there is no attention left over to think about anything irrelevant, or to worry about problems. Self-consciousness disappears, and the sense of timing becomes distorted".* Knight (2006) suggests that HCI research and design should be widened into the realms of emotion to achieve more engaging products and services with richer interactions. Engagement also requires an ethical and aesthetic approach to design, but including human values can produce better products and transformative qualities as well. In an online study by Tullis and Albert (2008:159), they defined an engaging website as one that (1) stimulates your interest and curiosity, (2) makes you want to explore the site further, and (3) makes you want to revisit the site.

2.5.3 User Experience in Web Design

Chalmers (2005) studied users' emotions while trying to find information on two websites, one with high usability score and another with low. The same information existed on both websites and participants reported their frequency of excitement, satisfaction, fatigue, boredom, confusion, disorientation, anxiety, and frustration. Results, unsurprisingly, favoured the site scoring high on usability.

2.5.4 Input devices & Remote Controls

Since the iTV platforms are interactive, there must always be some device that is used to control the device and the content. In this area, there is again an absence of standards and each device uses quite different remote controls, which vary from PC-like full-qwerty keyboards to very simple TV-like remotes, and, also, game controllers in the case of game-console devices. It is also important to note that most platforms have Mobile Apps available to fully control them through a smartphone.

2.5.5 Second screen experience

Second screen experience refers to the use of another device, usually a mobile phone or tablet, in combination to the Smart TV. The use of the second device is usually to find the content that the user wants and then choose to stream it to the larger TV screen. The reason for using a second device has to do with convenience, as the interfaces of mobile devices have proved to be much more efficient and user friendly than Smart TVs. On the other hand, their screens cannot compete in size with the TV, so watching larger videos is inconvenient on the small screens, so TV is preferred.

2.5.6 Responsive Web design

Responsive web design is a term introduced by Ethan Marcotte in 2010, to describe a way to make web sites friendlier to different viewing devices (Marcotte, 2010). The term, as Marcotte explains, was adapted from the field of Architecture, where it describes an experimental technique for buildings to respond to the people passing through them (e.g. by automatically adjusting lighting and temperature to using robotics to change structures instantly). This technique became increasingly popular the years to follow as the market share of mobile devices and their use for Internet browsing increased.

Much has been published on Responsive Design (Marcotte, 2011; Frain, 2012; Smashing Magazine, 2014) to describe the details of applying this technique to web sites using HTML, CSS and JavaScript web technologies. Nowadays it has become a standard in most new website designs to be able to “respond” to the user’s device. This technique is usually preferred to the “mobile-version” technique, which works by designing two completely separate versions of a website for Desktop and Mobile. One very important reason is that it needs more resources to maintain two websites than one, as it is a very common issue to maintain the main website with new features while leaving the mobile-site behind due to lack of time and resources (Barret, 2015).

Even in the original 2010 article by Marcotte, the author refers to TV game consoles, as another type of device, in addition to mobiles, to browse the web, and a field where responsive web design would be useful. Responsive device for TV however, hasn't been explored to much extent to this day, maybe because TV devices have not yet made enough impact as a popular device to browse web sites.

2.6 Research Aims and Objectives

2.6.1 Motivation

The transition of popular devices to more "smart" incarnations is something that has become ubiquitous over the past few years. "Smart" is used as a term to describe functionality previously only available on personal computers, such as interactivity with content, connectivity features, software upgrades, Apps etc. One barely remembers the time, less than a decade ago, when mobile phones were only used for calling and texting one's peers. Now, a mobile phone is a personal computer, connected to the Internet most of the time, performing almost any task a desktop computer can. Moreover, with the advent of the Internet of Things, "smart" features are being exploited in cars, home appliances, cameras, and even on our watches, glasses, and many more to come (Miller, 2015).

One of the first devices that became "Smart", just after the mobile phones, was the television. A traditional device which had not changed much for many years suddenly expanded its capabilities to TV Apps, Internet browsing, Skype calls and many more. Indeed, most televisions currently sold are Smart TVs - for example, in the defining market of China, 80% of TV sales in 2015 were smart TVs (YuMi, 2016). These devices have their own operating system and 4-core processors, much like a computer or a mobile phone. Samsung currently has a clear advantage on worldwide Market Share with 28.2% of devices followed by LG Electronics (15.2%), Sony (7.6%), Hisense (6.7%) and Skyworth (6.7%) (BusinessKorea, 2015).

So, has this transition of the TV been as successful as the one in mobile phones? Many surveys hint that this enhancement of the TV experience with Internet connectivity is not nearly as successful as sales figures suggest, with most users ignoring their TV's new abilities. Whilst buyers seem eager and excited to buy a TV with Internet connectivity, after they have owned the Smart TV for a while they do not seem to use these abilities at all, or at best they use a minimal subset, such as streaming videos from their mobile devices to the big screen (Tomorrow Focus Media, 2014; Nielsen, 2013).

A survey in Germany (Tomorrow Focus Media, 2014) indicates that only 1 out of 4 Smart TV owners use their device to go online and browse the Internet, providing an explanation that "many responders find the use of the Internet with the smart TV very inconvenient". The main reasons behind this are that it is inconvenient to browse the Internet with the remote control (79.6%), and the browser has limited capabilities (63.1%). A 2013 study by Nielsen (Nielsen, 2013) in Australia found that ownership of Smart TVs had increased significantly and that 33% of Australian homes owned TVs connected to the Internet. However, only 5% of them use this feature on a regular basis, a much lower percentage compared to all other devices in the same survey (38% for Mobile phones, 68% for desktop and 65% for laptops). According to the Australian Connected Consumer Report (Nielsen, 2013), the key barriers of users employing the Internet capabilities of their Smart TV devices are: the lack of interest, lack of know-how, bad UX (user experience), a slow connection speed and a lack of interesting content/Apps. With very few exceptions (e.g. YouTube and a few News and Sports Apps) most of the web, although accessible, is being ignored by Smart TV users. Another report by the NPD group in North America (NPD Connected Intelligence, 2012), highlights that the main Smart TV feature that is employed is actually watching videos on a big screen (70%). Web Browsing activity only captures the interest of 10% of the users, while other functionality such as Social Media, Shopping, Maps etc. have an even lower than 10% usage.

In contrast to the current highlighted issues in respect of user acceptance, manufacturers continue to develop new Smart TV devices, as well as improving their Web Browsers. However, it is also relevant to recall that smartphones also took a number of years to adapt to Internet features, with many failures on the way. Moreover, the wealth of the Internet content and services arguably has many benefits to provide to Smart TVs, such as online video, so it is no surprise that most viewers are still interested in this functionality. Hopefully, Smart TVs are going to follow the same route as smartphones, since technology is improving and also content (and web sites) are increasingly becoming TV optimised. Recent surveys bear this out: a recent Nielsen North-American survey reveals an increase in Smart TV enabled households of +78% for Q3 2014 compared to the same quarter in 2013 (Nielsen, 2014). A clear advantage of Smart TV devices is the large screen, which makes these devices ideal for browsing multimedia content such as images and videos (Jeong & Lee, 2011). This kind of content resides on many websites and Smart TV users can gain access to all this just by using their web browser. However – and arguably so - the most pressing problem of using multimedia content through a Smart TV is the problematic user interface, which can decrease the level of user satisfaction with the new Smart TV capabilities (Jeong et al., 2011).

2.6.2 Research Question

From consumer surveys, as the ones described in 2.6.1, it is clear that Smart TV users are not content with the Internet capabilities of their TVs, which results in not using these at all in many cases. Their main complaints are concerned with UX and usability aspects, as well as the lack of content. The problems are identified on the hardware side, especially in respect of input/control devices, and on the software side, namely the lack of content, and the bad UX.

In this thesis, we focus on ways to improve the usability on the software side. As millions of TV devices are already owned by consumers, we try to find a way to address the problem given the existing hardware capabilities and limitations of the devices, thus focusing mostly on content. Given that Smart TVs are connected to the Internet and have a web browser, practically the content available to these devices is the entire web itself. However, as the content is not optimised for TV, it is no surprise that, although devices have a browser capable of displaying it, users are not interested in accessing it through their TVs. Responsive Web Design has been utilised in the past, in exactly the same way to greatly improve the UX and usability of mobile phones accessing the web. Besides, the current trend for Smart TV content is clearly favouring HTML-based applications, as does the Smart TV Alliance, while standards like HbbTV 2.0 are converging with HTML5 (HbbTV, 2016). Even the SDKs provided from Smart TV manufacturers have switched from traditional programming languages (e.g. Java) to HTML5 technologies (Samsung, 2014; LG Electronics, 2014).

So, in brief, we defined the following research aim for this work:

Propose and assess techniques to develop a set of guidelines that web designers can use to improve their web content, with minimal effort in resources, in order to be exploited to Smart TV devices with better usability and experience for the users, regardless of which of the numerous different TV platforms and technologies they use.

In order to achieve this, the following objectives need to be fulfilled, as described in detail in the following chapters:

Objective 1: Explore the feasibility of developing web-based interactive ads that will be compatible with all Smart TV platforms and provide a seamless viewers perception regardless of the capabilities of his device.

In Chapter 4 we propose such a system and develop a prototype using only standard Web Technologies, that possess all the features of enhanced interactive TV ads, and put it to the test to ensure that users have a seamless experience across different devices. Interactive TV Ads are used as a representative category of Smart TV web applications. It is a good characteristic example of a TV app since it uses numerous features such as animation, video, subtitles, audio and interactivity. So it's a baseline for other TV apps that usually use a subset of these features. A more detailed description of Interactive TV Ads and other TV app categories can be found in section 2.4.2.

Objective 2: Investigate the possibility to have real-time 3D implemented on Web, so that different Smart TVs with different capabilities can view it and interact with it.

In Chapter 5 we evaluate the Web3D performance of representative Smart TV devices by performing numerous 3D benchmarks and a basic prototype was developed to test the application of the proposed guidelines for cross-platform Smart TV 3D apps.

Objective 3: Asses the current adaption of popular websites in terms of compatibility with Smart TVs in comparison to Mobile devices.

In chapter 6 we studied the 50 most visited websites world-wide, according to Alexa research, to evaluate their compatibility with Mobile, Tablet and Smart TV devices. The findings of the study clearly showed that although the website designers give great importance to mobile user experience of their website, they ignore the Smart TV optimizations in most cases, leading to very bad usability on these devices.

Objective 4: Explore the possibility of exploiting Responsive Web Design, a standard technique for mobile website optimization, to the Smart TV, in order to achieve better usability and user experience while making more content available in a better way to these devices.

As we have seen in Chapter 6, RWD has not been adopted for TVs yet. The challenges for the best adoption of this model for the TV experience are explored and methodologies for the best application of this technique are outlined. The resulting prototype system has been tested for compatibility across different TV platforms to make sure is cross-platform as intended. Then, a user study was performed to put it to the test against the normal non-optimized website on a Smart TV. The results are explicitly outlined, showing the aspects in which, the experience of the users was enhanced.

Objective 5: Propose a set of guidelines, which can be applied to either new or existing websites, for improving usability and user experience of web content on a Smart TV environment.

Our ultimate goal is that by adopting these techniques, it will be a first important step in more accessible web content from Smart TV users and it will significantly contribute in the evolution of Smart TV as web access devices. Chapter 8 combines findings from all other objectives into a set of comprehensive guidelines.

These objectives will be steps toward achieving our aim: Objectives 1 and 2 will use two representative examples of TV apps (Interactive Ads and more demanding 3D apps) in different Smart TV platforms, Objectives 3 and 4 will expand the scope to more generalized use cases of websites, not just specific ads, while Objective 5 will combine all these results from the previous experiments in an easy to reference set of guidelines, as required by our aim.

2.7 Conclusion

In this chapter we have gone through a brief history of TV, from the first analogue models to the latest Internet Connected TVs (Smart TVs) and explored their interactive features as these developed. We have also explored the most common Applications of SmartTVs. Next, focusing on the experience of the users, we quoted many consumer and user studies that reveal several important shortcomings of these devices. This led to our motivation for this research work, which is clearly laid out as our research question. To answer this question, we have defined 5 objectives, as described in the previous section, which will be met in chapters 4 to 8. But first, the following chapter will outline the research methodology used to reach these objectives.

Chapter 3 - Research Methodology

3.1 Introduction

In chapter 2, the research aim and the five objectives of this study have been clearly defined. In this chapter, we will describe different methodologies to achieve our research objectives, especially regarding the evaluation of aspects of user experience, such as usability, as well as evaluation methods used in advertising to assess a TV ad. We will also justify on which of these methods we chose to use in our experiments. Additionally, we will elaborate on sampling and statistical analysis, and also present the different devices we used. Finally, a discussion about field studies vs laboratory studies is justifying our experimental choice.

3.2 User-Centered Design

User-Centered Design (UCD) or Human-Centered Design is an approach to interactive system development that focuses specifically on making systems usable and optimized for their users (W3C, 2008). The users are in the center of the system, and everything works and adapts in favour of the user to have an optimal experience. So, this is different to the older approach of the users adapting their behaviour to be able to use the system. The term was introduced by Donald Norman in the 1980s and described further in his book entitled: User-Centered System Design: New Perspectives on Human-Computer Interaction (Norman & Draper, 1986).

Users can be involved during the design and development of the system in several ways, such as interviews and questionnairs in the beginning of the design project, in order to identify needs and problems of existing systems, to Usability and UX testing in the final stages, to evaluate the success of the design and perform improvements before the final release (Preece et al., 2002). In todays systems (e.g. Apps and Websites), the process can continue even after a product is released, in order to introduce further improvements in subsequent releases, which can be deployed very frequently and even automatically.

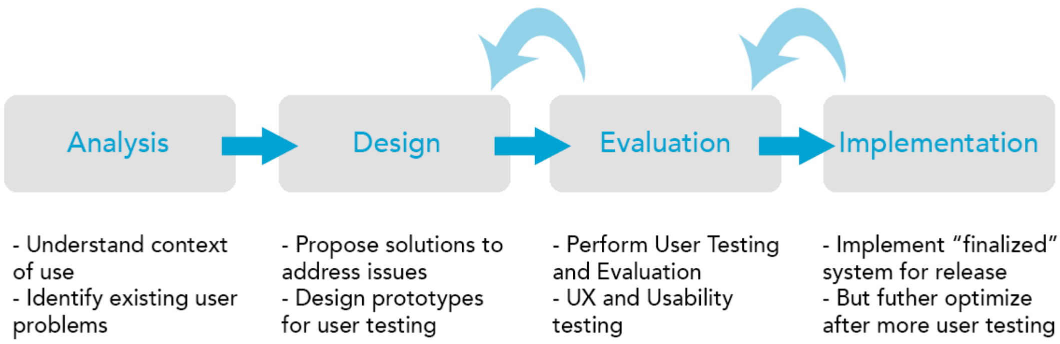

Figure 3-1 An approach in User-Centered Design process

In Figure 3-1, a typical User-Centered Design Process is outlined: It begins with **Analysis** of the project by understanding the context of its use and identifying existing user problems from previous approaches. In the **Design** phase, solutions are proposed and one or more prototypes can be designed to be **Evaluated** by the users in the next phase using UX and Usability tests. The prototype is not a finalized product and could be a "dummy" in terms of actualy performing all the system tasks, but it has to be as close as possible to the final product in terms of user interaction for more accurate results. Note the backward arrow at the top, which means that if the results are not satisfying it is common to repeat the Design process for to procude improved prototypes until optimal performance is met. When a prototype is satisfying to the users, then further **Implementation** is done to complete the fully functional product to be released to the wider audience. Again, this process does not mean the end of the system cycle, as user-testing can continue with a wider audience, using various recording and analytics tools to identify further UX shortcommings and improve the system for better upgraded versions.

3.3 Evaluating User Experience

"User research is the systematic study of the goals, needs, and capabilities of users so as to specify design, construction, or improvement of tools to benefit how users work and live" (Schumacher, 2010).

3.3.1 Measuring Usability

Designing a usability study has many factors to be considered. According to Tullis and Albert (2008) a well-designed and though-out study will effectively answer your research questions clearly while a poorly designed one can result in a waste of time, money and effort without getting the needed answers. To design a good usability study the following must be answered priory:

- Sampling: The type of participants needed.
- Sample size: The number of participants needed.
- The groups of participants to be compared or a single group
- Counterbalance on the order of tasks.

User Performance, Efficiency and Satisfaction are different aspects of usability that sometimes (surprisingly) do not correlate. Performance has to do with how fast and well has a user actually performed a task, while Satisfaction has to do with what the user actually thought about his/her interaction with the product. It's evident that satisfaction is more subjective and has also to do with values such as the design and aesthetics of the product. *"Unless domain specific studies suggest otherwise, effectiveness, efficiency, and satisfaction should be considered independent aspect of usability and all be included in*
usability testing" (Frøkj a er et al., 2000) .
The types of data that can be gathered in such studies include Nominal data (e.g. task success), Ordinal data (e.g. ratings, rankings), Interval data (for example using the Likert scale) and Ratio data (completion time, average task success etc). Different tests gather different types of data. There are hundreds of different usability tests that can differ quite vastly, but in general can be categorised as (Tullis and Albert, 2008) :

- **Post-Session Self-Reported**: There are mainly questionnaires that are answered by a number of participants after they are asked to perform some tasks according to a system use scenario.
- **Usability Issue Based**: In these tests, usability experts are expected to use and analyse a system and identify the usability problems (issues) the system has. The issues can also be identified by groups of users.
- **User Performance Based**: Measure the performance of the users while using the system. Some basic performance metrics include Task Success, Time-on-task, Errors during the task, Efficiency (amount of effort for a task, e.g. number of clicks in a website) and Learnability over time.

- **Behavioural Metrics:** Sometimes, taking note of indirect aspects of a participant's behaviour during his/her session of interaction with the system, can help in measuring its usability/UX. Their reactions can include smiles, laughs, grimace, groans, nervous shaking of their legs etc. Observing these can help the expert to possibly identify UX issues that would not be seen in a self-reported questionnaire.
- **Sensory Input**: Specialty equipment can be utilised, such as eye-trackers, in order to capture the user's real-time interaction to a system. Other examples include facial expressions, pupil dilation, heart-rate and even brain-wave analysis.

Combining the aforementioned categories of tests is not rare and can drive to more complete studies.

3.3.2 Post-Session Self-Reported Usability Tests

This is one of the most popular methods for gathering usability data mostly through questionnaires. The participants are asked to fill-in a questionnaire after they have finished their interaction with the system, performing specific tasks according to a scenario set by the experiment methodology. Interaction scenarios usually include a number of tasks that outline some of the most representing aspects of the system. The questionnaires can be filled in with the user responses in various ways: on paper by the participants, verbally by the participants while the lab staff fills in the questionnaires or on the computer screen either on-line or off-line. Most questionnaires prefer the user's answer to come using rating scales, but it is also quite common to include some open-ended questions in addition to the rating scales. Although the open-ended questions cannot contribute to the quantitative data, in some cases can provide useful ideas about the improvement of certain aspects of the product (Tullis & Albert, 2008).

3.3.2.1 Rating Scales & Rating Statements

One of the most efficient ways to capture **self-reported** data in a usability test is by using a rating scale. Giving the users free-text questions will be very difficult to process, analyse and visualise later. Two of the most popular rating scales are the Likert (1932) and the Semantic Differential Scales. A Likert scale typically work by giving a statement to the participant, which may be positive or negative and s/he will use a n-point scale (usually 5 or 7-points) to indicate his/her agreement. When designing the statements, it is important to avoid adverbs like very, amazing, extremely etc. because it will bias the answers, as the participants will avoid the absolutely opposite statement. For example, the statement "This is a useful application" will work better than "This is an amazingly useful application" which will possibly refrain the users from strong disagreement.

Another popular rating scale, the Semantic Differential Scale, was developed by Osgood et al. in 1957. It involves, presenting pairs of opposite adjectives at either end of the scale (e.g. Weak…Strong, Hot…Cold, Beautiful…Ugly, Friendly…Hostile etc.). As with the Likert scale, 5 or 7-point scale can be used. The difficult part in using this scale is in finding truly opposite adjectives, while the choice of pairs will not give the same answers in most occasions (e.g. a pair of Friendly…Unfriendly will possibly give different results from Friendly…Hostile).

The After-Scenario Questionnaire (ASQ) was developed by Lewis (1991) and provides a set of three statements for use after the user has completed a set of tasks on a usability test scenario. The three statements are:

1. ''I am satisfied with the ease of completing the tasks in this scenario.''
2. ''I am satisfied with the amount of time it took to complete the tasks in this scenario.''
3. ''I am satisfied with the support information (online help, messages, documentation) when completing the tasks.''

Each one of the ASQ questions targets the three fundamental areas of usability: effectiveness, efficiency and satisfaction.

3.3.2.2 The System Usability Scale (SUS)

Possible the most popular questionnaire for measuring usability is the System Usability Scale (SUS) by John Brooke (1996), first developed in 1986. Although, it was initially utilised for old technology Terminal "Green-Screen" systems, it has proven very technology independent and was later used in modern software, hardware, web-sites, cell-phones and many other systems. It is a "quick and dirty" method, using the least possible number of questions to quickly and easily asses the usability of product or service.

Accordingly, SUS is a 10 item questionnaire utilizing the Likert scale for the user's response with 5 options (1-5, Strongly Disagree to Strongly Agree). The ten questions are:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

And the user has to respond in each of these using the following scale:

Strongly Disagree 1	2	3	4	Strongly Agree 5
○	○	○	○	○

The final SUS score for the test can be calculated using the following algorithm:

- For odd items: subtract one from the user response.
- For even-numbered items: subtract the user responses from 5
- This scales all values from 0 to 4 (with four being the most positive response).
- Add up the converted responses for each user and multiply that total by 2.5. This converts the range of possible values from 0 to 100 instead of from 0 to 40.

According to Sauro, who studied 500 evaluations using the SUS, the average SUS score was calculated to be 68. Any score above 68 should be considered as above average, while scoring lower than that means that usability must be improved. Although the maximum score is 100, it is virtually impossible to be attained and a score above 80.3 is considered an A grade in usability (Sauro, 2011).

Originally, the SUS was used to determine a single usability and satisfaction score for a product. However, Bangor et al. (2008), after studying 10 years of SUS data, have identified six major ways that the SUS can be used to positively supplement a usability testing and evaluation program. These are:

1. Providing a point estimate measure of usability and customer satisfaction
2. Comparing different tasks within the same interface:
3. Comparing iterative versions of the same system
4. Comparing competing implementations of a system:
5. Competitive assessment of comparable user interfaces
6. Comparing different interface technologies

Conclusively, SUS is an effective method for quickly evaluating the usability of a product. However, as with any metric, the SUS score should not be used in isolation to make absolute judgments about the "goodness" of a given product. Factors such as success rate and the nature of the failures observed when the system was tested with representative users should play a large part in determining how usable a product is (ISO, 1998).

3.3.2.3 Computer System Usability Questionnaire (CSUQ)

CSUQ was developed by Jim Lewis (1995) for evaluating the usability of a computer system. It consists of 19 statements that the user rates on a 7-point Likert scale, plus the option of N/A. It is similar to SUS, however all statements are worded positively. The questionnaire examines four main usability aspects: System Usefulness, Information Quality, Interface Quality and Overall Satisfaction. In addition to the 19 questions, two extra free-text questions are assessed for the users to list the three most negative and the three most positive aspects of the system. An online version of the questionnaire is available at http://hcibib.org/perlman/question.cgi where the user can complete it and email it.

3.3.2.4 Usefulness, Satisfaction and Ease of Use Questionnaire (USE)

The USE questionnaire consists of 30 rating scales divided into four categories: Usefulness, Satisfaction, Ease of Use and Ease of Learning (Lund, 2001). For each positive statement the user must indicate the level of agreements using a 7-point Likert scale. Lund found out that 21 of the 30 scales had the highest weights for each of the categories, contributing more to the results.

3.3.2.5 Questionnaire for User Interface Satisfaction (QUIS)

QUIS (Chin et al., 1988), consists of 27 questions. Each question is rated on a ten-point scale with appropriate anchors at each end (terrible/worderful, frustrating/satisfying, difficult/easy etc.). The questions are divided into five categories:

- Overall Reactions to the System: Includes no questions just opposite adjectives, e.g. difficult/easy, rigid/flexible
- Screen: Addresses the visual presence of the system, e.g. Characters on the computer screen (hard to read/easy to read)
- Terminology and System Information: e.g. Position of messages on screen (inconsistent/consistent)
- Learning: e.g. Learning to operate the system (difficult/easy)
- System Capabilities: Has to do with smooth system operation. For example: System Speed (too slow/fast enough)

3.3.2.6 Product Reaction Cards

An alternative approach for usability evaluation comes from Microsoft (Benedeck & Miner, 2002). It includes a set of 118 cards containing both positive and negative adjectives that users can choose to describe a product. These include words like: Accessible, Creative, Fast, Slow, Stable, Unstable, Boring, Old, Fun, Stressful etc. Participants are asked to first choose all the cards that they feel that describe the system and then choose the top five more relevant ones, explaining the reason for their choice. This use of free-text obviously makes this method more qualitative and harder to analyse than other more quantitative test previously discussed. However, the researchers can use this in a quantitative way by counting the number that each adjective is chosen by the participants.

3.3.3 Comparison of Usability Tests and Sample Sizes

Tullis and Stetson (2004) conducted a comparison study of SUS, QUIS, CSUQ, Product Reaction Cards questionnaires as well as their own questionnaire. For the study two well-known financial websites were chosen and the scenario asked participants to perform two actions on these websites. 123 participants took part, and different questionnaires were randomly assigned to them. All five questionnaires revealed that one site was significantly preferred over the other. An interesting aspect of the study was that the data was analysed to see the effect of different sample sizes (number of participants to the test) on the results. This showed that 6 participants were inadequate to identify one site as significantly preferred over the other, as only 30-40% of them indicated that. By increasing the sample size to 12, most of the data reached an apparent asymptote to the full sample of 14 (Figure 3-2). As far as the reliability of the different tests is concerned, the study concludes that SUS, one of the oldest test and with only 10 rating scales, yielded among the most reliable results across sample sizes. Also, all tests managed to identify more or less the "best" website with a sample size of 12 participants.

