A Review of Voice User Interfaces for Interactive Television

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Abstract. The design of interaction models for Voice User Interfaces is changing. The increasing number of devices such as home assistants, mobile devices and televisions supporting natural language interaction that are transforming and introducing voice interaction in multiple home scenarios is leading to important changes in the design of its interaction models. In the TV context, voice interaction is being introduced with multimodal interaction, supported on graphical interfaces or voice-first devices.
By compiling voice interaction best practices and guidelines of a significant range of voice user interfaces for the television context and analyzing commercial solutions, this paper presents an analysis of leading-edge use cases and trends. It also examines the applicability of various user input approaches, the integration of visual signifiers and elements, and how the user experience changes due to those variations. Combined with interactive television trends, use cases are analyzed on how they take the user's context and habits as personalization tools in the television experience.
The analysis reported on this paper will support an industry and academic R&D project that aims to develop an interface for a natural language interaction solution for a broadcaster's set-top box. Future research concerning voice user interfaces for TV products and applications can also benefit from this survey.

Keywords: Voice User Interfaces, Natural Language Interaction, Television, Conversational Interface.

1 Introduction

As the main communication method used amongst humans, voice – and the dialogue it supports – is a mean capable of quickly and clearly express feelings and desires [1]. While the technology for voice interaction between user and machine is still being improved, progress and advances in this area are becoming faster than ever [2], with the human language itself becoming a new User Interface (UI) layer [3]. Voice interaction occurs on what can be defined as voice user interface (VUI). The VUI is characterized by the interface for communicating with a spoken language application [4], where the

input is primarily or exclusively speech, whereas the output can be audio or also visually supported [1]. VUIs are comprised by prompts, grammars and dialog logic, making it possible to enclose possible inputs and queries, as well as responses, in a call flow database [4]. The user's spoken speech is collected via microphone and is decoded by Automatic Speech Recognition (ASR) systems to generate a response and feedback. Advanced systems usually include further natural language understanding (NLU) component which could recognize and perceive more complex user intents.

Voice in multimodal platforms can enrich the user experience while allowing users not to "focus all their attention on one channel for feedback" [1] and lessening the cognitive load on the "ephemeral nature of output" in auditory-only interfaces [4] when combined with screens and visual information. In addition, the voice in multimodal solutions is a naturally more intuitive input for humans than touchpads, keyboards, or remote controls [1]. With technological advances in voice and speech recognition and word error rates dropping to near 5 percent, voice is at the forefront of interactive systems for the near future [5].

The referred opportunities are also true when considering interactive television solutions, associated with more private and domestic contexts of use with less noise than a public space where the user feels safe and at home. These contexts help to surpass some of the most common voice interaction user issues, regarding privacy concerns, distress in speaking to a machine or the influence of external noise (e.g. the speech of other users) [6]. To reach a successful VUI is a particularly important task when thinking of television systems, most of which are constrained by remote controls, making the user experience dependent on the interactions with the respective set of keys. And although industry experts believe that users are not ready to completely dismiss the remote control in the near future, they claim that voice is "set to play a significant role in the future of TV UI" [7] in a multimodal interaction.

The research pertaining the compilation of existent, past and present, voice user interfaces and its visual analysis is still modest. The study of user voice interaction with the television is mostly limited to the efficiency and accuracy of such systems, while its graphical representations and overall user experience hasn't been the object of in-depth study. This paper analyses the visual elements that are being implemented on voice user interfaces supported in interactive television platforms, set-top boxes (STB), smart TVs or home assistants connected to the television (with commercial releases from 2016 to 2018). Cases were collected based on awareness and sales, as well as in a previous survey concerning trends for UI in interactive television platforms [8], to provide a general outlook of VUI for interactive television made available in 2016 and first half of 2018. From the considered set of products, four examples were later selected due to distinguishable elements and characteristics to be further analyzed.

2 An Overview of Voice User Interfaces

2.1 A brief history of voice user interfaces

Starting with single digit recognition systems in the 1950s, VUI systems evolved in the following decades through research, by expanding the understanding of vocabulary and

including NLU. In the 2000s, these systems evolved from labs to the real world as interactive voice response systems, turning into an easy and simple way to carry out tasks using a landline telephone [6]. Some examples included checking the traffic and tracking a mail package.

In the subsequent years, voice user interfaces suffered little change, until the 2010s, with the emergence of new systems. These new systems are becoming mainstream, either with the growing use of voice-interacted mobile apps that combine visual and auditory information, or voice-only devices like smart-speakers or smart-displays. This "second era of VUIs" [6] is entering daily living much more significantly than earlier systems. In 2016, Google reported that 20% of searches were done by voice when using the Google app and in 2017 almost 70% of smartphone requests done through the Google Assistant were expressed in natural language, contrary to the regular keyword-based input [9]. As Cohen [4] predicted, as these new VUIs become more intuitive, efficient and ubiquitous, they deliver a more enjoyable experience for the user.

2.2 Voice user interfaces today

Overall, expectations for VUI are different than when dealing with a graphical only interface, as users tend to expect a more natural interaction after activating a command or talking to the machine because "they are used to talk to other people, not technology" [10]. This affects the way users formulate their requests, using more complex utterances [11], which can implicate the success of the user experience.