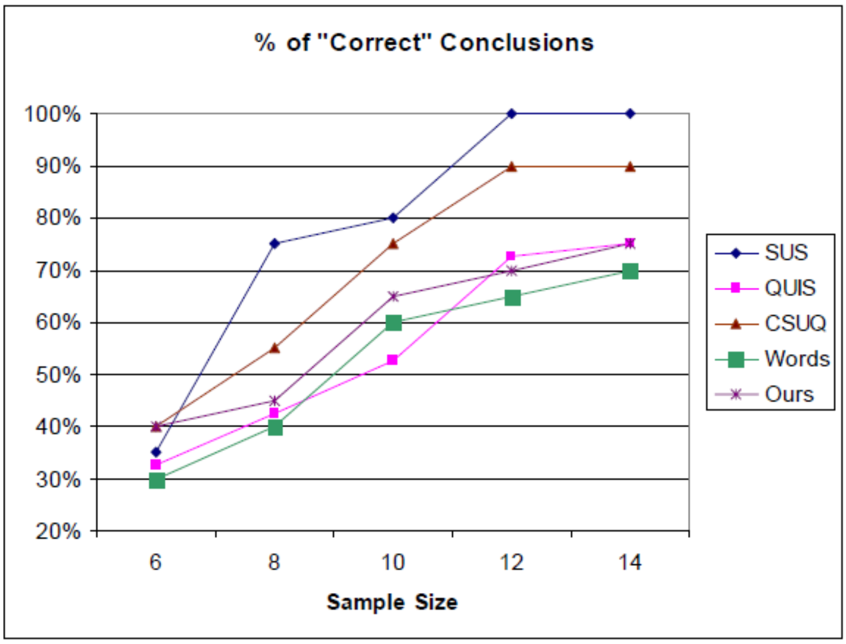

Figure 3-2 Comparison of % "Correct" Conclusions in various usability tests with different sample sizes. Tullis and Stetson (2004)

3.4 UX Testing for the Interactive TV

It would not be efficient to conduct evaluation studies in a platform without carefully noticing its distinct features. It's true that most usability tests were designed with the typical computer system in mind, but can be used for other systems as well, although not without modifications. A web service for example, does not share the exact same features to a native PC software application, as, for example, load times, browsers, security access limitations etc. can play a major role in its evaluation. Different devices can differ even more. A typical example is the Mobile Phone and the PC. There are many differences in key user experience factors between these two devices, such as Screen Size and Input Methods and even the user's location (home/work or on the move) that cannot be disregarded in a UX study. Chorianopoulos and Spinellis (2006) argue that ITV applications must be evaluated with consideration for the ordinary TV viewer, not for the computer literate user, or else a great part of the TV audience will be excluded from easily accessing to these services. The Interactive Internet TV is also

Scale	Original Anchors	Translated Anchors
Hedonic quality–identification (HQI)		
HQI_1	Isolierend—verbindend	Isolating—integrating
HQI_2	Laienhaft—fachmännisch	Amateurish—professional
HQI_3	Stillos—stilvoll	Gaudy—classy
HQI_4	Minderwertig—wertvoll	Cheap—valuable
HQI_5	Ausgrenzend—einbeziehend	Noninclusive—inclusive
HQI_6	trennt mich von Leuten—bringt mich den Leuten näher	Takes me distant from people—brings me closer to people
HQI_7	Nicht vorzeigbar—vorzeigbar	Unpresentable—presentable
Hedonic quality–stimulation (HQS)		
HQS_1	Konventionell—originell	Typical—original
HQS_2	Phantasielos—kreativ	Standard—creative
HQS_3	Vorsichtig—mutig	Cautious—courageous
HQS_4	Konservativ—innovativ	Conservative—innovative
HQS_5	Lahm—fesselnd	Lame—exciting
HQS_6	Harmlos—herausfordernd	Easy—challenging
HQS_7	Herkömmlich—neuartig	Commonplace—new
Pragmatic quality (PQ)		
PQ_1	Technisch—menschlich	Technical—human
PQ_2	Kompliziert—einfach	Complicated—simple
PQ_3	Unpraktisch—praktisch	Impractical—practical
PQ_4	Umständlich—direkt	Cumbersome—direct
PQ_5	Unberechenbar—voraussagbar	Unpredictable—predictable
PQ_6	Verwirrend—übersichtlich	Confusing—clear
PQ_7	Widerspenstig—handhabbar	Unruly—manageable
Evaluational constructs		
Beauty	Hässlich—schön	Ugly—beautiful
Goodness	Schlecht—gut	Bad—good

Figure 3-3 The AttrakDiff questionnaire's bipolar verbal anchors (Hassenzahl et al., 2003)

a very different system from a typical PC device in terms of UX. Differences include both technical (e.g. input methods, Screen Size, hardware limitations, bandwidth) and user oriented (e.g. usually many users instead of one, living room comfort instead of desk, relaxed state instead of stimulated, etc.).

There is a variety of UX evaluation methods that go beyond the task-based approach, and can be utilised for the iTV device. Hassenzahl et al (2003) proposed the AttrakDiff questionnaire (Figure 3.3) to measure perceived pragmatic quality (PQ), perceived hedonic quality-stimulation(HQS) and perceived hedonic quality-identification (HQI). The questionnaire consists of 21 7-point scale bipolar verbal anchors. HQI, HQS and PQ scores are calculated by averaging the respective item values per participant. "*A high HQI score means a high perceived capability of communicating identity to others. HQI attributes are primarily social (i.e. outwards). A high HQS score implies a high degree of perceived novelty, stimulation and challenge. HQS attributes are primarily related to personal growth (i.e., inwards). A high PQ score primarily implies high usability. In addition, the evaluative constructs beauty as well as goodness was measured with a single 7-point differential item each" (Hassenzahl, 2009)*.

Desmet et al. (2001) developed the Emocards concept (Figure 3-4), which consisted of 16 cards depicting cartoon faces with 8 distinct emotional expressions (8 male and 8 female). These expressions vary on the basis of the dimensions 'pleasantness' and

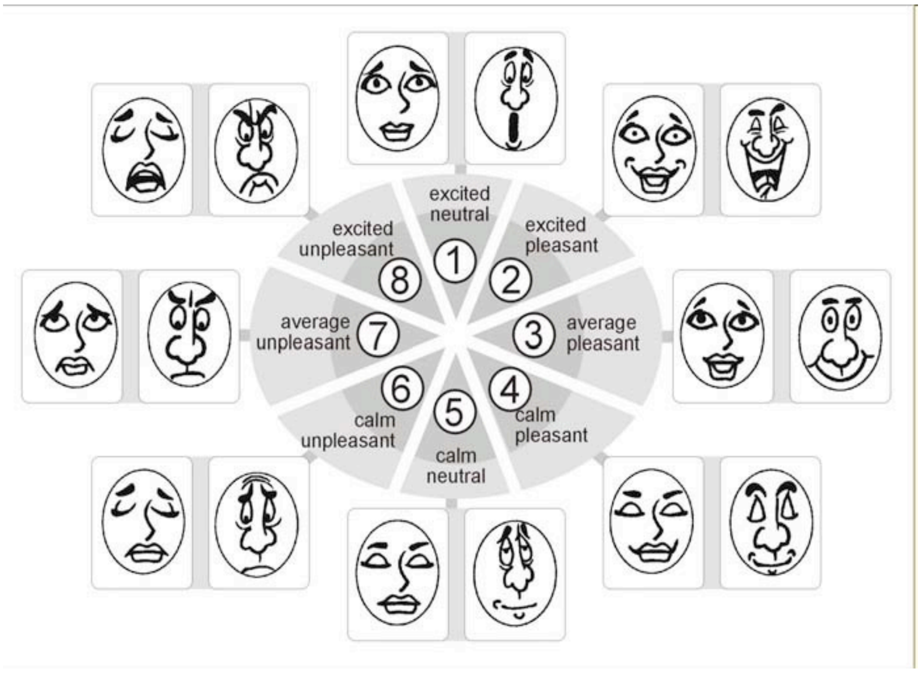

Figure 3-4 The Emocards concept (Desmet et al., 2001)

‘arousal’ (physical state of activation). In psychology, these are the two most accepted dimensions of emotion (e.g., Schlosberg, 1952*). “Each emotion can be described in terms of the level of pleasantness and arousal. Excited emotions come with high levels of arousal (e.g., ‘annoyed’ and ‘euphoric’), calm emotions come with low levels of arousal (e.g., ‘bored’ and ‘content’). The pleasantness of an emotion ranges between very pleasant (e.g., ‘thrilled’) to very unpleasant (e.g., ‘horrified’). Some emotions are neither pleasant nor unpleasant (e.g., ‘surprised’)”.* This test can be used for comparing similar/rival products or design proposals and examines the different emotional stimuli that are produced by the participants.

3.5 Testing the User Experience of an Interactive TV ad

While often in Computer and Mobile software, usability evaluation has to do with performance metrics, in interactive Television this is possibly not the most important factor in most cases. Especially in the case of Interactive TV ads, subjective factors like Engagement, User Satisfaction, Emotional Response, Brand/Product Awareness, and Memorability play a major role for evaluating a successful System. Evaluation of Interactive TV ads will try once again to address one of the oldest problems in advertising, initially expressed by John Wanamaker, the father of modern advertising, in his famous quote: “*Half the money I spend on advertising is wasted; the trouble is I don't know which half.*”

3.5.1 Traditional TV Advertising Testing

Advertising and marketing research usually utilise the Liking (preference) and Recall (recognition) measures to study the potential effectiveness of advertising in various forms, such as print, radio and TV. Recall is most frequently measured by questionnaires and interviews which ask for recall of specific commercials sometime after they are viewed in the home during regular scheduled programing (Eldridge, 1958). Subjective measurement of Liking usually requires viewers themselves to judge and record preference for commercials by means of questionnaires. Other measurement methods include biometric tests, such as pupil dilation, heart rate etc. However, these are more expensive to be performed as they require specific technical equipment. Traditional TV ads are short in length and are placed during a “commercial break” while often repeated during each break. Studies have been conducted on the effects of the repetitions of ads on the audience, and found that recall measure is increasing by repetition; however, this does not seem to significantly affect attitudes and purchase intentions towards the product (Belch, 1982).

3.5.1.1 Low and High Involvement products

Marketing communication separates products into two main categories, of Low and High involvement products, depending on how much the potential customer will research for a decision to buy one product over the other (Zaichkowsky, 1986) . For example, a car is typically a high involvement product that the customer will carry on extensive research and comparison between antagonist products in order to choose the exact product that fits its needs. It is important to notice that in the traditional TV ads it is impossible to make this decision based only on the ad since the information provided is inadequate. The TV ad will try to trigger the interest of the potential customer and s/he will then carry out research in other sources such as the Internet. It is arguable that an Interactive ad in which the user can access much more detailed information right through the ad will be very handy.

Low involvement products on the other hand are not of vital importance to consumers, who will not think too much about choosing a product over an alternative. Typical low-involvement products include coffee, beverages, food, shampoo etc. Another common difference from high-involvement products is the price as they tend to be much cheaper to buy. In this category of products, the consumer will rarely seek more information about the product online or otherwise, and the favour of one product over the other can more easily change. On the Internet, e-marketing campaigns for these products don’t include much information about them, as the user is not interested, but utilise other methods to gather attention, such as contests, games etc.

3.5.1.2 Copy Testing

Copy Testing (pre-testing) is a field of Marketing Research that determines an ad’s effectiveness based on consumer responses, feedback and behaviour. In 1982, a consortium of 21 leading advertising companies released a public document where they laid out the **PACT** (Positioning Advertising Copy Testing) Principles on what constitutes a good copy testing system. According to PACT, a good copy testing system must meet the following criteria (PACT Agencies, 1982):

1. Provides measurements which are relevant to the objectives of the advertising.
2. Requires agreement about how the results will be used in advance of each specific test.
3. Provides multiple measurements, because single measurements are generally inadequate to assess the performance of an advertisement.
4. Based on a model of human response to communications – the reception of a stimulus, the comprehension of the stimulus, and the response to the stimulus.
5. Allows for consideration of whether the advertising stimulus should be exposed more than once.
6. Recognises that the more finished a piece of copy is, the more soundly it can be evaluated and requires, as a minimum, that alternative executions be tested in the same degree of finish.
7. Provides controls to avoid the biasing effects of the exposure context.
8. Takes into account basic considerations of sample definition.
9. Demonstrates reliability and validity.

3.5.1.3 Recall Measure

Here, participants are asked questions relevant to the commercial to determine if they remember it and the brand/product it represents. Specific properties of the product are also asked (e.g. how many flavours). The answers can be given in various forms, depending on the design of the test, including Likert scales, Yes/No answers even free-text writings or interviews. The tests can be performed orally or can be written, at a specific place (e.g. lab), on the phone or even using a specialised device (e.g. set-top box or computer). The context of the questions focuses on questions about the product that the marketers wanted to communicate to the users. For example, in a beverage ad it could include flavours, taste appeal, low calories, etc.

3.5.1.4 Liking Measure

The Likeability of an ad refers to whether the viewers actually like the ad. Many scientific studies have been conducted to evaluate the effect of liking on a commercial from viewer response and even actual sales performance. Research also shows that ad Liking is one of the most important predictors of brand liking (Moore and Hutchinson, 1985). "*Liking is moderately but significantly correlated with other validated measures of effectiveness. Used in conjunction with other appropriate measures, liking measures* *add substantial value to the assessment and optimization of advertising effectiveness"* (Walker and Dubitsky, 1994). In an in-depth study of likability by Alex Biel (ARF Copy Research Project, 1990) he found five dimensions labelled: Ingenuity, Meaningfulness, Energy, Warmth and Rubs the Wrong Way. Biel offers the following hypotheses:

1. Commercials that are liked get more exposure (also the Kopelman hypothesis).
2. Commercials are brand personality attributes and affect sales through their overall contribution to the reputation of the products.
3. Ads that are liked are given more mental processing (liking is a mediator).
4. Liking is a "gatekeeper" to whether or not the ad is processed at all. (Liking is a moderator.)
5. There is less counter arguing against ads that are liked.
6. Liking engenders trust (source credibility).
7. Liking the commercial translates directly to liking the brand (emotional rub-off).
8. Liking evokes a gratitude response. Consumers buy the product to reward the advertiser for likable advertising.

ARF's Copy Validity Project concludes on Likability that it should not be considered as a stand-alone measure of copy effectiveness. Persuasion and recall justifiably remain as important copy testing measures and are likely to remain primary evaluative measures.

3.5.1.5 ARF's Copy Research Validity Project

The ARF project originated in a speech made by Ted Dunn at the ARF Annual Conference in 1977, on the validity of copy testing, where he proposed the formation of a committee to survey results of copy-testing files to ARF, in order to gather large amounts of data and draw safer generalised conclusions on ad effectiveness. The ARF project was completed in 1990 and the results have been a key reference point in ad evaluation since then. The copy-testing measures that were built into the questionnaires for the off-air cells fell into six general types: measures of persuasion, brand salience, recall, communications (playback), overall commercial reaction (liking), and commercial diagnostics. The main findings of the project are that: Copy Testing works and relates to sales, multiple measures are needed for evaluating an ad (confirming the

PACT principles), all types of copy testing measures in common practice have predictive value in terms of sales performance. Another important finding of the ARF project was that ad Likeability had a much stronger effect on sales while ad Recall had a less significant one.

3.5.1.6 Advertising Response Modeling (ARM)

ARM is an attempt to provide a framework to assess advertising performance by means of integrating several measures to evaluate if the advertising in question fulfils the marketing communications objectives set for it (Mehta and Purvis, 1994). According to Mehta, an ad must break through the clutter to gain attention. If this is succeeded, processing on the receiver part occurs along one or two routes of processing: central and peripheral. In central processing, the focus is on the product/brand information while in peripheral processing, focus is on the ad itself. Both routes can influence the Buying interest/intention of the viewers (Figure 3-5).

3.5.2 Interactive TV Advertising Testing

In order to evaluate the performance of the interactive TV ad prototype developed in Chapter 4, a methodology for interactive TV ads evaluation had to be used. Researching through the bibliography, we could not identify a method for evaluating interactive ads. So, we developed a methodology for evaluating of interactive TV ads based on traditional TV ad evaluation methods, but also combined these with the System Usability Scale (SUS) test to have a more complete picture. The detailed questionnaire used can be found in section 3.6.4.

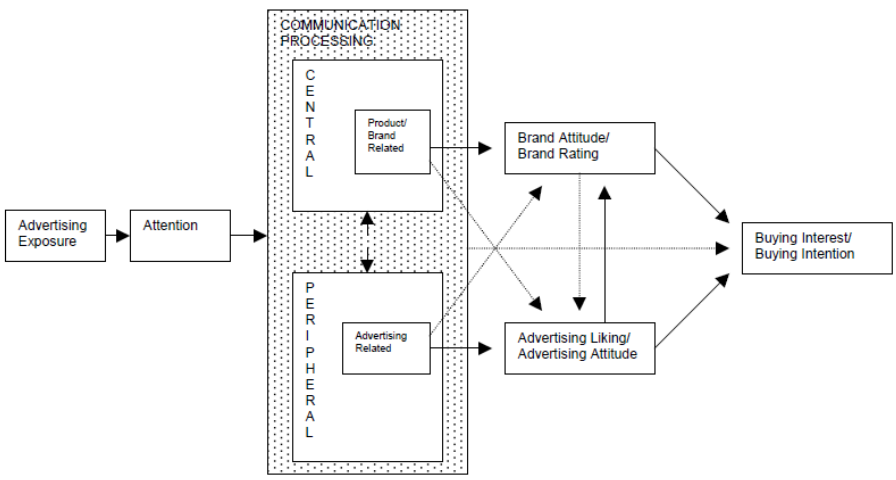

Figure 3-5 The Advertising Response Model (ARM) Coneptual Model (Mehta and Purvis,

3.6 *Experimental Content*

3.6.1 Laboratory and field studies

Depending on the environment where a study is conducted, we can categorise it as laboratory or field study. A laboratory study is taking place in an environment where all the variables that can influence the aims and objectives of the experiment can be controlled. The positive points of this method are the consistency and accuracy that can be achieved. According to Coolican (2014), the negative aspects of laboratory studies are: (i) it takes place on an artificial environment, (ii) it is difficult to generalise experimental results and (iii) the restricted number of variables. Field studies, on the other hand, are taking place in a real-world environment. Due to this, it is impossible to have full control to all variables, in contrast to laboratory studies, so only some variables are controlled. This limitation of variable control can lead to inconsistent results.

The experiments performed in the context of this thesis can be mostly seen as laboratory studies, although some elements of field studies where introduced to try to gain some benefits from both methods. For example, although the user evaluation experiments described in chapter 4 were taken place in an office at a university, the experiment in chapter 5 was situated in the living room of a home. We believe that this potentially created a more relaxing environment for the subjects, thus producing more real-life results. However, the actions that the subjects performed to test the systems were directed by the researchers, so this is characteristic of a laboratory study. In the next section, there is more detail on the location of each experiment.

3.6.1.1 Location of experiments

The user evaluation experiments described in Chapter 4, were carried out in an office at the University of Applied Sciences (TEI) of Crete. All variables were controlled by the researcher while the participants were given specific directions on what actions to perform (Figure 3-6). This was clearly a case of a laboratory study.

Figure 3-6 A subject during testing of the HTML5 ad

In Chapter 7, a second user evaluation study was carried out, in order to assess the improvements on user experience aspects of the Responsive TV prototype. This time, the experiments were carried out on a more natural Living Room environment of a residence. However, the methodology was again to ask the participants to perform specific tasks. This was also a laboratory study but with limited combined elements of field study.

3.6.2 Experimental Devices

There is a great variety of different connected TV platforms while it is increasing every year with new models. Due to the fact that the experiments that were carried out in the context of this work were taken place over a period of 4 years, the devices that were used are not the same throughout the study.

For the experiments in Chapter 4, three devices were utilised in order to evaluate the differences in user perception of an Interactive TV ad in different devices: A Sony nsz-gs7 set-top box with GoogleTV OS, a Samsung smart TV (2012 model) and a Nintendo Wii console. In chapter 4.4 there is detailed analysis of the specifications of these 3 devices.

To test the performance of our Web3D experimental system described in Chapter 5, a greater number of TV devices had to be exploited. This included several TV models build in 2012 to 2016 by Samsung, LG and Sony. The detailed list of these models can be found in table 5-1.

In order to evaluate the compatibility of the top visited websites with Smartphones, Tablets and Smart TVs, as described in Chapter 6 the following representative devices were used:

- **Smartphones**: An iPhone 5s (iOS) and a Samsung Galaxy S4 (Android)
- **Tablets**: An Apple iPad 2(iOS) and an ASUS transformer (Android and MS-Surface)
- **Smart TVs**: a Samsung Smart TV 2014 model UE55F6670, an LG Smart TV 2013 model 42LA660S and a Google TV Sony NSZ-GS8 set-top box

Finally, for testing the performance of our Responsive Web Design prototype described in Chapter 7, there were 8 different models of Smart TV devices put to the test. A detailed list of the models and their capabilities are shown on Table 7-4.

3.6.3 Web Content used in experiments

In every one of the performed experiments, various Web content had to be utilized. Also, some of it had to be developed in the form of Prototypes. More precisely:

For Chapter 4, a connected TV ad prototype had to be developed. In order to create a representative TV interactive ad, several ads were examined to find their more common features in addition to bibliographical review on the subject. The prototype was developed according to these findings.

For Chapter 5, where 4 different Smart TV devices were put to the test for their HTML5 3D capabilities and performance, the web content used was the ThreeJS (Figure 3-7) and the X3DOM websites, that contain a number of 3D experiments to test your device's capabilities, while displaying the number of FPS (Frames per second) which is the main indicator for 3D performance.

For the survey in Chapter 6, to test whether actual websites are optimized for TV and mobile devices, we extracted the top 100 visited websites in the world according to Alexa Research. From these, after removing duplicate versions for other languages, pornography sites and network services 49 websites made the list of the content that was tested for Smart TV compatibility.

Finally, for Chapter 7, a News-style website prototype was created based on an existing HTML template that was responsive for mobile devices, to further extend its capabilities to be responsive for Smart TVs as well. Some sample news content was added for the websites to look more realistic to the participants.

Additionally, the HTML5test (HTML5test.com) was used in Chapters 4 and 7 to assess the HTML5 capabilities of the experimental devices. The HTML5test is a popular free online service for testing each HTML5 feature compatibility with a web browser.

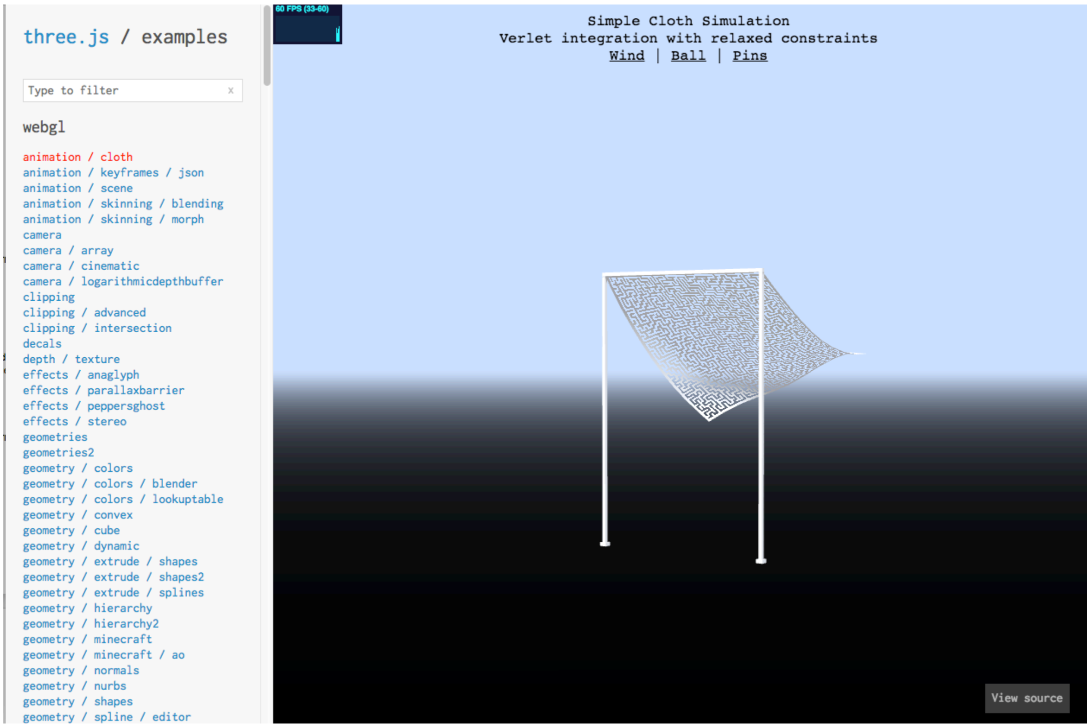

Figure 3-7 The ThreeJS examples website

3.6.4 Experimental Questionnaires

The questionnaire used for the Evaluation of the Smart TV ad experiment described in Chapter 4, was created by combining a System Usability Scale test with traditional TV ad performance measures. More details on the individual methods for evaluating TV ad performance were described in section 3.5.1.

System Usability Scale

The modified version (modified text in *italics*) of the SUS usability test contained the following 10 statements. The participant had to choose on a Likert scale of 1-5 (Strongly disagree – Strongly Agree):

1. I think I would like to use *this type of Ads* frequently
2. I found the *ad* unnecessarily complex.
3. I thought the *ad* was easy to use.
4. I think I would need *help* to be able to use this *ad*
5. I found the various functions in this *ad* were well integrated.
6. I thought there was too much inconsistency in this *ad*
7. I would imagine that most people would learn to use this *ad* very quickly
8. I found this *ad* very *confusing* to use
9. I felt very confident using the *ad*
10. I need to learn a lot about this *ad* before I could effectively use it.

Recall/Liking Tests

Likert scale and Yes/No questions about liking the ad/product and remembering what was the ad about

Liking

1. I liked this ad (Likert)
2. This ad does not look good (Likert)
3. The ad was informative (Likert)

Recall

1. What was the Brand of the cars you saw
2. What was the colour of the car you chose
3. How many cars were in the ad
4. What is the starting price for the car you saw
5. What is the Connected feature you saw in the ad

Open-ended Questions

1. Write up to 3 things you liked about the ad
2. Write up to 3 things you didn’t like about the ad

Similarly, to evaluate the prototype system of Responsive TV website developed in Chapter 7, again the SUS test was used but additional questions were added, separately from the SUS. These were 3 liking questions and 5 more questions on specific functionality of the evaluated websites.

System Usability Scale

The SUS usability test contained the following 10 statements. The participant had to choose on a Likert scale of 1-5 (Strongly disagree – Strongly Agree):

1. I think I would like to use website frequently
2. I found the website unnecessarily complex.
3. I thought the website was easy to use.
4. I think I that I would need help from a technical person to be able to use this website
5. I found the various functions in this website were well integrated.
6. I thought there was too much inconsistency in this website
7. I would imagine that most people would learn to use this website very quickly
8. I found this website very *confusing* to use
9. I felt very confident using the website
10. I need to learn a lot about this website before I could effectively use it.

Liking (Likert scale)

1. I liked this website
2. This website does not look good
3. This website was informative

Additional Questions (Likert scale)

1. The text was difficult to read
2. It was easy to navigate and choose elements of the page
3. I found the loading time between pages slow
4. It was easy to see the elements of the page that were bellow the visible part
5. I would like to use websites like this one on my TV

Open-ended Questions

1. Write up to 3 things you liked about this website
2. Write up to 3 things you didn't like about this website

3.6.5 Sampling and statistical analysis

Google Sheets was initially used for recording the answers of the participants, so the data was available in a spreadsheet. This allowed for the basic graphs from the experiments to be easily created while also to make calculation of SUS scores.

However, to perform more complex statistical tasks, such as ANOVA (Analysis Of Variance), it was needed for a more specialized software, so SPSS (Statistical Package for Social Sciences) was utilized. For our statistical analysis, the results were considered to be significant if $p<0.05$. This indicates that the mean of a specific data set is greater / less than two standard deviations from the overall mean, as a result of a specific variable adaptation - approximately 5 percent of all samples.

3.6.6 Convenience Sampling

Convenience sampling is a type of non-probability sampling that involves the sample being drawn from that part of the population that is easy to find (Saunders et al., 2012). It is very commonly used in academic studies as these studies usually rely on population from the university (e.g. students and staff) since they are available, in contrast to finding a sample from the overall population that is much more difficult to obtain. This method is extremely speedy, easy, readily available, and cost effective, causing it to be an attractive option to most researchers (Henry, 1990). In both our user studies we used convenience sampling, with participants being students and staff of the Technological Educational Institute (TEI) of Crete. The participants however, were not the same in each experiment.

3.7 Overall Project Methodology

As described in this chapter, a user-centered approach is taken towards the reach of our aim, which is to to develop a set of guidelines for better web usability/UX on Smart TV devices. In more detail, the user-centered process we took to succeed in our aim was:

- **Analysis**: Explore current state and popular uses of Smart TVs and identify user's current UX problems in these devices. This is initially done in chapter 2. Also, in chapter 6 for objective 3 to asses the current adaption of popular websites in terms of compatibility with Smart TVs. Additionaly, it is done for each of the objectives 1, 2 and 4 (chapters 4, 5 and 7) for the representative example use cases of Smart TV web applications.
- **Design**: Three Smart TV-optimized prototypes were designed and developed based on the findings from the Analysis phase, in order to be evaluated from the users in the next phase (described in Chapters 4, 5 and 7).

- **Evaluation:** In chapters 4 and 7 you can find detailed results from the user evaluation that was performed in the protorype systems that we developed.
- **Guidelines**: In Chapter 8, based on the results from user evaluation, Objective 5 was met by developing a complete set of guidelines for designers to apply to their project in order to produce better web UX for Smart TV users.

In Figure 3-8, we present a diagram of our approach to the User-Centered Design process as applied in this research work.

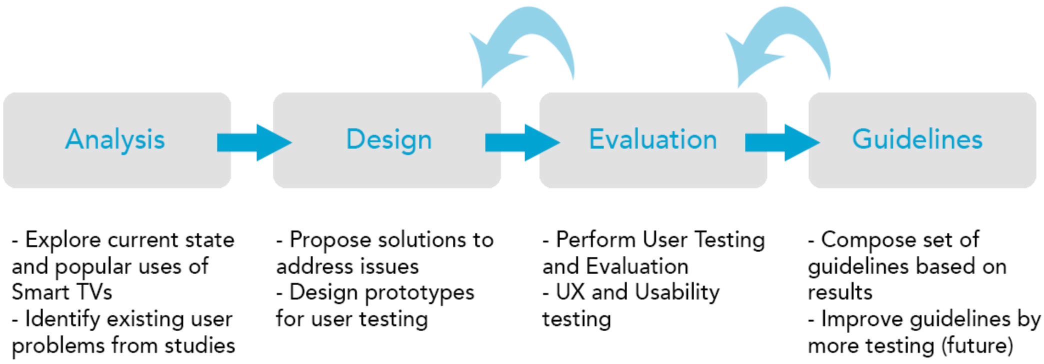

Figure 3-8 Our User-Centered Approach to improve web UX of Smart TVs

3.8 Conclusion

In this chapter, we described the different aspects of the methodologies used in the experiments carried out in the context of this research work. A number of different methods for evaluating User Experience and Usability were described, as well as ways to assess the performance of TV Ads. The chosen methods used in the experiments are described, including the questionnaires used. Also, there a list of all the different devices utilized for the experiments are outlined. In the following chapters, there are detailed descriptions of the experiments and the resulted conclusions.

Chapter 4 - HTML5 technologies for effective cross-platform Interactive/Smart TV Advertising.

4.1 Introduction

Developing an interactive TV Commercial (iTVC) for Internet connected TVs is complicated by the number of different platforms, each with its own Operating System and Application Programming Interface (API). To achieve cross-platform compatibility, we propose to use standard Web Technologies, instead of proprietary APIs for each device. With our approach only one iTVC was developed, which contained commonly used features of these kinds of advertisements, and used only Web Technologies (HTML5, CSS and JavaScript). The iTVC was first developed on a desktop personal computer and then tested on 3 different Smart TV platforms for feature compatibility. After achieving compatibility, a user study with 36 participants evaluated how platform related differences affect aspects of user experience (UX) and effectiveness of the interactive ad. The measured UX/effectiveness aspects and usability were consistent regardless of the iTVC performance on each device. These results show the potential of Web Technologies to deliver a uniform (and effective) interactive ad across a range of heterogeneous devices.

Traditional TV advertising consists of a short video clip (between 15 - 30 seconds). However, the increasing popularity and the interactive capabilities of Internet connected TV (or smart TV) devices are attracting attention from advertisers that see potential beyond the traditional "30-second" TV spot (Interactive Advertising Bureau, 2011). These commercials combine enhanced "30 second" TV spots and microsites/applications (Apps). These include interactivity and can even adapt to the viewing environment (e.g. using location information). Interactive TV advertising thus provides advertisers with new ways to pass their messages to potential clients, including instant purchase (t-Commerce), on-demand product descriptions, newsletter subscriptions, social media interaction, longer presentations, and games.

Nevertheless, developing interactive TV commercials (‘iTVCs’) for connected TV can be complicated due to the number of available platforms. Connected TV platforms are being developed by service providers, traditional TV manufacturers, Internet service companies, computer manufacturers, personal computer (PC) software developers, TV channels, set-top box / Media Player manufacturers, and even game console manufacturers.

In order to develop an iTVC, most of these platforms have proprietary APIs. However, there is movement toward the adoption of the standard web technologies of HTML, CSS and JavaScript for every connected TV device, either through their web browsers or their application development core (W3C, 2011). By adopting these technologies in the TV arena, a universal method for developing Apps and iTVCs seems feasible in the near future.

Because of the nature of Smart TVs, an HTML5 iTVC is not just a video broadcasted to the user's device but also depends on the client-side system for its correct rendition, similar to a web page viewed on different devices. Due to the many different platforms and capabilities of Smart TV hardware and software, it is virtually impossible to design for the exact same user experience on all Smart TVs. Thus, one concern is how users perceive these differences and if the differences can result in a decreased advertisement effectiveness.

This chapter investigates whether such technologies can offer the required features needed for developing interactive ads compatible with most connected TV platforms. Advertising and marketing research usually use recall and preference measures to study the potential effectiveness of advertising (Eldridge, 1958; Halley and Baldinger, 2000; PACT agencies, 1982; Walker and Dubitsky, 1994). Thus, we also investigate some aspects of the user experience on a cross-platform iTVC across different devices. In so doing, we address the first objective of our research, namely: **Explore the feasibility of developing web-based interactive ads that will be compatible with all Smart TV platforms and provide a seamless viewers perception regardless of the capabilities of his device.**

The structure of the remainder of this chapter is as follows: Section 4.2 explores the uses of Web Technologies such as HTML5 for creating iTVCs, section 4.3 outlines the platforms that were available at the time of the experiment for creating iTVs and their capabilities, section 4.4 describes the Prototype iTVC that was developed for this experiment using HTML5 technologies, section 4.5 presents the 3 different devices that were used to test the prototype and the results from testing it, section 4.6 explains the user evaluation experiment that was performed on the prototype while the results of the experiment are presented in section 4.7. Finally, section 4.8 discusses the conclusions of the experiment.

4.2 Utilizing Web Technologies for iTVCs

HTML5 is not meant as a standalone technology and is still being developed (Hickson, 2012). Usually, when referring to HTML5, it automatically includes the combination of three main technologies: HTML5 for structure, CSS3 for presentation/style, and JavaScript for interactivity/animation.

Accordingly, our proposed solution uses web technologies including HTML5, CSS3 and JavaScript to create a single interactive ad to target different platforms running on the devices' web browsers. Our solution is cross-compatible, using a JavaScript detection of features and providing a "fallback strategy" for any missing features. Advantages of this solution are:

- Universal cross-platform compatibility with a single ad that will run on all platforms;
- Adaption for different input devices (remote controls) can be programmed;
- Features of current TV ad platforms can be reproduced with HTML5/CSS3/JS;
- Use of HTML5 with native video support, a vital feature for an iTVC (Daoust et al., 2010);
- No need for platform-specific technical skills;
- Personalization of ads, localization, and mash-ups (e.g. maps, social media) are supported.

Table 4.1 lists important features of HTML5 that can be utilised for interactive TV ads. Other features include many new semantic tags for more specific content structure, and local storage for storing values even when the browser is closed or refreshed.

Table 4-1 Features of HTML5, applicable to Interactive TV Ads

Video	The <video> tag embeds a video onto the page. There are two different video formats supported with different browsers: (a) H.264 Baseline profile in an MP4 container and (b) VP8 in a WebM container, or Theora in an Ogg container. A workaround for cross-platform support is to include both video versions. There is a preload attribute for pre-loading videos.
Subtitles	Subtitles, for different languages, accessibility or for artistic enhancements (e.g. captions with only music as soundtrack) are supported using the WebM format and the <track> element. The track element supports specifying explicit external timed text tracks for media elements (Hickson, 2012).
Audio	The <audio> tag is for playing audio. Synchronizing audio with graphics, video and interactions (e.g. push of a button) is supported with JavaScript Events or Timers for time-based sync
Canvas	The <canvas> tag is an area in the browser where the developer can draw graphics or produce animation using JavaScript with the provided API. This is useful for real-time graphics.
Interacti-on Design	JavaScript can offer interactivity features. JavaScript is extended with libraries, like jQuery
Text / Typogra-phy	Text includes new fonts, with @font-type tag of CSS3 and also with text effects, so common on TV such as shadows and borders (text-shadow), rotation (box-rotate) and even gradients and advanced masks (-gradient). Text can also be animated using JavaScript.
Graphics Effects (CSS3)	Effects of CSS3, such as shadows, rotation, gradients, and opacity can be very useful for the presentation of content. As opposed to using pre-rendered graphics, real-time options are available.

JavaScript can detect compatible tags for the current browser and provide fallback strategies for when a feature is not available on the current device. For example, if the particular device lacks video support using the HTML5 <video> tag, an image could be displayed, or even a flash video, if the device supports it. Since JavaScript is supported on all devices, this technique will ensure that the iTVC will be viewable across all platforms. The client-side platform can be detected by using the standard navigator.userAgent property. Also, the document.createElement functions can show the availability of features (e.g. HTML5 video or audio).

4.3 Platforms and Enabling Technologies

There are a number of different platforms for developing iTVCs using their dedicated tools. Some of these are DIRECTV, Rovi (2011), YuMe, Activevideo and Adrise. Although these offer similar features, the methods to produce the iTVCs are quite different. Moreover, each is compatible with a limited number of platforms.

Even on compatible TV devices, these platforms work only in particular areas. For example, pre-roll ads can work before playing a video or film through a service like BrightClove. This will not serve for ads for example, inside a TV App, or the TV web browser. Moreover, all of the above are closed platforms/services which only serve ads on compatible platforms. Table 4-2 outlines some of the most popular platforms at the time of the experiment.

Table 4-2 Platforms for developing interactive TV Ads

Platform	Entry Point (Call to action)	Development Technology	Compatible TV Platforms
YuMe	Banner inside TV interface, Pre-Roll, During Loading	Flash / HTML5	LG SmartTV
Rovi	Banners, Menu placements	ROVI SDK/API	Samsung Smart HUB, DIRECTV, Sony PS3 and more
FreeWheel	Pre-roll	HTML5 / Flash	BrightClove (video website)
DirecTV	Video Banners, Menu placements, 30sec Spot	Undisclosed	DirecTV and compatible devices
adRise	Video, Banners, overlay, ticker	adRise SDK/ HTML5	Roku, Google TV, Yahoo TV, Samsung Smart HUB, WD, , Android and more

An empirical study of 25 iTVCs, 5 produced with each platforms shown in Table 4-2 identified the frequency of features that the Interactive TV Ads possess. The "Always" column means that 100% of the examined Ads had this feature, "Often" means that more than 50% of Ads had this feature, while "Sometimes" indicates that less than 50% of Ads examined had this feature. The "Always" and "Often" columns in Table 4-3 guided the development of our prototype system, meaning that our system had to successfully reproduce all 6 features of the first column, and it would be desirable to also reproduce the 4 features of the "Often" column.

Table 4-3 Commonly used features of Destination micro-sites

Feature	Always	Often	Sometimes
Intensively Graphically Branded.	X		
Graphics & Animation rich	X		
Music Soundtrack		X	
Audio Narration		X	
Sound Effects	X		
Interactive Menus	X		
Game / Contest			X
Signup Form (e.g. for a newsletter)			X
Textual Information about the product	X		
Extensive Information about products	X		
Utilises Social buttons (Like box etc)		X	
Playable On-demand Videos		X	
T-Commerce (e.g. order online now)			X

4.4 Prototype iTVC

As a proof of concept and expanded from our previous work (Perakakis et al., 2012), an iTVC was developed, using only web technologies (Figure 4-2). The first part of the ad could be either a clickable banner or a "30-second spot" (Figure 4-1). Technically, the 30-second spot is a normal HTML5 page that has a full screen video in the background using the <video> tag, a music soundtrack and some car sound effects using the <audio> tag, and a sequence of text sentences in the foreground layered and faded-in and out on top of the video. The fade-in and fade-out effects are produced using the jQuery library which animates the CSS3 opacity property. The viewer watches part of the TV spot but s/he has the option to press a button on the remote control in order to continue to the second part. The button can be tracked using JavaScript onKeyPress events. If the user presses the predefined button it will redirect to the destination.

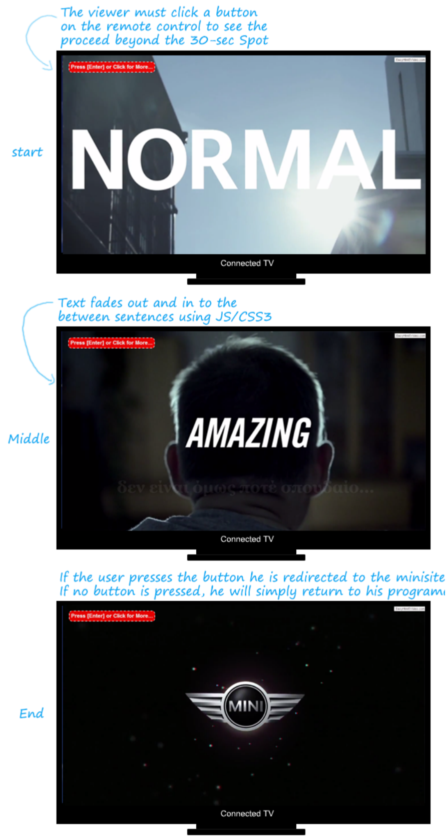

Figure 4-1 Entry Point - The "normal" video commercial

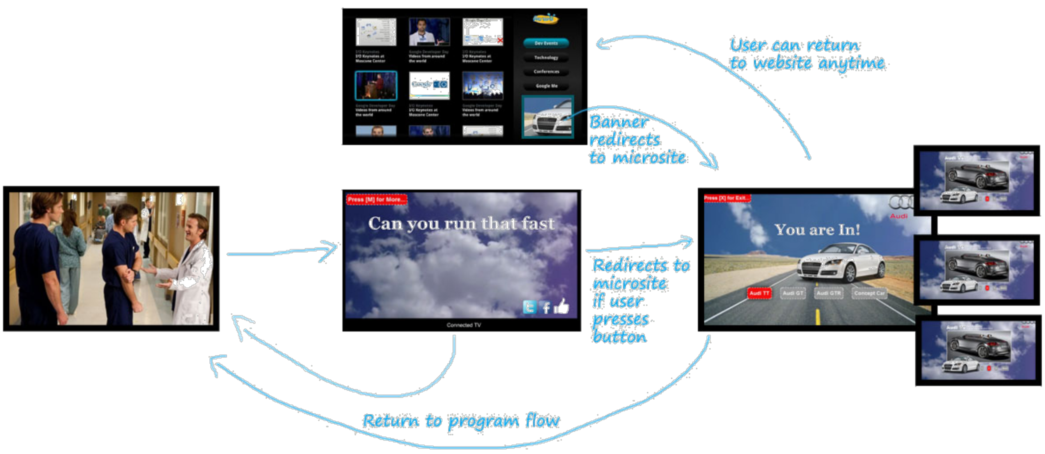

Figure 4-2 iTVC prototype system flow

The destination is the main interactive part of the iTVC (Fig. 4-3). It is composed of navigation menus and a number of screens for the main page and each menu choice. It is a single HTML5 page with a number of main DIV (division) layers that, depending on the user's actions, are hidden or shown using JavaScript. Each of these main DIVs contains all elements of each screen. A standard menu is displayed on the main screen, so the user can select a product for which s/he wishes to see more information.

The background for all screens is a video sequence of time-lapsed clouds in order to have a continuous sense of motion. This background video feature was not present in any of the commercial interactive ads examined. Since it is an HTML5 feature it is possible that it will not render on all connected TVs. A fallback strategy will show static clouds on unsupported devices. Alternatively, JavaScript can animate the background or Flash can be used. The menus can be navigated using the arrows on the remote control, where KeyPress events are traced with JavaScript and the current menu choice is highlighted by changing the CSS properties of box-shadow and background-colour.

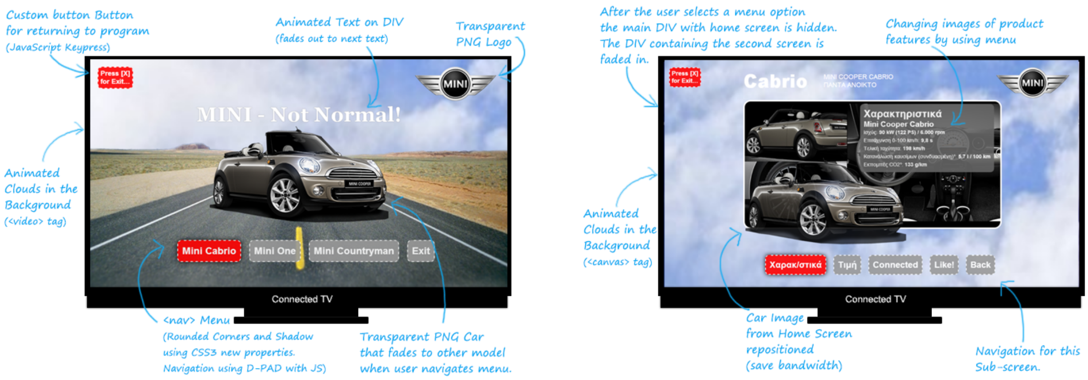

Figure 4-3 Screenshots of the iTVC Landing Microsite/app

Figure 4-4 The testing devices

4.5 Device Platform Evaluation

Three connected TV devices are considered in this work (Table 4-4). Google TV is a set-top box, and represents the devices that add connected TV capabilities to any TV. It has more powerful hardware, compared to the other two devices and runs a special version of Android (Google, 2012). The Samsung Smart TV is representative of a typical TV device with Smart-TV capabilities (Samsung, 2012) being developed by most major TV manufacturers. The particular model is a mid-range one, which means

Table 4-4 Web Standards Compatibility Of The 3 Platforms

Device	GoogleTV (Sony nsz-gs7)	Samsung Smart TV (2012)	Nintendo Wii
Performance	Middle-End	High-End	Low-End
Description	A set-top box with high-end hardware.	A TV with embedded Smart TV capabilities.	Popular but dated device, low specs.
OS	Android	Smart HUB	Linux (custom)
Browser	Chrome	Maple	Opera
HTML	FULL HTML5	FULL HTML5	Limited HTML5
CSS	CSS3	CSS2	CSS2
JS	YES	YES	YES
Remote Control	Remote with touchpad and Qwerty Kbrd	TV Remote	Wii Motion Controller

that the hardware is relatively limited. The Nintendo Wii is a popular but dated game console. Due to hardware limitations and the limited capabilities of the web browser, this device represents the low-end for testing purposes (Google, 2012) and would be useful for testing fallback strategies.

The system was developed on a desktop personal computer. It was tested using the Google Chrome browser and then on each of the three devices (Figure 4-5). The final version was compatible with all three devices. Overall, the iTVC was able to run on all test devices with most visual features displayed correctly, providing responsiveness to user commands of less than 1 second for the GoogleTV/Samsung and a larger response delay of about 2-3 seconds for the Wii (Table 4-5). These results compare favourably with the 0.1 to 1 second limit for keeping the user's flow of thought uninterrupted, and, indeed, to the 10 seconds threshold to keep the user's attention (Nielsen, 2004).

Figure 4-5 Developing and testing the HTML5 ad across devices

4.5.1 Technical observations

Table 4-5 summarises the technical observations. Following is an explanatory for the performance on each device.

Table 4-5 Results of ad performance on different devices

Device	GoogleTV (Sony nsz-gs7)	Samsung Smart TV	Nintendo Wii
Resolution	1024 x 577	1280 x 609	800 x 472
CSS3 effects	Supported	Supported	Partially Supported (except Shadows)
Text animation	Supported	Supported	Supported
Video	Smooth (fps ≥ 30)	Smooth (fps ≥ 30)	Not Smooth (fps ≤ 20)
Audio	Supported	Supported	Supported but disjointed
Navigation Controls	D-PAD and Qwerty	D-PAD	Wii-remote
Interaction Responsiveness	Uninterrupted ≥ 0.5 sec & < 1 sec	Uninterrupted ≥ 0.1 sec & < 1 sec	Frequent Delays >= 1 sec & < 2 sec
Overall Performance	Smooth (but slow on scrolling BG)	Smooth	Disjointed
HTML5Score	**354**/555	**283**/555	**82**/555

Google TV (on Sony NSZ-GS7 set-top box)

Google TV supported all visual features, at display rates of over 30 frames per second (fps), and was responsive to user commands within 1 second). This performance was expected as it is one of the newest devices, and is frequently upgraded. It uses a TV-optimised version of Google Chrome. Chrome as a browser offers compatibility with most HTML5 function and was able to display HTML5 video at a frame rate greater than or equal to 30 fps, while the Sony hardware was adequate for displaying the iTVC without noticeable disruptions. One exception was the scrolling background which performed slower than the other devices.

Samsung Smart TV (2012 model)

The custom Samsung TV browser offers compatibility with most major HTML5 capabilities (such as Video). The hardware performance of the device supported all visual features, displaying them at over 30 fps, and was responsive to users within a one second interval. It was able to present the iTVC without any noticeable visual or interaction disruptions. There was a need for some tweaking of the navigation elements, as the Enter key on the Samsung Remote D-Pad triggered the Click and Enter events simultaneously. This was addressed and did not cause any side-effects on other devices.

Nintendo Wii Internet Channel

Nintendo Wii uses a TV version of the Opera browser. The lack of video and audio support impacted the compatibility of the ad. A fallback strategy was included on the device for replacing the HTML5 video and audio tags with Adobe Flash FLV videos. In order to play the videos, an older version (3.17) of the JW-PLAYER (2013) was used. Videos were converted to a lower resolution (640 x 320 pixels) and a frame rate of 15fps. This was visually obvious. The device supported canvas scrolling. For navigation, the D-pad on the Wii remote could not be used inside the ad as it does not produce any events visible to the browser. However, the standard functionality of the Wii-remote was compatible with the ad, and the click and hover events worked the same as with a mouse. Overall the iTVC was workable but with noticeable limitations both visually and in terms of interaction responsiveness (delays greater than 1 second were experienced) when compared to the other two devices.

4.5.2 Discussion

The iTVC was optimised for compatibility with the three devices. Either primary or fallback solutions ran on the devices. The HTML5 syntax was very helpful in achieving compatibility. For example, the main navigation was initially implemented as a set of links on DIV tags, which did not work well on the devices that supported the D-pad navigation. Upon replacing the <div> element with the HMTL5 <nav> element, D-PAD navigation worked across all tested devices. This demonstrates that the same feature-packed HTML5 ad can be compatible with different platforms, without the need to use propriety APIs.

4.6 User Evaluation Methods

4.6.1 Participants

36 students and academic staff (13 male) from a higher education institution in Crete, Greece participated. Their ages ranged between 20 to 35 years. All were relatively unfamiliar with interactive Internet TV devices, although most had some IP-TV experience. All self-reported that they were experienced Internet/PC users.

4.6.2 Dependent measures

Subjective metrics were adapted from ad evaluation. System response metrics were also collected.

1. **Usability**: We used an adapted version of the System Usability Scale[3] (Sauro, 2011).

2. **Likeability**: Whether the users liked the ad.

3. **Recall**: If the users remember important parts from the ad. Ghinea and Thomas (1998) showed that Information Recall in multimedia clips can vary according to different Quality of Service parameters (such as frame rate). Accordingly, it was of interest to explore whether recall varies with the different platforms with different rendering capabilities.

4. **Open-ended questions**: User could state up to 3 things s/he liked about the ad and up to 3 things s/he did not like.

The exact questionnaire used can be found in section 3.5.4 of this thesis.

4.6.3 Procedure

The participant sat on a sofa and watched the iTVC on a 40 inch TV linked to the connected TV device being tested. The main control functions of the device were explained to the user and s/he was allowed 2 minutes to familiarise him/ herself with them. The following directions were given:

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[3] Available at http://www.e-bilab.gr/wp-content/uploads/2014/10/ITVA-questionnaire.pdf

"You will be watching a TV series on TV; at some point it will be interrupted by a TV Commercial. This is a normal TV commercial, but you also have the option to enter an interactive part of it. Please enter the interactive ad by pressing the [X] button on your remote when the instructor asks you."

The participant was asked to sit on the couch chair and watch the program (a short film) on the device. The film was then interrupted after 1½ minutes for a commercial break, at which point the pre-interactive commercial (30-second spot) was displayed and the user was asked to press a button to enter the iTVC. Simple tasks were performed inside the ad:

"Take a look around and then find the price of the 'Cabrio' car. Then "Like" it on Facebook and finally find out more about the "Mini Connected" feature". Upon completing these tasks, please exit the ad to return to your TV program."

After the user returned to the TV program, s/he continued to watch the program for 5 more minutes and the session ended. The participant completed a modified SUS questionnaire, a liking questionnaire and a recall questionnaire. Finally, each user answered 3 open-text questions.

4.6.4 Experimental Design and Data Analysis

12 participants were randomly assigned to each device. Data were analysed with the Statistical Package for the Social Sciences (SPSS). An Analysis of Variance (ANOVA) was applied to analyse the participants' responses.

4.7 Results

A significance level of $\alpha = 0.05$ was adopted for the study. Results are summarised in Table 4-6.

Table 4-6 User Testing results with the 3 devices (Means and STD DEV)

Device	SUS Score	Like iTVC	Like the Look of iTVC	Found iTVC Informative	Correct Recall (Out of 5)
Google TV	75.62	4.50 (0.90)	4.50 (0.90)	4.17 (0.94)	3.58 (1.08)
Samsung	83.75	4.58 (0.52)	4.50 (0.91)	4.58 (0.52)	2.75 (1.05)
Wii	76.87	4.25 (0.75)	4.00 (0.85)	4.42 (0.52)	3.08 (0.79)

4.7.1 System Usability Scale Score

The System Usability Scale scores across the three devices were not significantly different even though the Samsung TV handles the scrolling HTML5 background at a little higher frame rate and the response times for user commands were a little shorter. All devices scored above 68 which is considered a threshold for good usability on the SUS test (Sauro, 2011).

4.7.2 Likeability

For the three likeability questions (liking the ad in general, liked the visual aspects of the ad, and finding it informative), there were no significant differences between the devices. The conclusion was that the users liked the iTVC regardless of the device.

4.7.3 Recall

There were no significant differences for the devices with respect to recall.

4.7.4 Open-Ended Questions

Three users reported that they were annoyed by the performance (speed) of the ad on the Samsung device while only one reported the same thing on the (slower) Wii device. Also, there were two complaints about a video that was played inside the ad (Mini Connected) but only for the Wii device, which was not surprising, as it had loading issues. In general, most users liked the visuals, the music and the interactivity of the ad. Three did not like them on the Wii device, probably due to the low video quality and lower screen resolution. Overall, there were no major complaints for any device, but most were for the Nintendo Wii, as expected.

4.8 Conclusion

As more advanced hardware is available at lower prices, and Smart TV capabilities are integrated into an increasing number of devices, iTVCs are set to play a major role in the advertising industry. Here through developing and evaluating a prototype, we addressed whether an HTML5 iTVC can (i) run effectively on different connected TV platforms and (ii) offer a consistent user experience across these platforms. The results showed that, for the system in question, both of the above premises were true. All tested hardware systems, although very different, managed to run the iTVC effectively, without the need to use any device-specific APIs. However, users seemed to clearly like the iTVC and found it easy to use on all platforms, regardless of differences in the performance characteristics of the different input devices.

The example prototype was a simple iTVC, encompassing the most common features that these ads share. There were no significant differences across the three diverse platforms with respect to usability, likeability and memorability/user recall. This highlights a relatively seamless cross-platform user experience although it is not clear whether this was due to the novelty factor of the application tested. Table 4-7 shows a comparison of using Device-specific APIs compared to Web Standards, with conclusions drawn from this research. Web Standards thus seem the way forward towards cross-platform interactive TV.

In conclusion, this experiment showed that the first objective of this research can be achieved: **It is possible to develop a web-based interactive ad that is compatible with different Smart TV platforms and provide a seamless viewer perception regardless of the capabilities of his device**.

Table 4-7 Device-specific APIs compared to Web Standards for developing Interactive TV Commercials

	Device-specific APIs	Web Standards
Coding Language	Developers have to learn the language for each different platform. Sometimes this can be Javascript but with different API to be learned for each platform.	HTML5, CSS and JS are very popular and most developers have already experience on these languages, enabling them to develop these TV Ads immediately.
Development Environment	Some platforms need for the developers to learn and use a specific IDE while others make possible the use of a standard web editor or event text editor.	The developer can use its preferable text or web editor environment. So again, no learning curve here.
Deployment	Every platform has its own process for packaging and deploying the iTVC, usually through an ad-Service.	Can run through the Web Browser of any device. In some cases, it could also be deployed using platform-specific packaging.
Features	Can utilise Video, Audio, Controllers, animation etc. using the device API. Also, this guarantees that all device-specific features can be utilised (e.g. a special controller)	Can utilise Video, Audio, Controllers, animation etc. using HTML5, CSS3 & JS. Using these, the iTVC will have all the standard interactive features. However, in some cases a feature may not be available.
Performance	Performance using the device APIs is expected to be the maximum possible.	The performance will probably not be the maximum that can be achieved using the APIs, as there will possible not be more middleware between the iTVC and the device hardware.
Compatibility	The iTVC has to be explicitly re-developed for each device/platform. Each version can only run on a single platform.	The same iTVC can run across every TV platform with a web browsers. In most cases, it will also run well on new and untested devices, since all new devices now support web standards.
User Experience	It could easily be assumed that User Experience on the API-developed Ads would be better. This however, was not tested on this paper.	However, cross-platform User Evaluation of the same Web Standard iTVC showed very little to none perceived differences by the users, regardless the performance differences.

Chapter 5 - Web3D Applications on Smart TV systems

Figure 5-1 Our cross-platform Interactive TV ad with Web 3D on different Smart TV devices

5.1 Introduction

As highlighted in Chapter 2, Smart TV systems are becoming increasingly popular. New and more powerful models are being released, while more units are being sold every year, gaining an ever-expanding user base. One of the standard features of these devices is the Internet connectivity and the ability to browse the worldwide web.

Accordingly, in this Chapter we address research objective 2 of our work: **Investigate the possibility to have real-time 3D implemented on Web, so that different Smart TVs with different capabilities can view it and interact with it.** To this end, we undertake a study in which we explore the possibilities of viewing 3D web content on Smart TV systems. To do this, in section 5.2 we run a number of tests through the web browsers on some representative Smart TV devices, to verify both support and performance of 3D web graphics and present the results. Furthermore, in section 5.3 a system architecture is proposed for maximum compatibility of web applications that utilise 3D features. To test this model, a cross-platform interactive TV ad prototype with real-time 3D elements was implemented and tested for compatibility on popular Smart TV platforms as described om section 5.4. Results showed that real-time Web 3D is now possible on Smart TVs. Although a proof-of-concept, the proposed model can solve compatibility problems by using a fallback strategy for unsupported features. Finally, in Section 5.5, a set of guidelines is compiled for development of cross-platform web applications with 3D elements on Smart TV system, based on the results of the experiment carried out.

5.2 *Experiment to evaluate support for Web3D capabilities of Smart TV devices*

Most TV browsers do not support the installation of plugins, therefore the way to get real-time 3D graphics is through native WebGL support. It is encouraging that most new Smart TV sets support experimentally WebGL, something that was not available until 2012, but first appeared in

some 2013 models. Previously, remote rendering and delivering 3D content in the form of streaming video on the TV was a possible workaround (Zorilla et al., 2012), but not an easy solution. Table 5-1, presents some of the most popular Smart TV platforms and the results of their web browsers on HTML5 capabilities, their support for WebGL, X3DOM and Three.js, HTML5 video/audio and canvas. HTML5test is a popular online service for testing each HTML5 feature in a browser[4]. ThreeJS is one of the most popular JavaScript libraries to use WebGL functionality. It was found necessary to run separate tests for ThreeJS and X3DOM support as it turned out that WebGL support did not automatically mean that either of these worked in the system. An interesting finding from these tests is that although some browsers were found to support WebGL, ThreeJS did not function at all, while X3DOM worked in most browsers that support WebGL. Surprisingly, none of the popular game consoles currently support WebGL, regardless of having 3D hardware capable of high-performance 3D graphics (they were not included in the table). A promising conclusion however, is that new Smart TV platforms finally support WebGL, X3DOM and ThreeJS as of 2014, in contrast to 2012 where none of these platforms supported it. Also, X3Dom was earlier compatible, with most 2013 models supporting it.

An important problem with 3D support however was found concerning 3D glasses. While most of the tested TVs support 3D glasses, the manufacturers have chosen to disable this option for the Web Browser App in all of the tested devices. The 3D glasses function was supported in watching 3D TV channels and movies, while it also worked in several Apps, such as the YouTube App where 3D videos could be viewed with stereoscopic glasses.

[4] http://www.html5test.com/

Table 5-1 Popular Smart TV devices HTML5 and 3D support.

Device	*HTML5 test.com Score*	*HTML5 Audio/ Video*	*HTML5 Canvas*	*WebGL Support*	*X3DOM Support*	*Three.JS Support*
Samsung Smart TV 2015 (TIZEN)	**465**	**YES**	**YES**	**YES**	**YES**	**YES**
LG Smart TV 2014 (WebOS)	**434**	**YES**	**YES**	**YES**	**YES**	**YES**
Samsung Smart TV 2014	**407**	**YES**	**YES**	**YES**	**YES**	**YES**
Sony Smart TV 2013 (Opera 3.4)	**312**	**YES**	**YES**	**YES**	**YES**	NO
LG Smart TV 2013 (Netcast 4.5)	**399**	**YES**	**YES**	**YES**	**YES**	NO
Samsung Smart TV 2013	**350**	**YES**	**YES**	**YES**	NO	NO
LG Smart TV 2012 (Netcast 3.0)	**238**	**YES**	**YES**	NO	NO	NO
Sony Smart TV 2012 (Opera 3.2)	**258**	**YES**	**YES**	NO	NO	NO

5.2.1 Performance

While compatibility results were considered quite promising, especially concerning WebGL and X3DOM support on newer Smart TV models, we decided that another important test should be performed, to estimate the real-time 3D graphics performance on the supported devices. The methodology used included 4 representative Smart TV devices that supported WebGL, which were tested for a number of ThreeJS[5] and X3Dom[6] examples while the maximum fps was recorded during camera or object animation. The test devices were: a 2014 Samsung Smart TV, a 2014 LG Smart TV (with WebOS), a Sony 2013 Smart TV (with Opera Browser), and an LG Smart TV 2013 model. Additionally, the same tests were run on an iPhone 5s and a powerful MacBook i7 laptop for reference. All devices' web browsers and software were updated to the latest versions. In Table 5-2, the fps performance from 11 representative tests is exhibited. Results showed that overall, the frame rates in Smart TVs are much lower compared to a 2014 laptop and even compared to a 2013 mobile phone, where the iPhone 5s produced double the frame rate of the best performed TV used in this test. The MacBook i7 is not included on the table as it maxed all the tests at 60fps apart from

[5] http://threejs.org/examples/

[6] http://examples.x3dom.org/simpleExamples.html

Table 5-2 Popular Smart TV Devices max FPS performance for ThreeJS and X3DOM WebGL

	LG 2014 (WebOS)	Samsung 2014	Sony 2013 (Opera 3.4)	LG 2013 (webcast)	Apple iPhone 5s
ThreeJS Tests					
Animation / cloth	X	8	X	X	12
Camera	30	19	X	X	59
geometries	31	18	X	X	59
morphs / horse	33	19	X	X	59
materials / skin	4	4	X	X	22
X3DOM Tests					
Small / Primitives	19	26	5	4	60
Small / Single Mesh	19	26	3	4	60
Small / Texture	19	23	5	4	60
Large / Single Mesh	19	20	5	3	60
Dynamic Lights	15	X	X	2	20
Shadow	20	11	13	X	59

X3Dom/Dynamic Lights which ran at 22 fps. Results also showed that performance is greatly improving on newer devices, with the 2014 LG and 2014 Samsung showing an increase in fps of 400% over the 2013 Sony and LG models. Another surprise was that although the Sony and LG 2013 models support WebGL, and x3DOM examples worked as expected, even with low frame rates, the ThreeJS library proved incompatible. A paradox was found comparing the LG and Samsung 2014 models: although LG had a better fps performance by ~30% for the ThreeJS examples, Samsung showed a slightly better performance by up to ~20% at the X3DOM tests. Despite the fps performance, most ThreeJS examples did not look so good on the LG TV, where during camera movement and object animations the 3D scene was "blinking" in most instances. Finally, most complex examples, such as Dynamic lights, did not work at all in most of the devices tested while the cloth animation worked only in the 2014 Samsung and the 2013 LG device. These unexpected behaviours, exhibit the experimental nature of the Web3D support on Smart TV devices.

Conclusively, the hands-on tests on Smart TV devices showed that Web 3D support, although existing, is without doubt in an experimental level at this point. It is by no means a mass production-ready feature, but it is possibly a good time for some early adopters to experiment with. Frame rates for 2014 models are finally in a minimum level of greater than or equal to 15fps for simple 3D scenes, in contrast to the unaccepted numbers of less than 5fps for the 2013 models.

5.3 Proposed model for Web 3D on Smart TVs

From the results in the previous section of this chapter for Web 3D support and performance on Smart TV device, we draw the following conclusions: (a) WebGL is available on new (post-2013) devices, although on experimental level, (b) WebGL performance on these devices is limited and (c) most pre-2014 models do not support WebGL or they do not support it in a functional level. Combining this with the fact that the Smart TV market is very fragmented, a content developer who wished to use real-time Web 3D capabilities, and at the same time address most of the Smart TV audience, including older devices, must use a hybrid model, where the system will be able to switch between real-time client-side 3D and 2D fallback content, depending on the user's device capabilities. JavaScript detection libraries (e.g. Modernizer.js) exist that can easily detect in real-time if the system can handle the features that the web application needs and act accordingly. Figure 5-2 outlines a proposed architecture for Web3D web applications on Smart TVs. The system relies only in the standard web

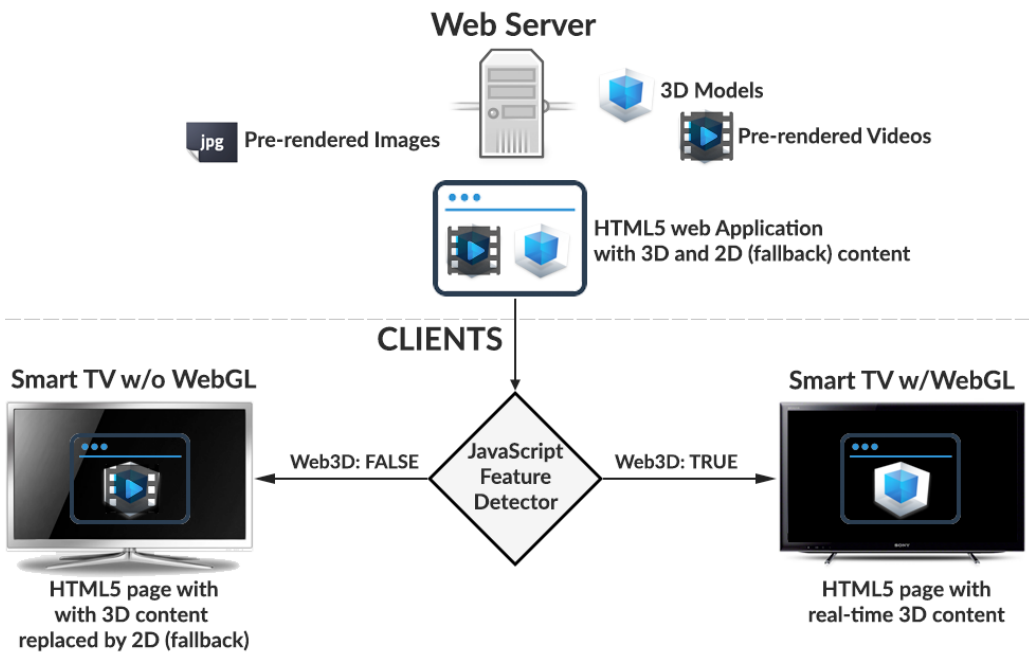


Figure 5-2 Overview of the proposed model for 3D on Smart TV

technologies of HTML5, CSS, JavaScript and WebGL. If the device is detected to be incompatible with WebGL, it is replaced by HTML5 videos or images, which, in its simplest form, sacrifices the interactivity features with the 3D model. Nevertheless, it is possible to preserve this functionality, by adding a more complex architecture, such as the 3DMaaS system, proposed by Zorilla et al. (2012), to allow real-time 3D rendering at server-side, following the user's interactivity requests, and stream the outputs as video to each client device. However, this model would require multiple the number of server-side resource power, so the simpler solution was presented here, as it can be easily adopted from more content providers. This system will run on the Web Browsers of Smart TVs to ensure a one-solution-fits-all model, instead of having to develop many different Apps to address each system and OS.

5.4 Application: Interactive TV ad prototype

From Chapter 4, we have concluded that HTML5 technologies can be a useful solution for effective cross-platform Smart TV advertising, which can be developed once and run in multiple platforms. As a proof of concept for the proposed model for Web3D web applications on Smart TVs we extended our previous system to include real-time Web3D elements, and further tested the system on 6 Smart TV devices (Samsung 2014/2013, LG 2014/2013, Sony 2013 and Google TV) for compatibility. The Interactive ad displayed a 3D car model using X3Dom that could be rotated in real-time by the user (Fig. 5-3), to examine it in all angles, something that was not possible in the previous 2D version of the ad that used only images and videos. More complex fun functionality can allow the user to "drive" the 3D car or manipulate its features such as the colour, wheels etc. If the system detects that the device does not support X3Dom, it then switches to the fallback solution to display pre-rendered video and images, so that the viewer can still use the ad, although with more limited functionality. It was however important to pay attention to the limitation of these devices, and use very simple low-polygon models, in order to have a satisfying frame-rate and also very small X3D files in order to avoid long delays before the content is loaded.

The Interactive ad, was able to run successfully in all the systems tested, while on older devices it switched to 2D-mode and was still functional. This proved that the proposed model can be used in production of cross-platform web application with 3D features on Smart TV devices.

Figure 5-3 The Web 3D Interactive TV ad prototype

5.5 Guidelines for utilizing 3D on Smart TV web applications.

From our experience garnered from the several devices we tested as well as from developing a web 3D application for Smart TVs, we comprised the following list of guidelines for developing real-time web 3D web applications for TV:

- **Blend simple 3D objects with 2D scenes / avoid full 3D scenes:** It is very difficult to maintain a satisfying frame rate on a full 3D environment. It will work much better if most of the scene is 2D and only few elements are simple 3D objects to maintain a minimum frame rate of at least 15 fps
- **Detect browser capabilities:** Use a detection library to find out information about the client system's 3D capabilities. Also, sometimes, it would be useful to detect the exact model so that for older model the application could switch to 2D to avoid extremely low frame rates. This can be done with JavaScript code or some JavaScript libraries for detecting specific features such as Modernizer.js.
- **Develop a fallback-strategy:** As not all TV platforms currently support WebGL, a fallback-strategy for unsupported systems is necessary, where an image or video stream can be displayed instead (HTML5 video is now supported on all new Smart TVs as tests showed).

- **Provide a force 2D mode:** As even those TV platforms that support WebGL are in a prototypical stage, it is possible that some elements of the system may not work satisfactory, and this cannot always be detected by the device capabilities. So, having an option to switch to the non-3D version manually can be helpful to the users.
- **Load Time:** As loading time can be an issue for 3D models, it would be useful to display a 2D image or an indication that the 3D model is loading.
- **Use well-structured HTML5 navigational elements:** This will allow for easier navigation using the remote-control D-PAD. Although new input devices are available in some models, it is much safer to use the D-PAD that is available across all smart-TV devices.
- **Test the application on diverse devices:** It would be important to test the application on as many as possible smart TV devices, at least LG and Samsung models, which are currently the most popular.

5.6 Conclusions

The main question that this chapter sought to answer is whether Smart TVs are ready for 3D web applications and websites and so address research objective 2 of our study. As our results have highlighted, these devices are not mature for serious web 3D, yet. However, looking at the evolution of these devices and their web browsers, HTML5 support and the improvement over these capabilities is steadily improving. At the same time, it is also important to note that webGL capabilities have been introduced by most Smart TV vendors during 2013 and improved considerably in the models of the following year. Moreover, gaming capabilities that are being added to new devices lead to more 3D power for improved performance. Furthermore, as most of these devices include the ability of displaying stereoscopic content using 3D glasses, it is expected that this function, although not currently supported on their web browsers, it will soon be expanded there, as it currently works on specific TV Apps. This will possibly create more user interest over Web 3D content on TV, and even confer some advantage over desktops and mobile devices, where 3D glasses are rarely available. Lack of TV stereoscopic content for 3D glasses could also boost user interest for viewing 3D websites, when this feature becomes available.

In conclusion, although web 3D on Smart TV systems is not yet ready for prime time, we have shown that it is nevertheless possible to start experimenting and exploiting simple 3D features inside HTML5 web applications, for momentum is gathering and in the following years the technology is expected to be ready to facilitate even more complex and complete web 3D TV content. Until then, our proposed model for hybrid 2D/3D web applications can solve the problem of compatibility with most Smart TV systems.

Chapter 6 - Are Websites Optimised for Mobile Devices and Smart TVs?

6.1 Introduction

In this chapter we target our third research objective, which is to **Assess the current adaption of popular websites in terms of compatibility with Smart TVs in comparison to Mobile devices**. Accordingly, we describe a study in which we evaluated the adaptation of some of the world's most popular websites to the "post-PC era" of using multiple devices for accessing the Internet. Up until recently the PC was the only device used for accessing the Web. This has changed dramatically over the past few years with the introduction of many powerful Internet-connected devices such as Smart Phones, Tablets and Smart TVs. Due to the many differences between these devices in terms of screen size, hardware power, input methods etc. in most cases a PC-optimised website is not optimally viewed in these devices, resulting in poor usability and UX. Thus, we examined 49 of the world's most visited websites, according to Alexa.com, to see if they offer optimised versions for Internet-connected mobile devices and Smart TVs. Results show wide support for mobile devices in contrast to very limited support for Smart TVs. The structure of this chapter is as follows: in its first part, a user's web browsing activity on non-PC devices is examined through existing studies and surveys. Then, the different optimization methods are described and explained. In the second part the results from the study are presented and conclusions are drawn.

6.2 Web Browsing Activity on Non-PC Devices

One of the main functions that an Internet-connected PC is used for is to browse the web. There are of course many other functions that the Internet is used for, such as Internet - calls, e-mail, system updates, on-line games etc. but web browsing is still the most popular application of an Internet-connected computer.

Internet connectivity was not something that mobile Phones where initially designed to do. Although the Internet was available at the time mobile phones became popular, their main use was limited to making phone calls and texting, while it took many years to become efficient web-browsing devices and start being widely used for this. Even today, it is common to prefer to use a mobile App for consuming and interacting with Internet content than the Mobile browser, as it offers a more optimised user experience (UX) in general, utilizing the full potential of the device capabilities. One of the main frustrations early mobile web users had to deal with was that websites were designed for much bigger screens, so viewing content and navigating with touch was problematic. However, web browsing on a phone is becoming increasingly popular, so much so as to become a necessity for a web-site to have a mobile-optimised version. Moreover, although there are speculations that mobile-optimised websites rank better in Google search results, this has not been officially confirmed, as Goggle rarely discloses its ranking factors. However, the latest addition in Google's Search Engine to always inform users in the result pages whether each website is mobile-optimised (Figure 6-1) makes it even more important than before, as it can now affect the choice of which search result users will prefer to visit (Google, 2014).

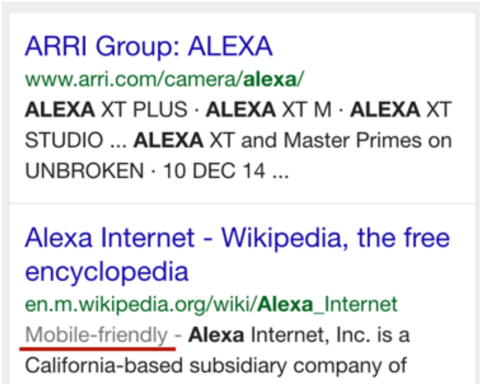


Figure 6-1 Google mobile search results, clearly indicating which website is optimised for mobiles (mobile-friendly)

Tablets are not quite the same story, as they became popular by the time web browsing was already popular using mobile phones. So, Internet browsing on a tablet device was considered a standard feature even from the days of the first massively popular tablet device, the iPad. Due to the larger screen size, a tablet device could display websites in a similar way to a PC screen, so most websites were usable on tablets from day one.

However, this does not mean that there is no need for website optimization on tablet devices. Although 7"-10" screens are larger than phones' 3.5"-5.5", they are not as large as the standard 21"-27" desktop PC monitors or 13"-15" laptop monitors, so small text sizes can still be an issue. Also, the input device of touch is significantly different to that of the mouse. For example, the mouse is more accurate than touch, so, small-size click areas can be a problem for usability. Also, the "hover" effect, very common in PC interfaces is not possible with touch screens.

Smart TV devices, on the other hand, are a totally different story. They are an evolution of a much older device (the TV), which people are used to handle in a specific way. Until Smart TVs came out, this was not an interactive medium, and the main possible interaction was limited to switching channels and setting the sound volume. Moreover, in contrast to all other devices, video has been the main TV communication method since the beginning of the medium, while text was sometimes present but limited. This was not the case in any of the aforementioned devices, where video has only recently been widely used, and popularised with services like YouTube after 2006, reaching 1 billion views per day in 2009 (Dickey and Wei, 2013). However, most Internet content remains in text format and probably will keep being in this form in the near future. A large amount of content is also available on images while relatively limited content is available in video or audio. This is arguably one of the largest caveats in TVs consuming standard Internet content.

Mobile web browsing is gaining popularity daily while desktop browsing is decreasing as many surveys indicate. For instance, according to StatCounter.com (Figure 6-2), worldwide mobile browsing has reached 32.12% as of December 2014, increasing from 22.16% a year earlier, and starting from nearly 0% in 2008. In contrast, desktop web browsing has decreased from 99.4% in 2008 to 61.17% in December 2014. Tablets on the other hand, a newer addition to Internet-connected devices, show a slower but steady increase, reaching 6.62% by the end of 2014.

A survey of 470 users of mobile phones and tablets in the United States tracked the day-to-day behaviour in regard of the use of their devices (Salesforce.com, 2014). 85% of the consumers that took part on the study said that mobile phones play a central part in their everyday lives, spending 3.3 hours on average per day on their smartphones. It is

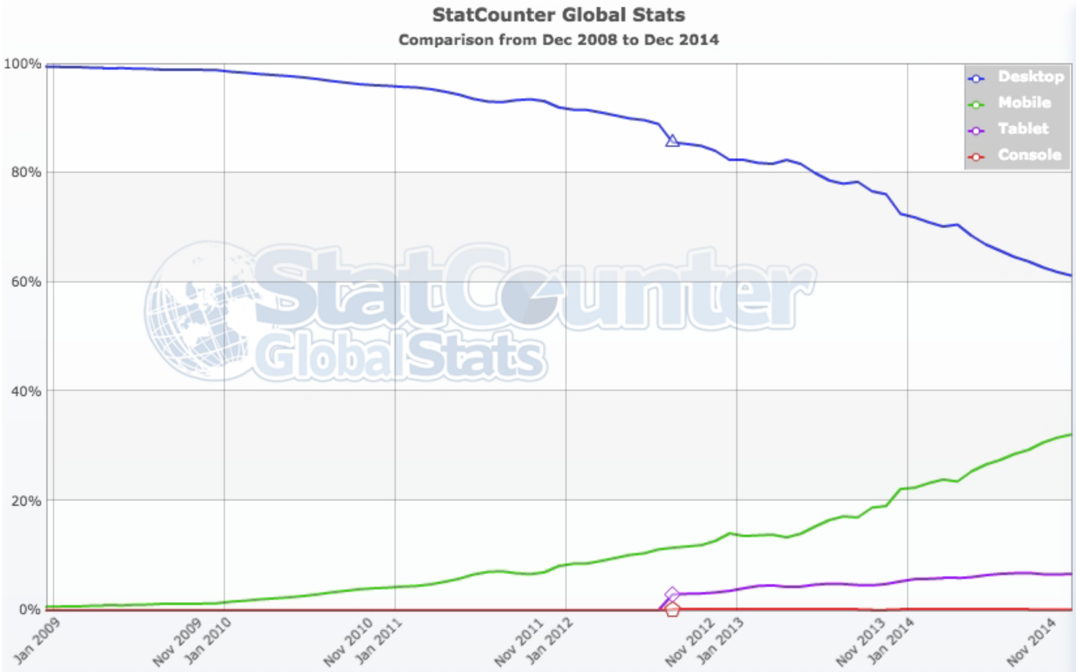


Figure 6-2 Use of desktop, mobile and tablet devices to browse the web

interesting to point out that 54% of survey responders, were not pleased with mobile-optimised content overall as, they say, these websites often don't have enough information compared to desktop websites. They are happier with using a tablet in this way, since the tablet versions are more complete. On smartphones, e-mail (91%), searching the Internet (76%), Social Networking (75%) and news alerts (62%) are among the most popular uses of the phone while traditional text messaging (90%) remains popular as well. On tablets, e-mail (69%) and searching for information online (70%) are the most popular daily activities to perform with social networking also popular at 64% and news alerts on 52%. Reading, as expected, was more popular on tablets than mobile phones (57% and 43% respectively). Another interesting finding was that 65% of tablet owners in the study reported using their tablet while watching TV at least once per day.

6.2.1 Smart TV Internet usage

Consuming Web on a Television device is not a new thing, but it is not a secret that it has failed to capture the interest of viewers so far. For instance, in a recent study by Nielsen (2013) in Australia although ownership of Connected TVs has increased (33% of Australian homes own a TV that can connect to the Internet), only 5% of them use it to access the Internet on a regular basis, a much lower percentage compared to all other devices in the same survey (38% on Mobile phones, 68% on desktop and 65% on laptop). Moreover, according to the Australian Connected Consumer Report (Nielsen, 2013) the key barriers from using the Internet capabilities of these devices are the lack of interest, lack of know-how, bad UX, slow connection speed and lack of interesting available content/Apps.

A survey in Germany (Tomorrow Focus Media, 2014) questioning 1,363 Smart TV owners indicates that "many responders find the use of the Internet with the smart TV very inconvenient". The main reasons for that are: inconvenient to browse the Internet with the remote control (79.6%), insufficient capabilities of the browser (63.1%), long boot/loading times for the Smart TV interface (50.2%), and a lack of multitasking (48.5%). The same survey also indicates that only 1 out of 4 Smart TV owners use their device to go online. Among them, 34% (n=466) used the Internet capabilities of their TVs.

Taking a look at the most popular Smart TV platforms it seems that Samsung currently has a clear advantage on worldwide Market Share with 26.4% of devices with LG and Sony being joint second place with significantly lower share of 14.3% and 14.4% respectively (Strategy Analytics, 2013).

In another report by NPD (2012) in North America (NPD Connected Intelligence, 2012), it is clear that the only major use for Smart TVs is to watch videos on a big screen (70%). Web browsing activity only captures the interest of 10% of the users while other functionality such as Social Media, shopping, navigation, etc. has an even lower than 10% usage.

Combining the findings of these surveys, it seems that the very limited use of web browsing on Smart TV devices can have been caused for many reasons, including:

- **Bad User Experience:** As most aforementioned studies indicate, the current UX on the Smart TV is not pleasant for users and causes frustration.
- **Input Devices:** Browsing a website - whose interaction design was built with the mouse/keyboard input devices in mind - with a remote control can be a very unpleasant and frustrating experience, which is quite the opposite from what viewers are looking for: relaxation, rest etc. In mobiles, browsing the web (before touch-screens were adopted), was very difficult and this technology actually solved this problem and helped it to become mainstream.

- **User State:** Users of a TV are in a different "state of mind" than when using a PC or a mobile device and normal websites don't take this factor into account. A relaxed navigation style should be preferred (Chorianopoulos, 2008)
- **Lack of TV-Optimised web content:** Although most new TVs include some kind of a web browser, websites are optimised for desktop or mobile, not TV, and this can easily result in an unpleasant UX.

However, manufactures are continuing to support and improve the Smart TV devices and their Web Browsers. The Internet of course has many other benefits to provide to Smart TVs, such as viewing online video, so most viewers naturally desire this functionality. It is also important to take note that smartphones also took many years to adapt to the Internet features, with many failures on the way (WAP is the most famous example). Hopefully, this will apply to Smart TV in the future, as technology is improved and also content (web sites) is becoming more TV optimised.

6.3 Device Optimised Content Guidelines

With the arrival and popularization of non-PC devices for Internet browsing, it became evident that a single version of a website that worked and looked well on a desktop device was not adequate. So, user studies started to appear in order to optimise the UX and usability on other devices as well, as shall now be described.

6.3.1 Mobile phones & tablets

The problems of browsing desktop websites on smartphones became evident from the beginning when these devices started being used for this function. The smaller screen size, lower resolution, touch interface, limited bandwidth were obstacles to a good UX. After years of testing, a number of guidelines and best practices have been developed for mobile web design, both from official organizations such as the W3C (W3C, 2008) and experts such as Smashing Magazine (2012). These guidelines include the use of large text, easy to read on the small screen, avoiding large width pages that the user has to scroll sideways and zoom in and out, avoiding excess and large-size content that takes a lot of time and bandwidth to load, links and buttons large enough to comfortably press them with a finger, avoiding free text writing boxes, and more.

Tablet web design guidelines share much in common with mobile phones, as the input method is the same (touchscreen) although it has more similarities to the desktop as far as screen size is concerned. There are websites and books on the subject, (Mobify, 2014), but usually tablets are treated as a subcategory of mobile devices, so guides for mobile devices usually contain subsections referring to their unique features.

6.3.2 Smart TV web content optimization

Smart TVs, being the newest type of devices, and not being an established medium for online browsing yet, do not have as many guideline material as mobile devices do. The only guidelines for optimizing websites for Smart TVs are by Google, which were created to support their Google TV platform (Google, 2012) and arguably represent the most comprehensive guide available. However, they also rely heavily on Google TV's browser and many examples will not be compatible with other TV devices. As of 2014, Google officially discontinued the Google TV product and announced a new platform under the name of Android TV (Google, 2014). The W3C is also showing a clear interest towards web on TV (W3C, 2013) although it has not yet released any design guidelines. There are however many resources available for app design on TV from browser developers such as Opera (Opera Software, 2013), Smart TV manufacturers such as Samsung (2014), TV channels like BBC (2006), and of course academic researchers (Chorianopoulos, 2008). From the afore-mentioned resources, some basic guidelines for optimised TV web-content can be derived, which would definitely include: large font-size (>22px), limited choices (menus etc) for more relaxed navigation, ability to navigate through remote control D-PAD, avoidance of scrolling (paging is preferred) and avoidance of text input, which is very difficult with the remote control.

6.4 Methods for Delivering Device-Optimised Web Content

Content always plays a major role in the success of any hardware platform. It was not until mobile websites became a standard that mobile Internet use increased dramatically. This is currently one of the major setbacks for Smart TV web use. In order to optimise web content for mobiles or Smart TVs there are three different techniques:

1) Custom device-specific websites
2) Device-specific Apps
3) Responsive websites

An overview of these methods can be seen in Figure 6-3. Following is a more comprehensive description of these methods.

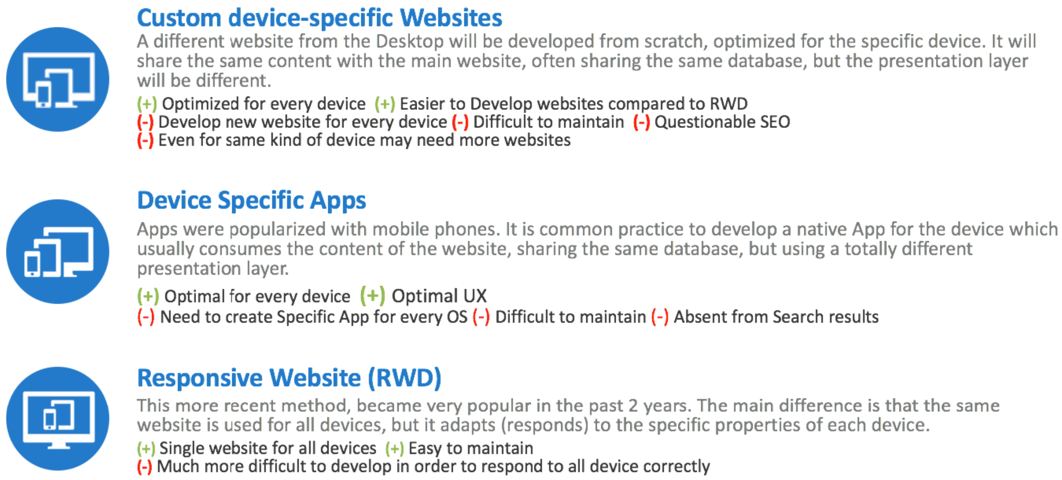


Figure 6-3 Summary of the three main methods to optimise Web content on devices

6.4.1 Custom device-specific website

In this approach, a different website is created which, although consuming the same content as the desktop-version website, uses a totally different presentation layer. Such websites usually reside on a different subdomain (e.g. m.website.com) or sometimes inside a subfolder (e.g. www.mysite.com/mobile/). The main advantage of this solution is that a website can be designed from scratch for mobile-only or Smart TV-only, which means it will be fully optimised for it, avoiding any excess material that the desktop version has, and taking the input method of touch as standard. The main disadvantage is that a new website has to be created and maintained, which will use a number of resources. Another disadvantage is that mobile devices and Smart TVs nowadays are not homogenous, having very different capabilities in terms of e.g. resolution, screen size etc., so creating a custom website for every type of device is going to be ever more resource-consuming. Therefore, real-time adaption to device characteristics will have to be done, which makes it a hybrid technique, compared with Responsive web design.

6.4.2 Device-specific App:

This is a device-specific developed application that consumes the same content as the desktop website. On smartphones and tablets, it would usually be for Android, iPhone or Windows Phone platforms. On Smart TVs, there are many more platforms available and could be developed for Google TV, Samsung TV, LG TV, Sony TV etc. This can be a considerable problem, as website owners will have to use extensive resources to develop and maintain many different versions of their app for each platform, since none of these are compatible to the others. So, usually an app will be available for one or two platforms at best, while users of other platforms will not be able to use it.

6.4.3 Responsive website

Responsive Web Design (RWD) is a technique introduced in 2010 by Ethan Marcotte (2010), in which essentially the same website adapts to the special device properties (e.g. changes font sizes, arrangement, menus, etc.) in real-time, after detecting some device properties. This method has become very popular recently due to its many advantages, especially in terms of efficiency, as the developers have to create and maintain only a single website for all devices. However, development of really responsive multi-device websites, takes more effort, testing and time than developing a device-specific website. Also, sometimes re-designing an interface from scratch will be more optimal for a specific device than just doing adjustments over the existing one. Even with these in mind, however, RWD is probably the most favoured technique for mobile-optimised websites today.

6.5 The Study

In order to study the current state on the levels of adaption of web sites to non-desktop devices, a survey was conducted on some of the world's most popular websites. A list of the 100 most visited websites was retrieved from Alexa Internet for June 2014 (Alexa Internet, 2014). From these, 49 websites that fulfilled our requirements (explained later), clustered into 8 categories, were tested whether they had (1) custom website, (2) app, or (3) responsive website for delivering their content on (a) mobile phones, (b) tablets and (c) smart TV devices.

6.5.1 Categorization of websites

In order to have a choice of representing websites, categorisation was used in some general categories depending on the type of each websites. Although Alexa Internet did have a categorisation system, it was not very convenient as such, since it contained many categories of similar types (e.g. separate categories for web services) and also it was noticed that the categorization in some websites was not accurate. This was probably due to changes in context in the website's lifespan. For example, Microsoft live.com used to host a search engine but now is mainly used for the outlook mail service since Microsoft's search engine was rebranded as bing.com.

In our study, websites were assigned to 8 main categories:

1. **Blogging Platforms (5)**: 5 popular blogging platforms were included in the lists such as Wordpress.com, Blogger.com etc.
2. **Commerce (17):** Commercial websites that are used for e-commerce (e.g. several country versions of Amazon, eBay etc) and companies (e.g. Apple.com, Microsoft.com, Adobe.com)
3. **Informational (4):** Websites that offer informational/reference material such as Wikipedia and About.com
4. **News (14):** Websites with news content such as CNN.com BBC.co.uk etc
5. **Search (26):** This list included 16 versions of Google search for different countries (TTLDs) as well as some other search engines such as Yahoo, Baidu etc. For this survey it was decided that only the US/Global version of Google will be used (Google.com) since the other versions work in the same manner. So, there were 10 different search engines after excluding the various Google versions.
6. **Services (6):** This included a number of popular web services, such as e-mail service live.com and mail.ru
7. **Social Media (9):** Many social networking websites were in the list of Alexa such as Facebook.com, twitter.com, linkedin.com etc.
8. **Video (5):** Five video services were included in the list (YouTube, vube, youku, Netflix and dailymotion)

The following 3 categories were also identified in the list but were <u>not included</u> in the survey:

1. **Network Services (8):** These were websites that contained services that in general are used by other websites, so they were not included in the survey. Most of these sites did not have a navigational website for users to access.

2. **Pornography (4):** Four pornographic websites were included in the Alexa top 100 lists. These websites however were not used in the survey due to their adult content.

3. **Torrent (2):** Two torrent websites were on the Alexa list but were not included in the survey.

The total number of websites that fell into the included categories for this survey was 71. However, 20 websites on the list were in the Chinese and Japanese languages and was decided to be removed from the lists, as it was considered likely to not have accurate evaluation, due to (our) language knowledge limitations. Also, blogspot and blogger, though listed separately, are the same websites, so blogger was removed to avoid double entry.

Conclusively, the final list came down to 49 websites: 3 Blogging platforms, 12 Commerce sites, 4 information websites, 8 News websites, 5 Search engines, 5 web services, 8 Social networks and 4 Video websites.

6.5.2 Test Devices

In order to have a complete picture for this survey, the following representative devices were used:

- **Smartphones:** At the time of running the study (2015) there were two representative smartphones, iPhone 5s for iOS devices and Samsung Galaxy S4 for Android devices. These two operating system platforms are currently the leading Smartphone operating systems.

- **Tablets:** An Apple iPad 2 (iOS) and an Asus transformer (Android and MS-Surface) were used.

- **Smart TVs:** Three devices were used, as there are more platforms for Smart TVs: Samsung Smart TV 2014 model UE55F6670, an LG Smart TV 2013 model 42LA660S and a Google TV Sony NSZ-GS8 set-top box

In order to confirm the availability of a responsive website, an App or a Custom website on a device category, it was decided that even one version is enough (e.g. if for the X website, an iOS app existed then it was enough to tick the App box, although there could not be an Android App). This was decided, as the main aim of this study is to compare the optimised content availability on 3 different device types (Smartphones, Tables and Smart TVs) and not the different platforms for each type of device.

6.5.3 Testing each website on the different devices

In order to have an accurate picture for this survey, each website was carefully examined. For each of the selected websites, two pages were loaded, the home page and a typical content page.

First, these pages were opened in the Chrome (v.39) browser on a Desktop computer at a resolution of 2560x1440 of a 27’’ display. Then, it was slowly scaled down to the minimal allowed window width to have an initial indication of whether the site is responsive. A further browser refresh was applied, as sometimes responsive websites work better when loaded on the desired resolution (real-time resizing was found to sometimes cause issues).

The second test was performed on the mobile phones of iPhone 5s (iOS 8.1) and Samsung Galaxy S4 (Android KitKat) where the website was loaded on the default browser. If the website was adapted to each devices screen (responsive) for any of the two devices then the responsive website box was ticked. By checking the website’s URL we could determine if the website was responsive (same url as desktop, e.g. www.website.com) or we have been redirected to a custom mobile version (url different from desktop, e.g. m.website.com). If the URL is different then the custom checkbox is ticked. In order to indicate whether there was an app available to consume the website content, a search for the site name and company was performed at the App Store of each device. A further search for a mobile app was also performed in Google Search, in case the App was not present in the App Store we were using, due to country specific limitations. It is interesting to point out that in most cases, upon entering the website with a smartphone, if an App was available, a banner to download it was displayed on the top part of the website.

The tablet devices were tested in exactly the same way as the smartphones, but the site was also compared to the desktop and smartphone versions to make sure that it was not exactly the same but has been optimised for this device. A tablet version should not be as limited and big (e.g. in terms of font size) as the mobile phone version and also not as cluttered with small text and objects as the desktop version. Especially in the early days of tablets, it was not unlikely that a tablet device was identified as a mobile phone and this version was displayed.

Finally, for the Smart TV devices, the website was opened on each device with the default browser. Also, a search was performed in each device’s App Store for an available app and a further search on the Internet was also performed. The latter proved a necessity in TV devices as Apps were not easily found and often there were many country-specific limitations. Also, a separate scan on each website was often necessary to find whether a TV-friendly version of the website was available, as automatic redirection was very rare. Responsiveness of a website for TV was a little more difficult to detect, since the common TV resolution of 1080p is very much used in desktop computers as well, so detection scripts that relied on screen size only have the result of displaying the desktop version on TV. A website optimised exclusively for TV would have at least larger font sizes compared to desktop for reading from distance and simpler navigation (avoid complex menus). If we took into account all the TV usability guidelines mentioned earlier (avoid scrolling, D-PAD navigation etc) then it would be even more difficult to find a fully optimised TV site, so for this experiment we focused on very basic optimizations (font-size, simplified navigation, correct rendering).

Figure 6-4 portrays 3 screenshots from the same website (CNN.COM) when viewed on a SmartTV, PC and Smartphone respectively.

Additionally, some notes were taken on problems and specific behaviour of websites for each platform that were encountered. This was quite often on TV devices.

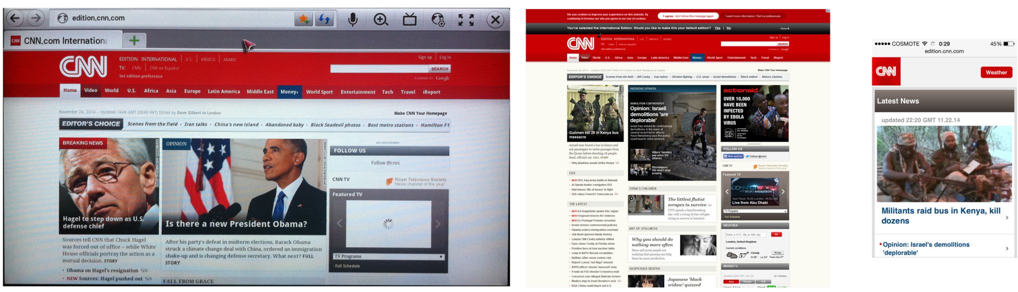


Figure 6-4 The same website viewed on TV, PC and mobile phone respectively

6.6 Results

Results on testing website adoption on the three different types of devices clearly show how serious website designers take the large movement of the users towards mobile browsing (Figure 6-5). It is also clear that TV devices are not considered very important yet, as only 24 out of 49 websites had some kind of optimised version for TV compared to 49/49 for mobile phones. Looking at the preferred optimization method, clearly Apps and responsive versions are preferred to custom device-specific websites (Figure 6-6).

6.6.1 Mobile

All tested websites had at least one mobile-friendly method to consume their content (Figure 6-5), either in the form of an app, custom or a responsive website. Quite often, websites had both an app and a mobile-friendly website (Fig. 6-6). This was not a surprise, as it is quite common to find the content of a website on search-engine results when looking for something, so having a mobile website would improve the search rankings, while having only an app would not have any results in search engines, and loose possible users that are looking for specific content. Looking at Figure 6-7, where a breakdown to the website categories is presented, it seems that blogging platforms and search engines prefer the use of responsive websites and completely avoiding custom designs, while News, Social and Commerce websites have a somehow equal allocation of the three types of formats.

6.6.2 Tablet

Tablet-optimised website versions were also very popular, with only 1 website out of 49 not having some optimised version for a tablet device. However, a more detailed look (Figure 6-6) reveals that although tablet-optimised Apps and responsive websites share a lot with mobile phones, only 8 out of 49 websites have a custom tablet website compared to 19 mobile-optimised custom websites. This is not very surprising, since the large screen of a tablet is able to display the desktop website quite well with only a

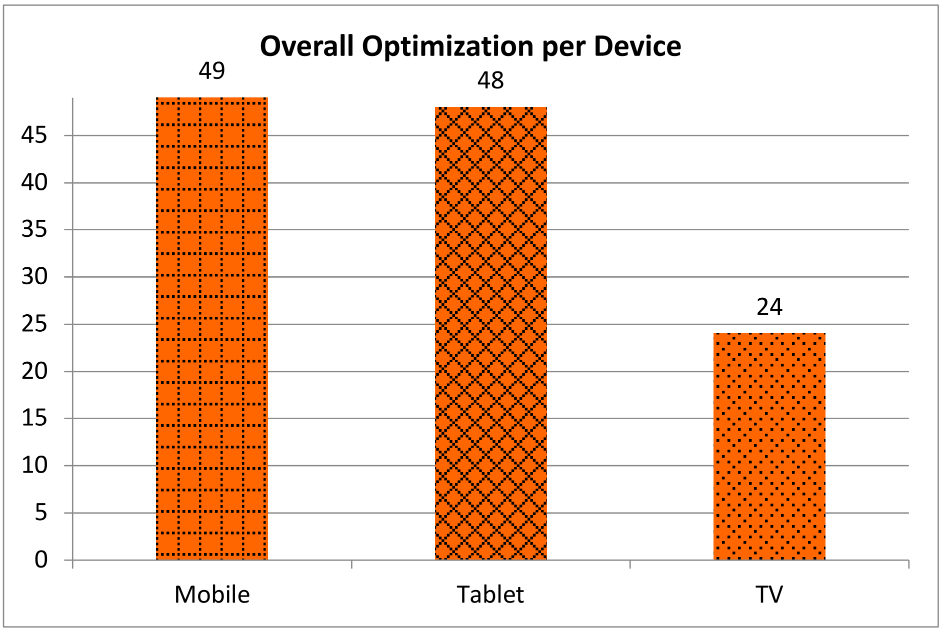


Figure 6-5 Number of websites out of 49 total that have at least one optimised version (custom, app or responsive) for each type of device.

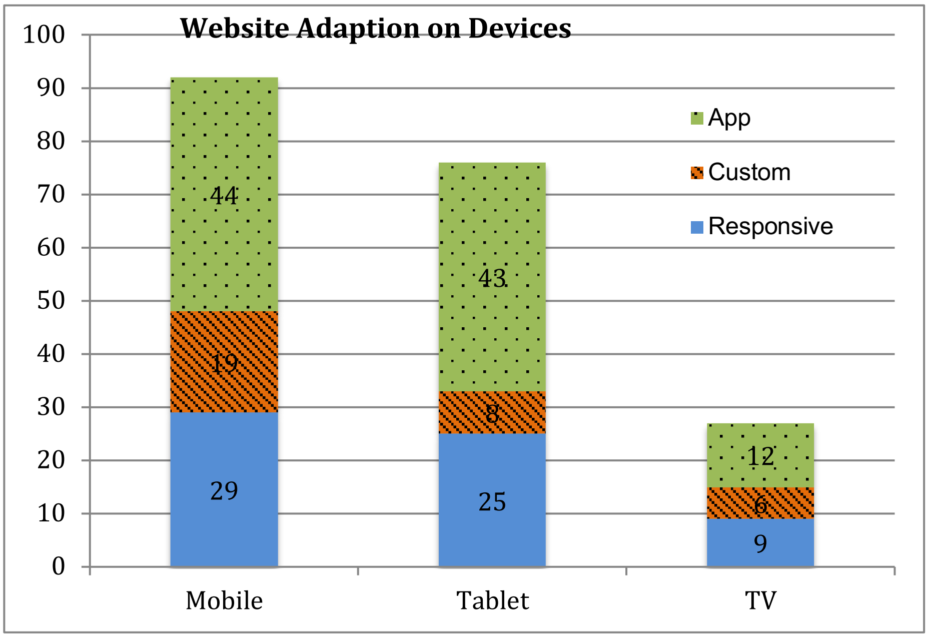


Figure 6-6 Breakdown of Responsive, App and Custom adaptation availability of top 50 websites on Mobile, Tablet and Smart TV

few changes, so much less adjustments are needed compared to mobile small-screen version and RWD is optimal for this kind of work. Since the resources of maintaining an extra website are considerable, it is often preferred to make a responsive version of the desktop website. Looking at the category breakdown on Figure 6-7 it is clear that only Social Media websites are really interested in custom tablet versions at least for the websites examined in this study.

6.6.3 Smart TV

Smart TVs, as the newest and less adopted technology, are clearly much less a priority for the world's most popular websites as results show. Only 12 TV Apps were found (~24%), compared to 48-49 (~100%) for tablets and mobile phones. Custom websites were also rare with only 6 out of 49 having one. Our findings showed that only 9 out of 49 websites were responsive for TV. It is important to note that this does not mean that other responsive websites did not work on the TV devices, but that they did not "respond" enough to make TV browsing pleasant. This, in most cases, meant that they did not have large enough text to be readable from a distance, or that they needed a lot of scrolling to be able to use it, and that the menus and links could not be navigated using the D-PAD of the TV remote.

One other interesting thing to point out concerning TV Apps, is that it when a user visited the website with the TV browser, there was no indication that the site had an available TV app to download. Although this was a standard practice on mobile phones, it was completely ignored on TV. It was even more surprising that even on websites that had a TV custom website version available, there was not an automatic redirect or even an indication that there is such a version available -the user had to know the URL of the TV version in order to browse it. This probably has to do with the difficulty involved for the website to detect a smart TV browser so that it will act accordingly, as these sometimes identify themselves as desktop browsers. The same issue also applied when a TV App for the website was available. In contrast to mobile sites, where a top banner was displayed informing the user for the existence of the App, this was not encountered in neither of the TV websites. Looking at the categories in Figure 5, it seems that News, Video and Social sites have more interest in TV experience, while commerce, informational and Services did not seem to have any interest on the platform at the time. Search engines, although compatible with TVs, are by design not very comfortable to use, as writing text with the remote control is not convenient (most smart TVs don't have keyboards).

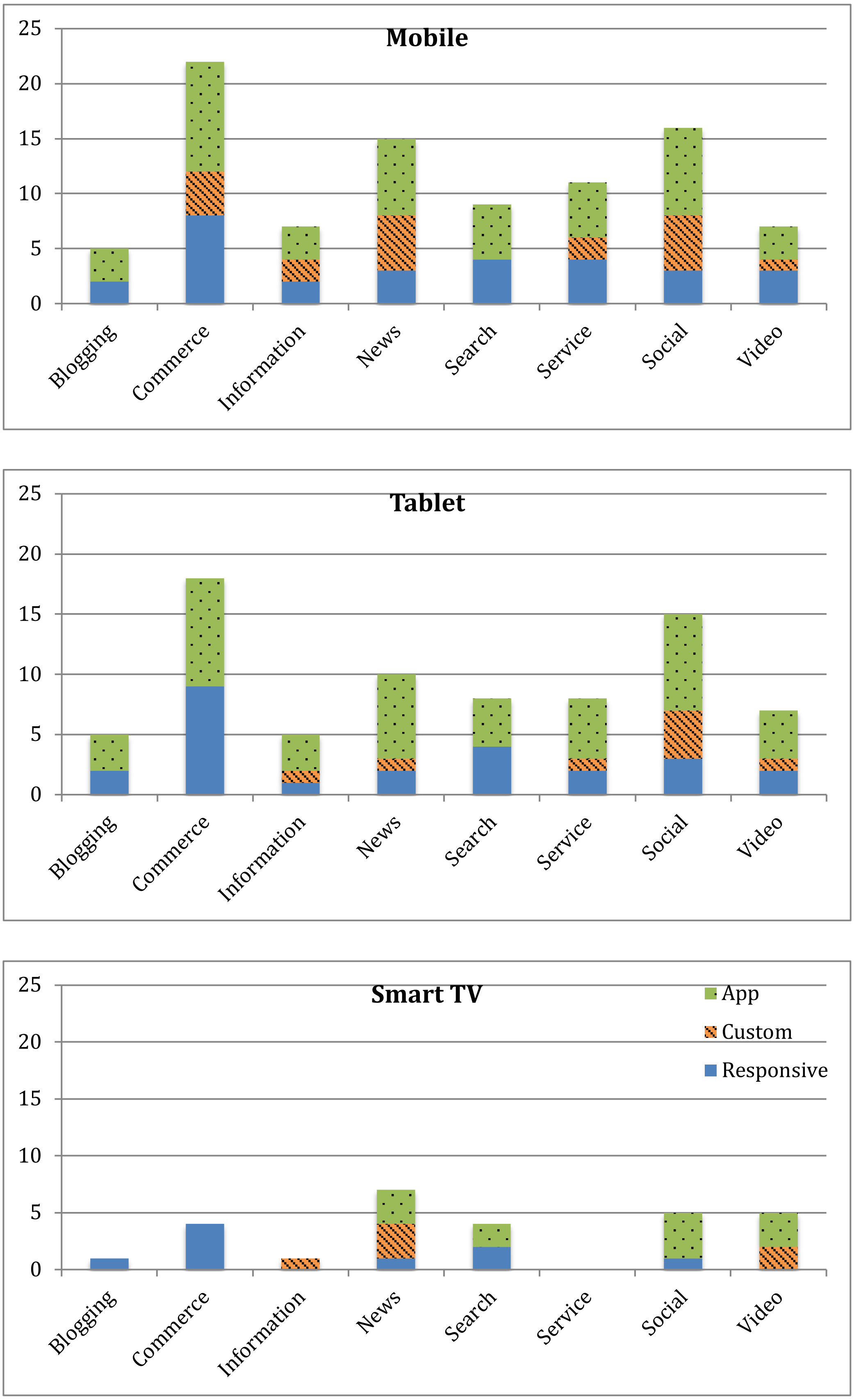


Figure 6-7 Responsive, App and Custom adaptation availability of top 49 websites on Mobile, Tablet and Smart TV categorized by type of website

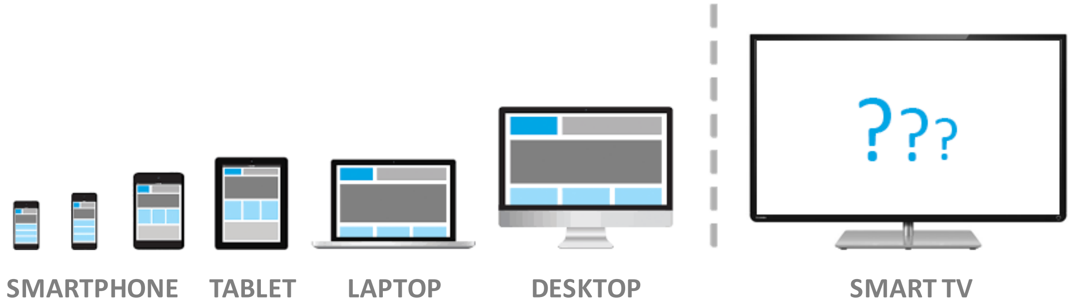
6.7 Conclusions

Smart TVs are a new popular type of device, with sales increasing every year although their user adoption is much less compared to mobile devices. From the survey detailed above on some of the world's most popular websites it was clear how far the adoption on mobile devices has come. As the popularity of these devices has grown considerably, all the websites of the survey have at least one mobile version, while many of them have both an App and a responsive or custom website optimised for smartphones and tablets.

It was evident, however, both from the surveys studied and from the tests that were performed in the survey described in this chapter, that current web content is problematic on Smart TVs and does not meet user expectations. Although these devices do have browsers that can handle web sites with HTML5, CSS3 and JavaScript satisfactorily, a website that was designed for desktop or mobile is not optimal for viewing on a TV as is. So, users of these devices, although initially interested in using their TVs to browse the web, soon become discouraged from the bad usability and UX of using non-optimised websites. It was surprising, that even among the top visited websites of the world, TV adoption was not standard, with only 50% of them having some form (often very limited) of TV-optimised version, compared to 100% of mobile-optimised versions. Also, it is interesting to point out that the most popular method for content-optimisation was the development of a TV App. This method, although probably providing full access to the devices capabilities, also has the drawback that it is only compatible with one platform. Moreover, with so many different Smart TV platforms available at the time, it is extremely resource-intensive to create a version for each of these and maintain it, in order to reach the maximum possible audience. It is however feasible to create a custom website, or a responsive TV-optimised site that will be compatible with all devices. Surprisingly, this method was not popular, with only 11 out of 49 tested websites using it (~23%).

In conclusion, the study performed in this chapter meets the initiative set for objective 3 of the Thesis, which was to assess the current adaption of popular websites in terms of compatibility with Smart TVs in comparison to Mobile devices. The results drawn from the sample of chosen websites are quite clear that Smart TVs versions of websites barely exist, in contrast to Desktop and Mobile devices.

Chapter 7 - Responsive Web Design for Smart TV



7.1 Introduction

Smart TV devices have become a commodity in the past few years, enhancing the television (TV) with an array of new features, providing capabilities of Internet connection and computer/mobile-like abilities. However, most websites are not designed with the smart TV experience in mind, and usability problems arise when websites are viewed and interacted with on a TV device. To solve this challenge, we propose the use of Responsive Web Design, a method that has become a standard in mobile devices, saving the need of developing custom TV-specific websites or Apps.

In this chapter we are addressing our 4th objective: **Explore the possibility of exploiting Responsive Web Design, a standard technique for mobile website optimization, to the Smart TV, in order to achieve better usability and user experience while making more content available in a better way to these devices.** Moreover, we also explore if this can be achieved with minimal effort on the part of content providers, i.e. without the need to develop new websites or TV Apps. In this way, the content available for Smart TVs could be expanded significantly; additionally, if the UX is improved, users are more likely to want to access it through their TVs. Specifically, in our study we focus on the usability and likeability aspects of the UX.

Accordingly, we tested the current usability of a typical "desktop" website on the Smart TV, and compared it to an alternative version of the same site but with our proposed responsive techniques being applied. Results provided an indication of improved usability and likeability by using our "TV-Responsive" method compared to the non-responsive one. However, while our TV-Responsive website had a higher usability score, the differences were not statistically significant, with the exception of the usability on the ease of scrolling and most measured task completion times.

This chapter suggests a method for improving aspects of the user experience of Web browsing on Smart TVs by exploiting Responsive Web Design (RWD). RWD has become very popular, after its introduction in 2010 by E. Marcotte, who originally suggested a way for a single website to be automatically adjusted for optimal viewing, using CSS media queries, to a user's particular device. Over the past few years, this technique has been successfully used to make websites friendlier to mobile phones and tablets with considerable success, and it has become a standard practice in web design. The popularity of RWD was also evidenced in a study on the 49 most visited websites, described in the previous chapter, which found that, while 60% of these were responsive, only 40% had a custom mobile website (Perakakis el al., 2015).

The structure of this chapter is as follows: Section 7.2 gives an overview of RWD, which is then followed by a review of Web Browsing on Smart TVs and the issues it raises, motivating the need for the study described in this chapter. Section 7.3 then explores the reasons behind the limited use of Web Browsing capabilities on Smart TVs and provides the research question of this chapter. Section 7.4 describes the prototype Smart TV-responsive system we designed and implemented, with Section 7.5 detailing its evaluation on different Smart TV platforms. After it was confirmed that the TV RWD website is compatible with all devices during device platform evaluation, it was presented to users in order to compare the UX aspects of Usability and Likability – the methodology employed is described in Section 7.6 and the results of the evaluation in Section 7.7. Finally, the conclusions drawn from this study are discussed in Section 7.8.

7.2 Responsive Web Design for Smart TVs

RWD is a technique for delivering the same content to multiple devices, using the same front-end HTML and CSS code for the most part, but adjusting sizes and hiding/showing elements of a page for an optimal UX on each device. Since the proliferation of many new devices such as tablets and smartphones, it has become a necessity to optimise websites for all these devices (Mohorovicic, 2013). This usually relies on CSS Media Queries that define Breakpoints with Feature Sets, which are collections of optimizations for different device types and screen sizes (Hill, 2014). Additionally, it is very common that JavaScript is also utilised for adding more complex device detection mechanisms and more dramatic changes on the layout. These detection methods are performed client-side, but there are also some server-side detection methods, based upon information sent in HTTP requests (Zorrilla et al., 2015). The server-side method can be useful for media content, i.e. selecting best resolution of bitrate for a specific device type. There are many books and online resources on how to develop a responsive website such as (Frain, 2012) and (Avery, 2012).

Indeed, it seems that RWD has been disregarded so far for the TV. In work described in the previous Chapter, we performed performed study on the world's 49 most popular websites and we discovered that, although all of them had an optimised version for mobile phones and tablets, less than half had actually some sort of - very basic - optimization for TVs (24 out of 49). In the same study, only 9 out of 49 websites were found to have responsive behaviour for the TV, and these were quite basic optimizations (font-size, relatively simple navigation, correct rendering). An important comment is that if the criteria were for fully-optimised TV employing RWD as discussed in the current chapter, then none of the 49 websites would fulfil them. Moreover, these basic optimizations were mostly features of the overall responsive design and did not seem specific for Smart TV, so they actually happened unintentionally.

An important note on RWD is that although its purpose is to result in optimally viewing a website on a device, a responsive website doesn't automatically mean that it responds well on *every* available device. For example, a website that was designed to respond well on mobile phones, if it responds in the same way on a tablet, will not be optimal for this other device. So, web designers must explicitly work on different device types to make the appropriate adjustments for optimal UX in each one. Even in this case, devices in the same category may need adjustments, and testing on many devices is crucial.

7.3 Web Browsing on Smart TVs

Why do people fail to use their Smart TV's Internet Browsing capabilities to access the wealth of available web content? An obvious reason has to do with the extended use of many popular Internet-ready devices, such as mobile phones and tablets, which are readily available in the living-room and are often used while watching TV. However, in this chapter we will focus on the reasons users refrain from the TV-browsing experience. The literature highlights a multitude of different reasons, which can be grouped around three main themes:

- **Lack of TV-optimised content**: Lack of Smart TV content is a finding of many user surveys (Nielsen, 2013). Although most new TVs include some kind of a web browser, websites are optimised for desktop or mobile platforms, not TV, and this can compound the aforementioned problems, making the TV experience even less pleasant.

- **Problematic Navigational/Input Devices:** A very common complaint in user surveys is about the input devices of the Smart TVs. Browsing a website with a remote control (when the website was built with mouse/keyboard input devices in mind) can be a very unpleasant and frustrating experience (Tomorrow Focus Media, 2014), which is quite the opposite from what TV viewers are looking for: relaxation, rest, etc.

- **Bad User Experience:** As user surveys indicate, the current UX on the Smart TV is not a pleasant one and causes users frustration (Nielsen, 2013). TV users are in a more relaxed "state of mind" than when using a PC or a mobile device and normal websites fail to take this factor into account. A relaxed navigation style, without many options requiring a lot of thinking should be preferred (Chorianopoulos, 2008)

Accordingly, in the following subsections we discuss each of these identified issues in more detail.

7.3.1 Lack of Web Content for Smart TVs

There are two main issues at stake here: the first is how one adapts content for Smart TV consumption, and the second is what properties does a webpage need to have to be optimised for Smart TV? Each is now addressed in turn.

The most popular method of dealing with device adaptation and optimal content delivery to Smart TV platforms is to develop a native App for each device. In this respect, TV Apps use the same structure as those developed for phones and tablets (Chorianopoulos, 2008). Following this approach, optimal UX and performance are ensured, but a big disadvantage is that such Apps are developed using each device's proprietary API, resulting in limited compatibility (i.e. compatibility with only one kind of device/operating system). Thus, developers have to create and maintain many versions of the App for each device and TV operating system. This becomes even more complicated considering that Smart TV manufacturers tend to change their operating systems every 1-2 years. Another disadvantage of this method is that users will have to download the App first in order to access the content, so it is not readily available – this is in contrast to a website, which is just one link/url away.

An alternative method for delivering device-optimised content, which was initially very popular with mobile phones, but is not very common on Smart TVs, is to create a separate (custom) website, optimised for each device. With this technique, multiple versions of a website are designed from scratch for mobile phones, tablets, Smart TVs etc. and use the best design practices for each device, consuming the same content as the main website (Perakakis et al., 2015). Server-side detection can be utilised to direct the browser to the appropriate version based on the HTTP request. A problem with this method however, is the increased maintenance needed, as two or even more (e.g. tablet version) websites have to be maintained. Although the content database is usually shared among these sites, a drastic change in the website would mean considerable work for web developers, who have to propagate the change across all versions of the website.

The most important advantage of the TV App method is that because the native API is used, there is usually more open access to hardware. For example, a 3D App (e.g. a game) can use the TV's 3D glasses through the API and that could be unavailable for Web Apps. It could also utilise GPU acceleration through WebGL, as most TV browsers have limited WebGL support as relevant studies reveal (Perakakis and Ghinea, 2015). However, this scenario is not very common as most web content is composed of text, images and videos, so standard web technologies such as HMTL5, CSS3 and JavaScript are adequate to deliver it. Table 7-1 exposes the main features of the two different content delivery methods, and also compares them to the RWD technique.

As far as optimised TV content is concerned, it is essential to define what this entails, in terms of specifications for a web page to have. Unfortunately, current resources for Web Design on TV are very limited. In fact, the little existing literature comes from Google (Google, 2014), which was made to guide Android TV developers, Opera

Table 7-1 Content Delivery Methods on Smart TVs

	TV App	Custom Website	Responsive Website
Content Readily Available to Users	No (requires installation of App)	Yes (but requires the users to find the custom website url)	Yes (the users need only go to the normal url)
Compatible with different TV platforms	No, just one	Yes (but not very different ones)	Yes (Can respond to all platforms)
Compatible with other platforms (PC, Mobile)	No	No	Yes
Capabilities of TV used	All (as it uses native API)	Basic (only ones available on web)	Basic (only ones available on web)
Maintenance	Separate for each App version	Separate for each custom website	Only one version has to be maintained
Development Skills	API of each device	Standard Web Technologies	Standard Web Technologies

(Opera Software, 2013), which have versions of their browser on some set-top boxes, Smart TVs (e.g. Sony Smart TV), and the BBC which have released a comprehensive guide for developing interactive TV programs (BBC, 2006). This guide covers basic principles and characteristics of the devices, even detailing which software to use. As these resources were not considered adequate, we expanded our focus to TV Apps design guidelines, since most of these principles can be applied on the web as well. Samsung, the most popular Smart TV vendor (YuMe, 2016), maintains a website with many guidelines for developing for TV, focusing on Samsung Apps (HbbTV, 2016), while LG has similar guides for their Apps (LG Electronics, 2014). Moreover, Google has also released comprehensive guides for their new Android TV platform, which are freely available online (Google, 2014a). Academic research on Interactive TV Services and Apps is also available, notably (Chorianopoulos, 2008) and (Ahonen et al., 2008). By studying such previous work on guidelines for Web and App content or interactive

TV services, basic principles for TV-optimised websites are summarised in Table 7-2. The underlying assumption is that, by applying the above principles to a responsive web site, the UX of website viewing on a Smart TV will be greatly improved.

Table 7-2 Optimizations for Interactive Content on Smart TVs

Font Size	Minimum font size of 18 - 22px is recommended (Chorianopoulos, 2008; Google, 2014; Google, 2016)
Text style and paragraphs	Line length of 10 words or less, generous leading (Google, 2016), Maximum full screen text to 90 words, text broken into small chunks (Google, 2014)
Navigation	D-Pad Navigation is preferred, instead of point-and-click (Chorianopoulos, 2008), as many TV devices do not have a reliable pointing device.
Focus	Clear focus of selected navigation item is also important, which can be easily achieved by stronger colouring/highlighting of the element (Google, 2016). Auto Focus and Scrolling to the selected element is also recommended (Chorianopoulos, 2008).
Content Layout	Grid layout is preferred, especially on navigational items for easy D-PAD movement (Chorianopoulos, 2008; Opera Software, 2013)
Paging/ Scrolling	Paging is preferred to scrolling (Google, 2014) which does not work well with most remote controls, as the pointer must usually move to the bottom of screen to initiate scrolling.
Overscan / Safe Margins	Content existing in the far-edges of the TV screen may be hidden due to overscan (Chorianopoulos, 2008; Opera Software, 2013; BBC, 2006). To prevent this, it is safer to avoid placing important elements at these locations.
Text Input (auto-suggestions)	One of the most problematic aspects of the TV browsing experience is the input of text with the remote control. Having software which autocompletes the words/sentences can be very helpful (Opera Software, 2013; BBC, 2006).

7.3.2 Smart TV Navigation devices & methods

An important aspect of Smart TVs, and a vital difference that can alter the usability of different devices, is the use of different remote controls. Unlike desktop computers, which have standard navigation devices of a keyboard and a mouse, or mobiles with touch screens, TV devices do not seem to have solved the navigation problem yet. PCs have solved the problem of effective navigation with the mouse, an addition to the sole use of the keyboard during the 80s, which greatly improved usability in the GUI environments. Mobile phones also had a problematic usability for many years since their introduction, experimenting with numeric keyboards, tiny joysticks and stylus touch screens, until the conductive touch screen provided the solution and allowed complex tasks, such as web browsing, to be performed with relative ease. This is not yet the case with the TV though, as the navigational device still hasn't reached the desired usability level that users expect. (Tomorrow Focus Media, 2014; Jeong et al., 2011). The standard method for traditional TV browsing has been for years the remote control. It only has buttons, and many smart TVs, especially low-budget models, still use just this control device (Geleijnse et al., 2009). In order to navigate through a web page or an App, one relies only on the D-PAD navigation keys, which will "hop" the user through the links of a page or the buttons of an App. This can easily turn into a nightmare situation, since most websites are not designed with this in mind, but with the mouse or the touchscreen. Thus, a page usually contains a multitude of navigational element (links, buttons, menus etc.) that are practically invisible on a desktop or mobile device.

Table 7-3 compares the many input methods currently available on Smart TV devices. The most popular methods used today are the pointing remote which is becoming a standard (but not in the lower-budget models) and the D-PAD of the standard Remote Control that is available as a standard on all TV devices.

Regarding web browsing specifically, none of the existing TV interaction methods provides the ease of use of the mouse/keyboard on the PC or the touchscreen of a mobile device. This explains why manufacturers are still experimenting and coming up with new proposals every year (e.g. voice control and gestures). By performing an empirical test on 8 popular Smart TV devices from the top selling manufacturers on models from 2012 to 2015, we concluded that the Pointing Remote is currently one of the most popular control devices along with the D-PAD remote control and is used by some of the most popular Smart TV devices. The TV remote controls provide acceptable UX as long as text input is not required, as typing with this method can be very inconvenient, since the user has to point on every character of the on-screen keyboard, which is a slow and error-prone process (Choi et al., 2016).

In summary, the mobile phone companion App is probably the most promising method to improve usability, but currently is quite experimental. Not all TVs support it and even the ones that do, don't work well with all smartphones. However, it can do much more than a simple remote control and allows multi-device interaction, where part of the content can be presented on the mobile phone app and part on the TV.

Following is a description of the main navigational methods that can be used within the web browser (voice and gestures do not work for web browsing). The device used can greatly alter the point and click experience, so it is explicitly defined in the narrative below:

- **Link-navigation**: Use of the D-PAD to move between links of a page. This can be a fast method if a page contains few links, but this is a very rare case on a typical website.
- **Point and click navigation with a D-PAD**: use of D-PAD arrows to move the pointer. This is arguably the most inconvenient method of navigation, requiring considerable time and effort to direct the cursor to the desired item.
- **Point and click navigation with the "pointing remote" (or 'magic remote'):** This is a much more convenient method of pointer navigation by pointing the remote on the screen and moving the cursor as the user's hand moves. It was originally popularised by Nintendo as the innovative controller of the Wii game console ("Wii-mote").
- **Point and click navigation with a touchpad:** Use of a touchpad, like the ones found in laptops. It was mostly used in earlier Smart TV remotes but can still be found in many low-budget Android-based set-top boxes.

- **Point and click navigation with a mouse**: This method requires a computer mouse connected to the TV. It works in a similar way to the desktop, but is not very convenient for the living room as it requires a surface below the mouse.

Pictures from a number of different control devices can be seen in figure 7.1.

Figure 7-1 Various Smart TV navigation controllers

7.3.3 The Smart TV User Experience

From the beginning of Interactive TV, it was evident that the user expects different things from his/her TV experience compared to other interactive mediums, such as PCs or mobile devices. There are two terms that refer to the TV user state: “the 10-foot experience”, referring to the distance from the TV device, and “the lean-back experience” referring to the user’s relaxed sitting position in their living room couch. Traditionally people lean back and relax while watching TV, so they do not like complex screen layouts and controls (HbbTV, 2016).

Another interesting aspect of the TV experience is that in contrast to other electronic mediums, the user is not always concentrated on the TV content, but the TV usage can take many forms as far as levels of attention of the viewer are concerned (Chorianopoulos, 2008). Another major difference from other interactive devices is that it is a more social medium, in the way that more than one person may be watching it at the same time (HbbTV, 2016). This can cause complications for an interactive medium, as there are questions as to who can perform the interactivity, given that normally there is only one control device.

Table 7-3 Comparison of Smart TV Navigation Devices

Device	Methods	Description	Positive	Negative
Standard Remote with D-PAD	- Link Navigation - Point and click	A combination of 4 arrow-buttons on a remote control plus an action-button allowing navigation in 4 directions and selection of items	- Inexpensive (suitable for low budget TVs) - Available on all TV devices	- Very difficult to navigate in normal Web pages - Very difficult to write text - Some devices don't support "link-navigation" but only moving the cursor with the D-PAD
Wireless Mouse/ Keyboard (has D-PAD)	- Point and click (mouse) - Typing (keyboard)	Most Smart TVs allow the connection of any wireless PC-keyboard and mouse combination. It is used just like on a PC interface.	- Familiar to users from the PC - Very easy to write text	- Mouse requires a flat surface (ie. not convenient for use when sitting on a couch) - Big and "ugly" for the living room - Doesn't come with a Smart TV - Compatibility Issues
Remote with touchpad/ mini - keyboard/ D-PAD	- Point and click (touchpad) - Typing (keyboard)	Some Smart TV devices include a remote control that has a touchpad on the one side, and a compact keyboard on the backside.	- Does not need a flat surface to use - Easier to write text than D-PAD or pointing remote	- Touchpad not so accurate to point small navigational elements - Not as easy to write texts as keyboard or touchscreen (very small buttons/hard to press)
Pointing (magic) Remote with D-PAD	- Point and click	Sometimes referred to as "Magic Remote" or "wii-style remote". The user can point with the remote (like pointing a finger) on the TV screen to move the cursor wherever s/he is pointing at. Sometimes it includes a **scroll-wheel** for easier scrolling.	- More expensive (available on mid to high-end models) - Much easier to navigate like a mouse than the D-PAD - Does not need a flat surface like the mouse	- Although more convenient to text-writing than the D-PAD, it is still far from the keyboard experience - Not as accurate pointing compared to mouse or touch (especially for webpages with small elements)
Microphone embedded on a remote	**Voice control**	Some remote control or pointing remotes have a microphone embedded to receive voice commands from the viewer.	- Can be used for easier text input	- Works only for very specific tasks - Still need to press the button on the remote to voice a command - Not for all languages
Camera on the Smart TV	Gestures	A 3D-camera on the TV is used to detect the gestures of the user.	- Does not require the user to hold any device	- Works for very specific tasks, so a remote control is also required - Still experimental
Smartphone	Mobile App (emulates touchpad, D-PAD and mini-keyword)	Many manufacturers have developed mobile Apps for controlling a Smart TV from a phone or tablet device.	- Using the touch screen to write text is far more convenient that the other methods - Does not require a new device (smart-phones are a commodity)	- Still experimental, not supported on all devices/ TV OSs - Not all TVs-Mobiles can co-operate well (in our tests, a Samsung TV and an iPhone didn't work well at all)

7.4 Prototype TV-Responsive System

As a proof of concept for exploiting RWD on Smart TVs, we extended an existing responsive website (Perakakis and Ghinea, 2015), which already supported other devices, to also adapt for TV systems. Presently, all websites show the desktop version when browsed from a big TV screen, but we developed a methodology to firstly recognise that the device on which the site is being displayed is a TV and then perform the necessary adjustments ("response") to look optimal for the Smart TV.

Our prototype web page was based on a News-site open-source Responsive design (WPfreeware, 2015), which was already optimised for phones, tablets and desktops (Figure 7-2). The template was created on the popular Bootstrap framework (Bootstrap, 2015), utilizing a 12-column grid for positioning UI elements and re-arranges them depending on the viewing device.

The elements contained on the TV page are exactly the same as the ones in the other versions, but considerable changes had to be applied both to their styling and their position. These optimizations were based on the TV UI guidelines extracted from existing research as described in section 7-3 and shown in Table 7-2.

7.4.1 Smart TV Detection

Intriguingly, one of the first problems we encountered when creating responsive websites for the Smart TV environment was to successfully identify the nature of the device. In standard RWD, this is usually done by utilizing the "media queries" feature of CSS. With this, one creates CSS breakpoints, which are a form of conditional statements, based mostly on the device's viewport/screen resolution and orientation. For each different breakpoint condition, a different set of CSS rules is applied to change anything on the page that should look different for this resolution/device. However, using the pixel resolution of the screen does no longer say much about its size or the actual nature of the device. For example, a 9.7 inch Retina iPad has a resolution of 2048 x 1536 pixels, which is greater than the 1920x1080 pixels of a 50 inch HD TV. Since traditional RWD is heavily reliant on screen resolution it is tricky to distinguish between a 1080p TV from a 1080p PC display or a 1080p smartphone/tablet (Pettit, 2012).

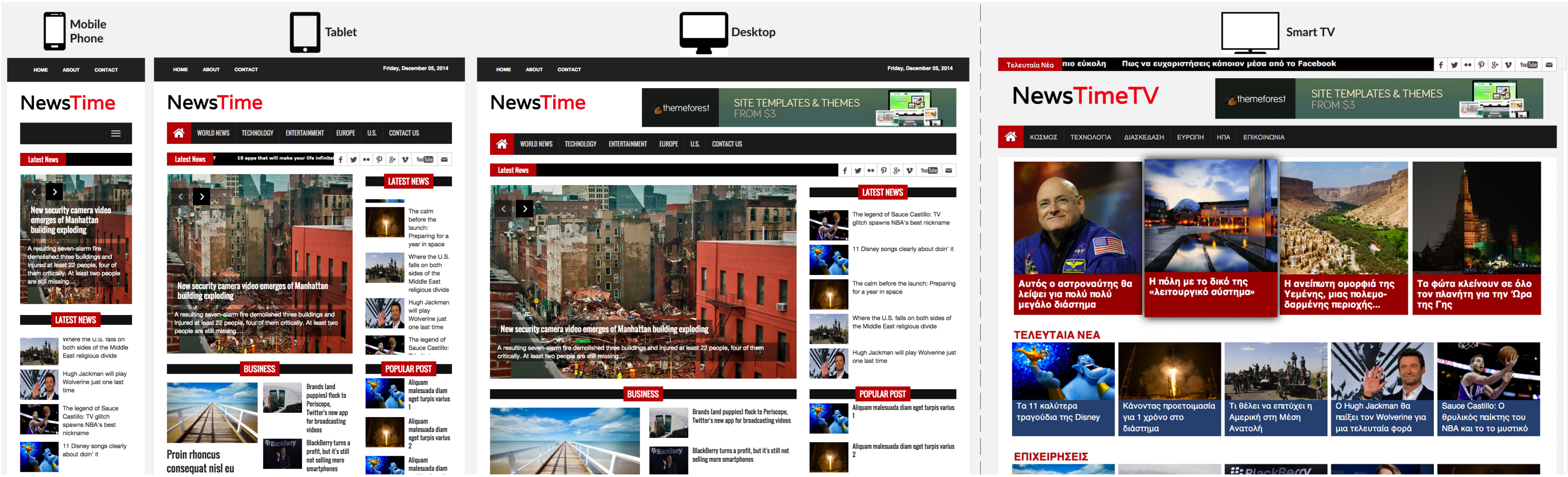


Figure 7-2 "The missing layout": A complete Responsive design template with the 3 common versions (Phone, Tablet, Desktop) and an additional one for Smart TV devices. The TV layout enables simple D-PAD navigation, larger fonts and simplifies the overall experience

The “@media type” attribute can be utilised when defining Styles (W3C, 2014). This theoretically can be used to define the device type and can take values of: screen, print and a few others, including TV. Although this looks like an obvious solution for TV styling, surprisingly no Smart TV supports this value. The reason that TV manufactures chose to ignore this feature is probably because of the fact that @media type queries are mutually exclusive. So, if the @media type=TV was used then it would not load the default @media=screen CSS at all, so any page that is not optimised for TV (which currently includes almost the whole of the web) would not show any styling at all (Grigsby, 2013).

An alternative solution for TV device detection would be to extract the User Agent (UA) string that all browsers have for identification. This is what popular scripts like Categorizr.js (Kasten, 2012) and Detectizr.js (Aydinoglou, 2014) are doing: they compare the UA string against a database of known devices UAs to identify the device used. We also searched for the text “Smart-TV” in this string, which is almost always included on TV browsers, although the syntax can have some minor differences (e.g. “Smart TV” or “Smart-TV”). This detection methodology can even identify other TV-based browsers, such as set-top boxes and game consoles, which is also an advantage. For our prototype page, this method was applied, as it provided the best results (explained later in section 7.5).

7.4.2 Styling changes

Where simple styling customizations are required, CSS-only code is adequate and also easy to implement. The basic idea includes a trigger class attached to the main <html> element to enable custom smart-tv styling. So, by having an <html class=”smarttv”> that will only appear when the site is viewed on a Smart TV, one can write specific CSS rules to be applied only in this case, e.g.

```
  html.smarttv .header_top_left {
float:right; width:auto}
```

which will affect the styling of the html elements that have the .header_top_left class but only if the device has been detected as a Smart TV. The detection process described in section 7.5.1 can append this “smarttv” class once the device is identified.

Using this class optimization, we enlarged the font sizes and hid some unimportant elements that were regarded dysfunctional (such as the links in the news tickets, separate links on both image and text of a news box, social media icons). The visual style of the news items was also changed completely to resemble navigation boxes in the fashion that most TV interfaces use. Also CSS3 effects were applied to the focused elements so that a strong shadow clearly showed which element was active for the user to click.

7.4.3 Navigation and Content Layout

It was decided that the prototype website would need to work seamlessly with the two most popular TV navigational methods, as these are present in all Smart TV models: The Link navigation (achieved through the D-PAD) and the Pointer navigation (achieved through the D-PAD, Motion controller, touchpad or mouse). Most complex changes needed to be done on the layout of the page, as it was quite "loose" without a very clear structure and that meant that D-PAD navigation would be confusing (Figure 7-3). This is normal for most websites as this is not a problem when mouse or touch is used and the user can go directly to the desired navigation element/link; however, with the D-PAD s/he will need to move ("hop") between all element/links to get where s/he wants. Therefore, the elements of the page were transferred to different parts of the layout in order to define a clear Grid where hops between links would be very straightforward.

It was also decided to replace the image slider on the top with a grid of 4 big images so that it would be easier to navigate through them and obtain a more TV-App like look. Alternatively, the slider could have been maintained and, when focused, the left and right D-PAD events could be used to switch between news stories. However, we thought that the 4-grid implementation would be clearer for the users to understand as this metaphor is used throughout the page.

Another simpler change was to move the News ticker box to the top of the page instead of below the main menu, again for a more TV-like approach. Also the links were removed from the ticker, as these would greatly confuse the D-PAD navigation if the user moved to these rolling items.

So, for example, the News ticker box had to be transferred to the top part of the page instead of below the main menu. In order to achieve this, CSS rules are not adequate and JavaScript has to be utilised. Since all Smart TVs support JavaScript, this is acceptable. Furthermore, using a library like jQuery (The jQuery Foundation, 2015)

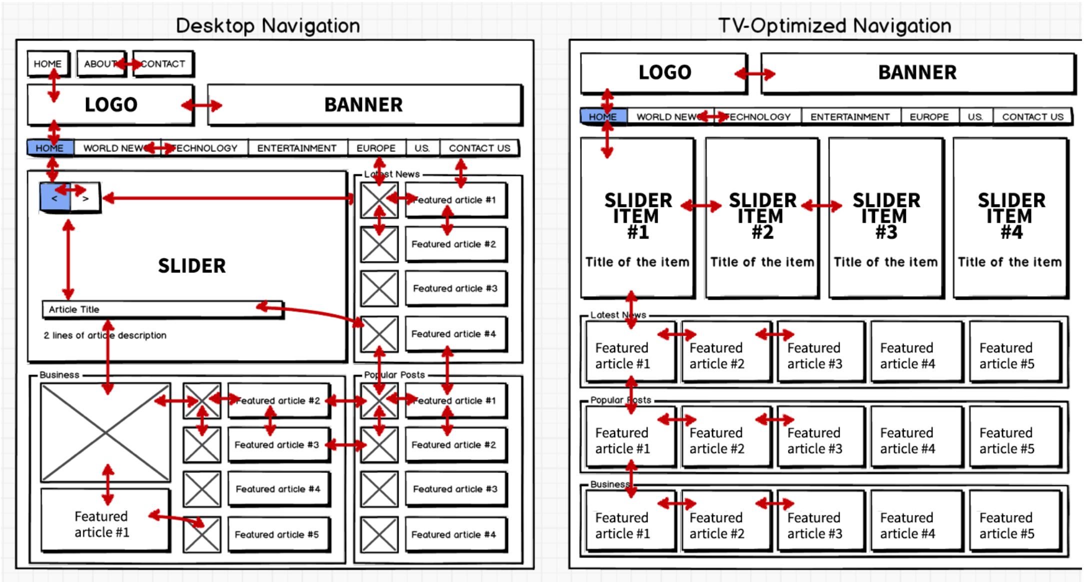


Figure 7-3 Comparison of the navigational elements between the Deskop and the TV-optimised versions of the page. The arrow lines show the navigational paths using "link navigation", a common feature in most TVs for navigating a page with the D-PAD of the remote control

ensures cross-browser compatibility while also simplifying the code. So, in order to move an element from one part of the page to another, the following code can be applied:

```
var element = $('.smarttv .header_top_left').detach();
$('.smarttv #navbar').append(element);
```

Similarly, to hide an element that is considered unnecessary for the TV version, the code is:

```
$('.smarttv .header_top').hide();
```

Or you can just hide with just CSS Styling:

```
.smarttv .header_top { display:none }
```

7.4.4 Overscan, Scrolling and Text Input

Although no overscan issues were identified in any of the test devices, to avoid any possible overscan issues in other devices, a safe margin of 55 pixels was adopted for all the edges of the responsive layout.

Scrolling was another problematic aspect of the TV devices that had to be improved. Initially we tried to split the longer pages to multiple "screens" that the user could move through with one click of the top and down buttons on the D-PAD or using the scrolling wheel (if the remote control had one). However, this technique did not work well, as most times the content was very difficult to be split and would require considerable work from the website developers, and that would not be in line with our goals, i.e. being easy to implement on existing websites. A more elegant solution was opted for in which breakpoints (anchors) were placed every few lines in long pages. JavaScript was then utilised so that when the user used the up and down D-PAD keys it would automatically scroll to that anchor point. So, in this way, scrolling was converted to paging without actually altering the page content, thus making it easy to implement.

As far as text input is concerned, this did not apply to the developed website. However, the majority of post-2013 Smart TVs automatically apply auto-complete on their on-screen keyboard whenever a text-input box is used on a website, so apart from using large-enough fonts for the input box, no other implementations are needed from website developers.

7.5 Device Platform Analysis

For the prototype web page to be considered as truly TV- responsive, it was important to test it on a range of diverse TV devices to confirm that it adapts properly, to uncover any incompatibilities and improve the technique to address them.

Therefore, the page was tested on 8 representative Smart TV models: LG Smart TV 4K (2015), Samsung Smart TV 4K (2015), Sony with Android TV (2015), LG smart TV (2014), Samsung Smart TV (2014), LG Smart TV (2013), Sony Smart TV (2013) and Sony Google TV (2012). As the operating systems and capabilities of each manufacturer change considerably each year, the evaluation devices were selected to include models from different years, while focusing on the most popular Smart TV vendors (in terms of sales). So the models were from Samsung, LG and Sony, which together possess more than 50% of the global Smart TV market share (BusinessKorea, 2015). Table 7-4 outlines the most important features of the test devices.

The evaluation criteria were that the prototype system should display correctly in all tested devices. For the system to display correctly we defined that the following 4 criteria should hold:

a) **Detect** that the device is a Smart TV, thus display the TV-optimised version.

b) Display the TV-optimised website in the full width of the device, without the need for horizontal-scrolling, regardless of the **device/browser resolution**.

c) Display all the important elements of the website correctly, regardless of the **hardware limitations** and **browser limitations** of the device.

d) Allow **navigation** to all the navigational elements of the website (buttons, links etc), through the remote control of the device.

Table 7-4 Features and Technical Characteristis of Tested Smart TV Devices

Device	LG Smart TV 4K	Samsung Smart TV 4K	Sony with Android TV	LG smart TV	Samsung Smart TV	LG Smart TV	Sony Smart TV	Sony Google TV
Year	2015	2015	2015	2014	2014	2013	2013	2012
Test Model	49UF7707	UE65JS9500	43W805CBAEP	42LB651V	UE48H6670	42LA660S	KDL-46W905A	NSZ-GS7
Price range	Mid-range	High-End	Mid-range	Low-End	Mid-range	Low-End	High-End	Mid-range
Browser Resolution	1920x1080	1920x1080	1920x1080	1920x1080	1280x720	1280x720	1920x1080	1128x634
OS/Browser	WebOS 2.0	TIZEN	Opera (download)	WebOS	Samsung Smart Hub	NetCast	Opera	Chrome
"TV" on UA	Smart TV	SMART-TV	InettvBrowser	Smart TV	SMART-TV	NO	InettvBrowser	GoogleTV
HTML5 test	495	465	498	418	407	238	312	281
CSS	CSS3	CSS3	CSS3	CSS3	CSS3	CSS2	CSS2	CSS3
Navigational Device	Pointing Remote with D-PAD, mic & wheel	Pointing Remote with D-PAD & mic	Touchpad with D-PAD & mic	Remote control with D-PAD	Pointing Remote with D-PAD & mic	Pointing Remote with D-PAD	Remote control with D-PAD	Remote with touchpad, D-PAD & mini-keyboard
Supported Navigational Methods	Point & Click Voice	Point & Click Voice	Point & Click Link Nav. Gestures Voice	Point & Click	Point & Click Link Nav. Voice	Point & Click Link Nav.	Point & Click Link Nav.	Point & Click Link Nav.

7.5.1 Technical observations

Pilot testing revealed a few minor issues, but with some further adjustments the system was able to run correctly on all devices, providing a smooth cross-platform experience as required. Some of the issues encountered included:

- **TV Detection:** As mentioned earlier, not all TV devices have the "Smart-TV" (or "smarttv") keyword on their UA string. Some have similar strings that can also work well (Sony uses the 'InetTVBrowser'). Although UA detection worked well for most models, there are a few, mostly pre-2013 models, that did not contain the "Smart-TV" keyword in their browsers UAs. In our 8 tested devices only the 2013 LG Smart TV had this issue. The workaround to this is to have a complete database of UAs, which explicitly contains even these models.

- **Graphics Resolution:** Browser resolution was not the same across all tested TV models, i.e. the fact that a TV is Full HD and has a native resolution of 1920x1080 does not mean that when in browser mode the same resolution is used. For example, in the Samsung 2014 model the resolution of the browser was 1280x720, while on LG 2015 (WebOS) model the resolution was 1920x1080. Another surprising fact regarding resolutions was in the 4K models, where the browser resolution was kept at standard HD, presumably for compatibility reasons, but also for the visual elements to not become very small since 4K is 3840x2160 or 4096x2160 pixelswhich means 4 times more pixels than 1080p.

- **Hardware Performance Limitations**: As the hardware capabilities of TV devices are limited, having even simple JavaScript animation can cause noticeable slowness of the visual elements and the navigation, so it is better to avoid them for a better UX, especially on older devices.

- **Browser Capabilities**: Unlike PCs and Mobile phones, where a handful of browsers (Chrome, Safari, Internet Explorer and Firefox) have become de facto standards, the TVs run a number of rather experimental browsers. All TV browsers in the tested devices supported HTML5, CSS2/3 and JavaScript to a varying extent. A method to evaluate the capabilities of the browsers was to use the HTML5 test (HTML5test.com). The HTML5test scores of most TV browsers were high (above

400), while newer models have scores close to a desktop browser (e.g. Chrome v48 on a Mac scores 521 while Safari on iOS 9 iPhone has a score of 409).

- **Navigation:** Navigation with the remote control or other control devices is extremely variable between different Smart TVs; moreover, the support for D-PAD navigation in the browser is not the same across platforms. Specifically, although D-PAD navigation is used throughout the TV OS and Apps, in some devices it has been disabled from the web browsers. So, both types of navigation (Link Navigation and Pointer) have to work correctly in order to have an optimal cross-platform experience.

7.5.2 Empirical pilot study on Link navigation performance for the Prototype website

As discussed previously, TV vendors are still experimenting with different methods of navigation on Smart TVs. Accordingly, for the user evaluation experiment (Section 7.6), it was decided to use the Pointing Remote navigation as it is now very common in the mid and high-range Smart TV models. Another reason was that some manufacturers have removed link-navigation from their models.

Nonetheless, an empirical experiment was carried out for the D-PAD link navigation, comparing the TV-responsive and non TV-responsive versions of the website in respect of the number of link "hops" needed to perform 4 simple tasks:

1. Open the main story: «the city with its own operating system»
2. Go to the end of the article and from the «related content» section, open the article about «Tarantino»
3. Return to home page
4. Watch the «Renegade Jeep» video.

Table 7-5 shows the number of "hops" required to perform the tasks in each version, showing how much more efficient it is for the user to perform the tasks on the

Table 7-5 Link Navigation "Hops" to Perform Tasks

Tested Version	Task #1	Task #2	Task #3	Task #4
TV Responsive (R)	3	8	5	9
Non TV-Responsive (NR)	8	25	5	18

responsive version. This was another reason that link navigation was not chosen for the user testing, as it would be glaringly obvious that the responsive version would perform better, leaving very little to be explored.

7.5.3 Results

The goal of the Responsive website was to be able to run efficiently on all TV devices, regardless of the manufacturer, operating system, resolution, available input device and web browser. As the test on all 8 diverse devices showed, our developed responsive-website system was fully compatible with all of them, meeting the 4 criteria we defined.

7.6 User Evaluation of the Prototype System

In this second part of the experiment, after it was confirmed that the TV RWD website is compatible with all devices during device platform evaluation, the website was presented to users in order to compare the UX aspects of Usability and Likability of the website against its non TV-optimised version. To ensure the consistency of the experiment, it was decided that only one of the aforementioned devices was going to be used in the tests: The Samsung Smart TV 2014. The reason for choosing this device was the popularity of the Samsung platform among buyers, as it possesses the largest share of the Smart TV market (BusinessKorea, 2015).

7.6.1 Participants and Experimental Design

40 students and academic staff from a higher education institution in Crete, Greece, participated. Their ages ranged between 20 to 35 years with an equal share of male and female participants. All were relatively unfamiliar with interactive Internet TV devices, although most had some IP-TV experience. All self-reported as experienced Internet/PC users.

Participants were split into two equal-sized groups. Thus, 20 participants were randomly assigned to test the TV-responsive version of the website while the remaining 20 tested the non TV-responsive (desktop) version.

7.6.2 Procedure

The participant sat on a couch at a distance of 3m (10-ft) from a 48-inch Smart TV, and the website was presented to him/her, within the web browser application. The TV browser resolution was 1280x720 pixels, which is one of the two most popular resolutions seen on TVs today. The other popular resolution is 1920x1080 but since the design is Responsive there is no difference on how the website is displayed, as the elements are automatically adjusted. Once the device functions were explained to the user by the experimenter and any questions answered, the user was then allowed a further 2 minutes to familiarize him/herself with those. Once this was done, it was explained that a Smart TV is a TV in which one can also use a web browser and see websites, similar to one's PC or smartphone and that the user will be shown a website in which s/he will be asked to perform some tasks. As it was important that this should remain a relaxed session, the researcher told users not to worry about how fast they perform any of the actions. The researcher then gave participants the following instructions:

"You will need to have the remote control next to you, not holding it in your hand all the time. I will be giving you a simple instruction to perform and after that, you will be taking the control, performing the task and then leaving the remote control next to you."

Participants were then instructed to have a look at the website for 1 minute after which they were asked to perform the following tasks:

[dt1] Open the main story on «the city with its own operating system»

[dt2] Read out the second paragraph

[dt3] Go to the end of the article and from the «related content» section, open the article about «Tarantino»

[dt4] Read out the first paragraph

[dt5] Go back to the home page

[dt6] From the «Videos» section, click to watch the « Renegade Jeep » video

[dt7] (after s/he has watched 20 seconds of the music video) Close the video.

The time (dt) to perform each of the tasks above was measured by the researcher (participants were not informed that they were being timed and the timer was hidden from view). Once the tasks were accomplished, each participant was asked to complete a questionnaire in Google Docs and take part in a short interview on his/her experience of the visualized website version, as will now be detailed in the following sub-section.

7.6.3 Variables considered

In terms of dependent measures, subjective metrics were adapted for website evaluation. Objective measurements of task completion times as well as system response metrics were also collected. Accordingly, what was collected was data in respect of:

1. **System Usability**: We used an adapted version of the System Usability Scale (SUS)[7] (Sauro, 2011). The only difference between our version and the original SUS test was that the word "system" was replaced by "website".

2. **Task completion time**: All users were asked to carry out the same specific tasks on the website. The time it took them to complete each task was measured.

3. **Likeability**: This targeted whether users liked aspects of the websites, and included 3 questions: (a) whether the users liked the website (b) whether they liked the visual aspects of the website and (c) whether they found it informative.

4. **Usability Questions**: 5 additional Likert-scale questions were introduced, asking the users about text readability, navigation difficulty, loading times, ease of scrolling and whether they would like to be able to navigate to websites like this from their TV. The main reason for using the Likert scale was consistency. Since we have used the SUS test which has a 5-point Linkert scale we believed that designing the rest of the questionnaire in the same fashion would be good for not confusing users, thus producing more accurate results.

5. **Open questions**: A user could state up to 3 things s/he liked about the website and up to 3 things s/he did not.

6. **Preference statement**: Throughout the experiment, each of the two groups of users had only been exposed to one version of the website. However, upon completing the questionnaire, each user was shown the alternative version of the website, invited to use it for two minutes, and then asked which one s/he would prefer if s/he

[7] Available at http://www.e-bilab.gr/wp-content/uploads/2016/03/RTV-questionnaire.pdf

had a Smart TV. After the response was noted, a justification of his/her preference was asked for and duly recorded.

Lastly, our study had only one independent variable, which was the website type (Responsive or Non-Responsive). The exact questionnaire used can be found in Chapter 3, section 3.6.4.

7.7 Results

Data were analysed with the Statistical Package for the Social Sciences (SPSS). A t-test was applied to analyse the participants' responses. The reason behind the use of a t-test was because we wanted to determine whether there is a significant difference between the means of the two groups: the ones that used the TV responsive version of the website versus the ones that used the non TV-responsive version. A significance level of $\alpha = 0.05$ was adopted for the study. Results are shown in Tables 7.6 – 7.9.

7.7.1 System Usability Scale

The SUS contains 10 questions. The SUS results showed that the responsive version of the website scored higher the non-responsive one. However, the difference was relatively small (4.38) and not significant. Both versions scored above 68, which is a threshold for good usability on the SUS test (Sauro, 2011). Table 7-8 details the difference averages and t-tests for each of the 10 questions. There were no statistically significant differences between the two groups for any of the questions (Table 7-6).

7.7.2 Task completion time

For the 7 aforementioned tasks that the users of each group were asked to perform on the website, we measured the time it took to complete the tasks (Table 7-9). These measurements provided the clearest indication of the superior usability of the TV-Responsive (R) version over the non TV-Responsive (NR) one. In all measured timings, the users performed the tasks faster in the TV-Responsive version. The smaller difference was observed in the task that asked them to return to the home page (dt5). This was unsurprising, as most users just used the back key on the remote control, which had the same functionality on both versions. The larger differences were observed in the first task, where participants had to open one of the main News stories. This was because the slideshow navigation was quite cumbersome on the TV device, as the use of the small arrows to switch manually to the other slides was hard to be clicked accurately, so users often clicked on the wrong slide and had to go back. The average time it took to complete tasks shows a significant better performance of task completion for the TV-Responsive version over the non TV-responsive one of 8.5 seconds, which is about 36% faster. The dt1, dt2, dt4 and dt7 completion times were statistically significant with $p < 0.05$.

Although further experimentation and validation are required, we can offer some explanations for the reasons behind the improved performance of the TV-Responsive version. As the links on the responsive versions for the articles were applied to the whole item, which was now more like a large button instead of just a link on the title and on the "read more", users found it easier to locate and click on the relevant links for tasks dt1, dt3, and dt6. The larger font size and the auto-scroll functionality also contributed to easing the user's mission for tasks dt3 and dt6. Regarding the faster completion times for reading tasks dt2 and dt4, this is probably due to the larger font sizes which made it easier for the viewer to read the text from the 10-foot distance of the TV set. As far as the faster response of users when asked to close the video (dt7), the most obvious reason was that the close button for the video was larger on the TV-Responsive version; thus, it was easier to click on it with a remote control (although this was not as accurate as a mouse).

7.7.3 Likeability

For the three likeability questions (liking the website, did not like the visual aspects of the website, and finding it informative), there were again slight differences between the users' answers (Table 7-7). However, the responses in respect of liking the website, showed a favourable bias towards the responsive version (4.20 over 3.90). The conclusion was that the users liked both versions of the websites on the Smart TV.

7.7.4 Usability Questions

In this set of 5 questions, users were asked to express their opinion on 5 specific aspects of the website (Table 7-6). The two groups averaged the same score for the loading speed of the versions, which was not a surprise, as both were running on the same network and device. Another question was about the readability of the text, where a significant difference was expected, as the non-responsive version font size was smaller (14px on the main text) compared to the TV-responsive version (20px). During the experiments it was clear that many participants struggled to make out the smaller text, as seen in the results, where the Likert average was 2.19 for difficulty in reading the text in the non TV-responsive version compared to 1.70 for the TV-responsive version. In terms of Ease of Scrolling this was the only parameter that showed there were statistically significant differences between the two groups $t(38)=2.162$; $p<0.05$. Scrolling seemed a little easier on the responsive version and navigation as well. This was probably due to the use of the guided scrolling method that allowed easier scrolling on particular page breakpoints on the optimised version. Finally, participants answered for both versions that they would like to use websites like this on their TVs.

7.7.5 Open-Ended Questions

Users of each group were asked to write things that they liked and disliked about this web on TV experience. It was clear that the most common complaint in both versions of the website had to do with the remote control pointing device which was found difficult to use and very different from the mouse or touch screen most people are used to. So in total, 14 people complained about the remote control (half from each group). Additionally, 4 users from the non-responsive website group complained about the text readability. In contrast, none complained from the responsive group, while 3 users from this group wrote they liked that the text was easy to read.

Continuing with the things that the users liked, 7 from the TV-responsive group and 11 from the non TV-responsive group found the website easy to navigate. 7 people from the responsive group stated that they liked the structure of the websites compared to 4 from the other group. The same number of users said that they liked the visual design of the websites respectively (7 on the responsive, 4 on the non-responsive).

7.7.6 Preference statement

Upon completing all other aspects of the experiment, the users of each group were shown and asked to try for a further 2 minutes the version of the website that they had not tested. They were then asked to state their preference, as to which one they would like to use on their TV if they had the option. From the group that first saw the Responsive version, 80% stated that they preferred it over the non-Responsive while 55% from the group that first saw the non-Responsive version stated that they preferred the Responsive version as well. Across all participants, there was a significant difference favouring the TV-responsive version where 27 users (67.5%) chose it over only 13 users (32.5%) who preferred the non TV-responsive version.

In an informal interview they were asked to justify their preference, in order to note any interesting findings. In most cases, the users who chose the non TV-Responsive version said that they found it more familiar, as it looked more like the sites they were used to on their desktop computers. Some stated that the grid navigation of the TV version was a little confusing to them while the other was clearer. However, the majority of the participants favoured the TV version, and their justification for this was a little more varied. Many said that they found it more “TV-like” experience, pointing out that it was “better” and “more impressive” visually. Some said that they liked the grid navigation as it was more clear and well arranged to them compared to the non-Responsive version.

7.7.7 Discussion

The user evaluation was used as a direct comparison of the usability of a typical website as it will appear on a Smart TV now, set against our proposed TV-responsive prototype. It was important to user-evaluate that the optimizations that were applied from the TV usability research we performed would actually result in a measurably better UX. The results of the experiments provided an indication of improved usability and likeability of the TV-responsive prototype over the current method of displaying the desktop version of a website on a Smart TV.

7.8 Conclusion

In this chapter, we propose the exploitation of Responsive Web Design techniques to Smart TV devices. Our proposed technique can be implemented relatively easily on existing responsive websites, improving some aspects of the User Experience, more specifically shorter completion times and ease of scrolling, for the TV users. Applying this technique to websites could be a solution to an optimised availability of the vast amount of web content to Smart TV devices, a new and quickly developing Internet-connected landscape, with need for more content.

The developed prototype system described in this chapter showed the advantages of using TV-responsive methods over the current desktop versions shown on the TV. This is completely in line with the successful completion of our objective to explore the possibility of exploiting Responsive Web Design, a standard technique for mobile website optimization, to the Smart TV, in order to achieve better usability and user experience while making more content available in a better way to these devices.

Table 7-6 Usability Questions Responses (Means and Std Dev)

Tested Ver.	Slow loading	Ease of Scrolling *	Difficult to read text	Like to use on my TV	Easy Navigation
R	1.90 (0.91)	4.00 (0.92)	1.70 (1.13)	4.05 (1.10)	4.30 (0.87)
NR	1.90 (0.97)	3.25 (1.25)	2.20 (1.44)	4.35 (0.99)	4.00 (1.12)
t-test	t(38) = 0; p =1.0	t(38) = 2.162; p < 0.05	t(38) = -1.224; p = 0.228	t(38) = -0.908; p = 0.370	t(38) = 0.946; p =0.350

Table 7-7 Likability Questions Responses (Means and Std Dev)

Tested Ver.	Like website	NOT Like the Look of website	Found website Informative
R	4.20 (1.01)	1.45 (0.51)	3.90 (0.97)
NR	3.90 (1.07)	1.45 (0.61)	3.45 (1.36)
t-test	t(38) = 9.13; p=0.367	t(38) = 0; p=1.00	t(38) = 1.208; p=0.235

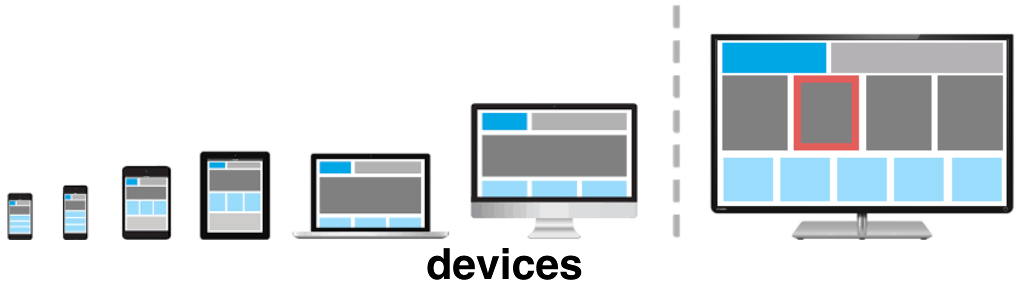
Table 7-8 SUS Questionnaire Results for each version (R- Responsive/NR= Non-Responsive) and SUS Score (Means)

Tested Ver.	SUS Score	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
R	82.13	3.90	1.65	4.30	1.35	4.30	1.70	4.10	1.35	4.25	1.95
NR	77.75	3.70	1.60	3.85	1.55	4.00	1.75	4.35	1.60	3.95	2.35
t-test	-	t(38) = 0.650; p = 0.520	t(38) = 0.169; p =0.867	t(38) = 1.185; p =0.243	t(38) = -0.591; p = 0.558	t(38) = 1.064; p = 0.294	t(38) = -0.158; p = 0.875	t(38) = -0.787; p =0.436	t(38) = -0.870; p = 0.390	t(38) = -0.940; p = 0.353	t(38) = -0.949; p = 0.349

Table 7-9 Completion Time For Each Task/Version (R- Responsive/NR= Non-Responsive) in Seconds (Means and Std Dev)

Tested Ver.	overall	dt1*	dt2*	dt3	dt4*	dt5	dt6	dt7*
R	14.93	6.75 (7.04)	31.20 (5.83)	13.33 (5.97)	21.45 (4.48)	10.90 (5.87)	15.45 (6.84)	5.40 (1.98)
NR	23.39	36.90 (19.37)	39.55 (10.67)	17.50 (11.1)	30.70 (13.56)	12.50 (7.63)	19.25 (10.92)	7.35 (3.69)
t-test	-	t(38)=-6.544; p<0.05	t(38)=-3.073; p<0.05	t(38)=-1.477; p=0.148	t(38)=-2.896; p<0.05	t(38)=-0.744; p=0.462	t(38)=-1.318; p=0.195	t(38)=-2.082; p<0.05

Chapter 8 - Recommendations and Guidelines for Optimal Web User Experience on Connected TV



8.1 Introduction

In this chapter we address the last objective of our research. Accordingly, based on all previous work, especially what we have described in Chapter 7, we **propose a set of guidelines, which can be applied to either new or existing websites, for improving usability and user experience of web content on a Smart TV environment.**

Following is a complete list of problems that current websites have on a TV device and our proposed TV-responsive solution, which, as our evaluation has shown, results in improved usability and likeability. Nonetheless, even if all of the proposed techniques are used, it is also very important to thoroughly test the website on as many devices as possible, since not all of them work as expected. Different resolutions, control devices and hardware performance are all very likely to call for adjustments and optimizations. This is not a TV-specific problem however, but a standard practice in RWD, e.g. for mobile phones, testing on as many diverse devices is essential. Although there are online tools to emulate a website on a plethora of mobile devices for this purpose (i.e. BrowserStack.com, 2011), there are no such tools for Smart TV devices currently, so it has to be done explicitly on the physical devices.

8.2 Recommendations and Guidelines for Smart TV websites

8.2.1 Device Detection

It's impossible for CSS to adjust anything, even if it uses traditional responsive design, as the CSS queries cannot recognise the TV device.

Solution: Utilise a JavaScript Device detection script, such as Detectizr (Aydinoglou, 2014), and also parse the UA-browser string to find a the "TV" substring or compare it to specific list of TV UA strings for devices that don't have the TV substring. If a TV device is detected, append a ".SmartTV" class on <body> tag.

8.2.2 Font Size

Desktop websites usually utilise relative small fonts (11 to 16px) for text, since the distance from the viewer is short, a problem for TVs where the distance is much longer.

Solution: With CSS, the font size can be altered to a minimum of 20px or more, so that it is easily readable for the "10-foot" experience.

8.2.3 Textual Content

Despite the wide-spread usage of multimedia content, the most basic form of web communication is still textual. This is perfectly acceptable on a desktop website but reading large chunks of text on the TV can be tiring.

Solution: Avoid (hide) large chunks of text where this is possible. For example, on a list of articles on the TV the description could be hidden, and the title should be enlarged. (see boxes in fig. 7-2). Also an HTML5 reader could be utilised to read out the text (Google, 2014).

8.2.4 Navigation

A Desktop web page can contain many navigational elements, even awkwardly positioned as the mouse allows to easily pick an element accurately from anywhere on the page. This however is very problematic for A TV remote control, especially when link-navigation is used.

Solution: First remove any non-critical elements and links from the page to streamline the navigation, which will have to be simple and ideally follow a grid structure where left-right and up-down movement is feasible (Fig. 7-3). Also, utilise D-Pad Navigation using correct syntax HTML5 (Check CSS3 nav-down property for D-PAD response).

Make sure the focused element is clearly standing out. This can be done by applying a CSS border of a strong-contrast colour or by applying a shadow to the element.

8.2.5 Scrolling/Paging

Most webpages have more content than the display can show at once, so scrolling is utilised to see any excess content. This can be several pages long. Scrolling with the TV remotes is also very cumbersome, as they rarely include a scroll-wheel (LG's *Magic controller* is the exception).

Solution: Utilise JavaScript to auto-scroll to the current navigational element when using link navigation.

Also create paging break points on a long page and trace with JavaScript the scroll-down or arrow-down keypress to automatically move to the break-point. When the content is a long text document, always include a small part from the previous page, otherwise the user can be disoriented.

8.2.6 Auto-Sliders

Auto-sliders, a popular presentation technique at the header part of many websites, e.g. for alternating the main News articles. The user can usually use some arrow keys to alternate the articles or just wait until this happens. Although this is visually consistent with the TV experience it often produces navigation problems, as the user struggles to choose the slide s/he wants to click.

Solution: This navigational problem can be solved in two ways. The more drastic one, which we used in our prototype was to alter the slider in displaying all the slides at once, thus creating a 4-column grid, which was much easier for the users to navigate as user testing proved. However, it would also be possible to keep the slider but use JavaScript to trace the left and right D-PAD keys so than it can slide in one click. In this case, arrow buttons should be added on the sides of the slide for use with pointer navigation.

8.2.7 Animation/Performance

Many new websites, especially the ones that showcase a product, make use of HTML5 animation to look more impressive. At first, this looks ideal for a TV experience but unfortunately the limited capabilities of TV hardware can cause disturbing slow-downs on the browsing experience.

Solution: Avoid complex animations when a TV device is detected. This however is not so much of a problem on 2015 or newer models that more powerful hardware is used, but it is important for older models' compatibility.

In contrast, for a website that is very static it could utilise some very basic CSS-animations so that it feels more "TV-like".

8.2.8 Text Input

Some websites require for the user to fill in text boxes for many reasons. While this is easy to do with a keyboard, and even with a touch-screen, it is easily one of the most horrific aspects of the TV experience, where the user must pick every single key with on the on-screen keyboard to write a sentence.

Solution: This is a very difficult problem to address, and the best recommendation is to completely avoid it unless it is absolutely necessary. If there is a finite set of choices (or most common ones) these can be displayed as a set of options to pick one. When this is not possible (e.g. for a search box), then an auto-suggest JavaScript plugin can be utilised, so that it can make writing of text a little easier (It is already used in many TV Apps, such as YouTube).

8.3 Conclusion

In this chapter, we have addressed the final objective of our research, which was to **propose a set of guidelines, which can be applied to either new or existing websites, for improving usability and user experience of web content on a Smart TV environment.** Table 8-1 provides an one-page "cheat-sheet" version of these recommendations, for easier use from prospective web-designer who want to work on Responsive SmartTV websites.

Table 8-1 Problems of Desktop Websites when Used on TV and Solutions with Proposed Responsive Design Method ("Cheat-sheet")

	Non TV-Responsive Problem	TV-Responsive Solution
Device Detection	It's impossible for CSS to adjust anything, even if it uses traditional responsive design, as the CSS queries cannot recognise the TV device.	Utilise a Javascript Device detection script (such as Detectizr.js) and also parse the *UA-browser* string to find a the "TV" substring or compare it to specific list of TV UA strings for devices that don't have the TV substring.
Font Size	Desktop websites usually utilise relative small fonts (11 to 16px) for text, since the distance from the viewer is short, a problem for TVs where the distance is much longer.	With CSS, the font size can be altered to a minimum of 20px or more, so that it is easily readable for the "10-foot" experience.
Text	Despite the wide-spread usage of multimedia content, the most basic form of web communication is still textual. This is perfectly acceptable on a desktop website but reading large chunks of text on the TV can be tiring.	Avoid (hide) large chunks of text where this is possible. For example on a list of articles on the TV the description could be hidden and the title should be enlarged. Also an HTML5 reader could be utilised to read out the text
Navigation	A Desktop web page can contain many navigational elements, even awkwardly positioned as the mouse allows to easily pick an element accurately from anywhere on the page. This however is very problematic for A TV remote control, especially when link-navigation is used.	First remove any non-critical elements and links from the page to streamline the navigation, which will have to be simple and ideally follow a grid structure where left-right and up-down movement is feasible. Also utilise D-Pad Navigation using correct syntax HTML5 (Check CSS3 nav-down property for D-PAD response). Make sure the focused element is clearly standing out.
Scrolling/ Paging	Most webpages have more content than the display can show at once, so scrolling is utilised to see any excess content. This can be several pages long. Scrolling with the TV remotes is also very cumbersome, as they rarely include a scroll-wheel.	Utilise Javascript to auto-scroll to the current navigational element when using link navigation. Also create paging break points on a long page and trace with JavaScript the scroll-down or arrow-down keypress to automatically move to the break-point. When the content is a long text document, always include a small part from the previous page, otherwise the user can be disoriented.
Auto-Sliders	A popular presentation technique on the top part of many websites, e.g. for alternating the main News articles. The user can usually use some arrow keys to alternate the articles or just wait until this happens. Although this is visually consistent with the TV experience it often produces navigation problems, as the user struggles to choose the slide s/he wants to click.	This navigational problem can be solved in two ways. The more drastic one, which we used in our prototype was to alter the slider in displaying all the slides at once, thus creating a 4-column grid, which was much easier for the users to navigate as user testing proved. However, it would also be possible to keep the slider but use javascript to trace the left and right D-PAD keys so than it can slide in one click. In this case, arrow buttons should be added on the sides of the slide for use with pointer navigation.
Animation/ Performance	Many new websites, especially the ones that showcase a product, make use of HTML5 animation to look more impressive. At first, this looks ideal for a TV experience but unfortunately the limited capabilities of TV hardware can cause disturbing slow-downs on the browsing experience.	Avoid complex animations when a TV device is detected. This however is not so much of a problem on 2015 or newer models that more powerful hardware is used, but it is important for older models compatibility. In contrast, for a website that is very static it could utilise some very basic CSS-animations so that it feels more "TV-like"
Text Input	Some websites require for the user to fill in text boxes for many reasons. While this is easy to do with a keyboard, and even with a touch-screen, it is easily one of the most horrific aspects of the TV experience, where the user must pick every single key with on the on-screen keyboard to write a sentence.	This is a very difficult problem to address, and the best recommendation is to completely avoid it unless it is absolutely necessary. If there is a finite set of choices (or most common ones) these can se displayed as a set of options to pick one. When this is not possible (e.g. for a search box), then an auto-suggest javascript plugin can be utilised, so that it can make writing of text a little easier (It is already used in many TV Apps, such as Youtube).

Chapter 9 - Conclusion

9.1 Research Domain

There is an undeniable movement towards connecting all kinds of devices to the Internet, thus extending their capabilities in terms of connectivity and content. From Cars to light switches, internet connectivity is gradually extending beyond PCs and mobile devices. The TV was an obvious candidate for internet connectivity and one of the first devices to experiment on this, long before the Internet of Things era, as we have seen in section 2.4. Although Smart TVs have become the standard for new TV devices, since almost all models include Internet connectivity since 2016, users are still not satisfied with their connected TVs experience. As discussed in section 2.6, users' main complains have to do with the limited availability of content as well as usability issues. The main question behind this research work was that since an Internet-connected TV has a web browser and can access the whole of the Web, how can the users complain about limited content? After some initial research on user studies and experiments, it was clear that accessing the web on a TV is very different from browsing a website from your computer. This is a familiar issue that also had to be addressed when the web was introduced to mobile phones: The websites had to be adapted to special mobile versions in order to be easy to use from the mobile phone touch interface, limited bandwidth and smaller screen. A popular technique was also to create a "responsive" website, where a single version could "respond" accordingly to the user device. In overall, what can be done for websites to be better experienced on existing and future TV devices?

To address this, we defined the following research aim for our work:

Propose and assess techniques to develop a set of guidelines that web designers can use to improve their web content, with minimal effort in resources, in order to be exploited to Smart TV devices with better usability and experience for the users, regardless of which of the numerous different TV platforms and technologies they use.

In order to achieve this, the following objectives had to be addressed, as described in detail in the previous chapters:

- **Objective 1: Explore the feasibility of developing web-based interactive ads that will be compatible with all Smart TV platforms and provide a seamless viewers perception regardless of the capabilities of his device.** In Chapter 4 we proposed such a system and developed a prototype using only standard Web Technologies, that possesses all the features of enhanced interactive TV ads, and put it to the test to prove that users have a seamless experience across different devices.

- **Objective 2: Investigate the possibility to have real-time 3D implemented on Web, so that different Smart TVs with different capabilities can view it and interact with it.** In Chapter 5 we evaluate the Web3D performance of representative Smart TV devices by performing numerous 3D benchmarks and a basic prototype was developed to test the application of the proposed guidelines for cross-platform Smart TV 3D apps.

- **Objective 3: Asses the current adaption of popular websites in terms of compatibility with Smart TVs in comparison to Mobile devices.** In chapter 6 we studied the 50 most visited websites world-wide, according to Alexa research, to evaluate their compatibility with Mobile, Tablet and Smart TV devices. The findings of the study clearly showed that although the website designers give great importance to mobile user experience of their website, they ignore the Smart TV optimizations in most cases, leading to very bad usability on these devices.

- **Objective 4: Explore the possibility of exploiting Responsive Web Design, a standard technique for mobile website optimization, to the Smart TV, in order to achieve better usability and user experience while making more content available in a better way to these devices.** As we have seen in Chapter 6, RWD has not been adopted for TVs yet. The challenges for the best adoption of this model for the TV experience are explored and methodologies for the best application of this technique are outlined. The resulting prototype system has been tested for compatibility across different TV platforms to make sure is cross-platform as intended. Then, a user study was performed to put it to the test against the normal non-optimized website on a Smart TV. The results are explicitly outlined, showing the aspects in which the experience of the users was enhanced.

- **Objective 5: Propose a set of guidelines, which can be applied to either new or existing websites, for improving usability and user experience of web content on a Smart TV environment.** Our ultimate goal is that by adopting these techniques, it will be a first important step in more accessible web content from Smart TV users and it will significantly contribute in the evolution of Smart TV as web access devices. Chapter 8 combines findings from all other objectives into a set of comprehensive guidelines.

9.2 Contributions of this work

The main contribution of this work, is that for the first time there is a comprehensive guide on how to create or adapt an existing website, so that it will be better viewed and experienced on a TV. This is something that has not been researched before, as we have seen in Chapter 2, since existing research work has been solely focusing on TV Apps, not websites. The conclusions and the guidelines derived from this work, have been summarised in Chapter 8, so that web designers can adapt them in their work.

On the way to our main contribution, the following contributions were also made:

- We developed a **methodology for evaluating Interactive TV ads**, by combining previous methods of traditional TV ad evaluation with usability tests for websites. To the best of our knowledge, there was no test available previously for evaluating interactive TV ads. This test is described in Chapter 3 and was used to evaluate our interactive TV ad prototype in Chapter 4.

- We created a methodology for developing interactive TV ads for Smart TVs that would be compatible with all Connected TV devices with a web browser. Although there existed methods for developing interactive TV ads for a specific platform, there was no methodology for designing Ads that would only use standard web technologies and would not be dependent on a specific Ad vendor (Chapter 4).

- We extended previous research in Web3D, by exploring the capabilities of the platform on Smart TV devices. A model was proposed for allowing Web 3D content to be exploited on Smart TV web apps (Chapter 5).

- Although there have been studies on websites that have been optimized for Mobile Devices in addition to PCs, there were no studies on status of optimized websites for connected TVs. We have contributed the first study of this kind by testing the top 100 websites worldwide for TV compatibility in addition to Mobile devices (Chapter 6).

- We extended the existing technique of Responsive Web Design to include Smart TVs in addition to Mobile devices and PCs. In Chapter 7, we used the base of an existing template that was responsive for PCs and Mobiles and described in detail how to expand it to also support Smart TVs. This is the first time this has been explored comprehensively in existing bibliography.

- We developed a methodology to test aspects of User Experience and usability of a TV website. This test is described in Chapter 3 and was used to evaluate the prototype of TV-Responsive website in comparison to PC website in Chapter 7.

9.3 Research Findings

Following is a list of the most important findings from our Smart TV research:

- As we have concluded from studying available consumer surveys in Chapter 2, users of Smart TV devices are very interested in the functionality of Internet connectivity of their TVs, however they are not happy with the lack of content that is currently available as well as the usability aspects of their devices. This was the basis of this work: explore ways to make more content available in a more usable way on existing connected TV devices.

- In Chapter 4, we have concluded that it is feasible to create web-based interactive ads for Smart TVs, that are compatible with existing devices, regardless of the capabilities of each device. Our user testing showed that the effectiveness of the Ad was consistent across the different devices, regardless that there were small differences in the way the Ad was displayed due to the capabilities of each device.

- In Chapter 5, we have established that it is possible to have real-time 3D implemented on Web, that can work with different Smart TV models and have proposed a method for this content to be viewable even on devices that don't support Web3D.

- By studying a representative sample from the Top 100 websites in terms of visits worldwide, we have concluded in Chapter 6 that most websites are indeed designed to be compatible and adapt accordingly when viewed on Smartphones and tablets (to lesser extend). However, none of these websites had a version designed for Smart TV, although a few have separate Apps to view their content.

- We have concluded both by going through existing research, and our study of 100 websites in Chapter 6 that the technique of Responsive Web Design, which has become the standard for most websites in order to be optimally viewed on mobile devices in addition to PCs, has not been applied to in the case of Smart TV.

- We have extended the existing technique of Responsive Web Design to be used in Smart TVs for the first time. A prototype was developed as a proof of concept in Chapter 7, while in Chapter 8, we have comprised a set of guidelines on how to create Websites for Smart TVs with RWD.

- The sample sizes for our studies have been small but aligned with other usability/UX studies. We make no claim of the sample size being representative of any particular demographic, so any conclusions from our research have this limitation and should be generalized with caution.

9.4 Future Work

As we have seen in user surveys, Smart TVs are here to stay, and people are excited by the internet connectivity in their TV devices. However, they are dissatisfied with the lack of well-designed internet content. We believe that this work is the first important step, towards a Web friendlier to TVs. If web designers decide to adopt the techniques developed in this research work, we believe that users will find it more attractive to use their TV browsers more often and browse some websites on their TV devices. This will open the way to the vast amount of content that exists on the web to be experienced on a TV. Although this first step is important, we believe that it would be important for further work to be carried out in several areas, to move towards more TV-friendly content. Following are some suggestions and considerations for future work, that will take the base of this research forward.

Future work on the proposed RWD prototype (Chapter 7) can be done on the same basis with extensive user tests and more Smart TV devices. It would also be interesting to explore responsive design applications in the scope of multi-device interfaces. As viewers frequently use their tablet and smartphone devices simultaneously with TV (Zorilla et al., 2015), it would be challenging to explore how a responsive interface could be split among multiple devices and allow interaction between those. Another avenue for future work is to use carousels, for selecting elements on the TV interface, so that the focus is always on the center of the screen, in order to avoid side-scrolling. Also, alternative methods for detection of the screen resolution can be put to the test, for example using PPI information in CSS, but this will require considerable testing of different TV devices.

Also, a categorization of websites could be done, and purpose different approaches for making their content more TV-friendly. For example, could a Wikipedia-style website be presented on TVs in a more “documentary-type” manner? Maybe a system could be developed that would take a page of a Wikipedia entry and automatically convert it in Video-style documentary by parsing the different elements of the page, such as images and videos, and utilize the new animation and voice synthesizing methods of HTML5 to do this.

Hopefully, website designers will start employing the described responsive technique to allow TV-optimised content in our living-rooms and improve the web UX for Smart TV users.

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Appendices

Appendix A

The SUS Usability Questionnaire (slightly modified by Tulis and Stetson for Websites - 2008)

	Strongly Disagree				Strongly Agree
1. I think I would like to use this website frequently.	○	○	○	○	○
2. I found the website unnecessarily complex.	○	○	○	○	○
3. I thought the website was easy to use.	○	○	○	○	○
4. I think I would need Tech Support to be able to use this website.	○	○	○	○	○
5. I found the various functions in this website were well integrated.	○	○	○	○	○
6. I thought there was too much inconsistency in this website.	○	○	○	○	○
7. I would imagine that most people would learn to use this website very quickly.	○	○	○	○	○
8. I found the website very cumbersome to use.	○	○	○	○	○
9. I felt very confident using the website.	○	○	○	○	○
10. I need to learn a lot about this website before I could effectively use it.	○	○	○	○	○