VUIs are now slowly but steadily progressing into conversational user interfaces, with search expanding to more demanding and complex tasks (action-oriented) in digital personal ecosystems. Contrary to simple voice commands, that rely on a set of utterances and replies, conversational user interfaces are built to create interactions where both agents – the user and the machine – are "working towards a mutual goal" [1], pushing for a cooperative conversation in "quality, quantity, relevance, and manner", to be truthful, concise, relevant and clear [6, 12]. In this way, a successful conversational user interface should unfold like a negotiation, not with one-off questions and answers, but a "graceful interaction" [13]. Conversational user interfaces should thus not rely solely on user input but act one step forward of what the user wants or needs [14]. Cooperative conversation is therefore of the utmost importance: the more capable the machine is to perform conversation like a human with all that entails – continuous speech, management of answers in response to what was said before, speaking in turns – the happier the user will be with a system that "allows them to participate actively rather than one that leads them through a series of navigational obstacles" [1]. Therefore, voice systems are increasingly being designed. In the end, a truly conversational user interface should surprise the user with wonder, and when that happens, it pushes the user to keep the conversation going on until hitting a dead end. It is expected that data science and machine learning can improve systems to make that happen, making it feel like magic, by developing "real insights and accurate answers to valuable individual questions" [14].

Voice-activated assistants are playing a defining role in making conversational user interfaces popular. By relying on technology in Natural Language Processing (NLP),

assistants are created to support a new personal user experience, by combining advanced Artificial Intelligence (AI) with an ever-improved conversational persona and creating an ongoing two-way dialogue. The complexity in building a satisfying and successful conversational product and user interface is connected to the intricacies of human speech and dialogue. Considering a diversified audience, today's systems should not only be able to understand defined intents but to do so across generations, speech patterns, and accents.

The easiness provided by voice-activated systems combined with hands-free approaches are proving to be widely used for day-to-day tasks such as setting appointments or controlling smart home environments [15]. With Google Assistant, user queries are "40 times more likely to be action-oriented than Search" [16]. There is also a tendency for users to employ verbs and full sentences in their intentions in a complex conversational type of dialogue with voice-activated assistants [11].

2.3 Voice user interfaces on interactive television

Voice interaction is an "efficient input modality" [17], especially in an interactive television scenario where it brings speed and ease of use to a complex remote-control dependent situation. Regarding the television domain, most significant VUIs were introduced in the early 2010s. Television makers offered voice interaction to make the device more accessible to those with disabilities, while media centers and smart TVs resorted to external interactive devices to provide voice control, such as Xbox's Kinect or Google TV's companion apps with Google Voice [18]. However, these systems were still comprised of a defined limited set of controls and commands, made up of just a few words and actions.

Nowadays, VUIs are increasing in their number of applications regarding television. In most cases, they are used to skip tedious and slow text inputs when searching for content, providing the opportunity to bypass intricate navigation and the on-screen keyboard interacted with a remote control [19]. But the challenge is also in offering the user what he/she is asking considering the specificities of the television ecosystem. This includes a peculiar lexicon and language model to address actions including access to live and recorded catalog, user preferences, logged accounts and available offers.

Furthermore, from a design perspective, these interfaces and the visual components that integrate them are an intrinsic part of the user experience contributing to a successful or failed outcome. In this way, the design of systems that support voice interaction, built on big data and intensive training, should be able to clearly and conveniently convey information and responses to the user's requests and intentions. And while in voice-only user interfaces there are no visual affordances, multimodal voice user interfaces presented in television screens can and should be designed with appropriate visual feedback to improve the user experience [20]. A screen allows the VUI to present the user with options and suggestions of commands, setting clear expectations and improving discoverability [21], and the remote can provide a different input mode and help the user reach a valid answer to his request when voice is ineffective.

Additionally, the opportunity for the television to become a visual translator for voice-activated assistants and smart speakers is still highly relevant – half of the American owners say they would be interested in having this technology on their television [15]. The direct and instant connection to personal devices and platforms makes the home assistants perfect messengers in a hands-free environment as more than 50% of smart speakers are placed in the living room where most TVs are located [15]. Accessible from any place in a room, regardless of position and direction, smart speakers can be both convenient or influenced by multiple sounds in that environment – interactive television VUI with smart speakers should consider the sound and dialogue provided by TV content to avoid mistakenly triggering the system [22].

While speech technology has become commonplace in some operator's player devices and smart TVs, "only 50% of consumers occasionally talk to their device" [7], revealing that talking to a machine still leaves some users uncomfortable [6]. However, the number of voice-activated commands is increasing. Xfinity's X1 Voice Remote reports more than 500 million monthly voice commands generated and more than 1.5 billion in the first quarter of 2018 [23].

3 Current visual approaches for voice user interfaces in television

To identifying current approaches and trends (section 4) in voice interaction for the television, a set of VUIs from different contexts was analyzed. VUIs from technologically advanced players, media centers and Smart TVs were selected from a previous survey of 48 disruptive commercial interactive television interfaces [8]. Of these, 24 products incorporate a VUI solution – 15 that include remote-based voice interaction, 2 that provide native hands-free interaction and 7 that only work with an external smart device assistant. Additionally, brand new products such as conversational assistants (Google Assistant, Amazon's Alexa, Microsoft's Cortana, Apple's Siri, Samsung's Bixby) as well as voice-controlled TVs (LG's ThinQ, Roku's Enhanced Voice), and voice-enabled STBs (DirecTV and Swisscom) were considered. This selection considers a significant range of commercial options, supporting a general view of VUIs in television.

The analysis of VUIs shows that the recent advances in voice solutions in interactive television platforms have resulted in coherent interactions models supported on similar visual elements, such as microphone icons, animated visual signifiers of the start and duration of the interaction, textual input feedback and visual results to the queries made by users.

In this way, most contemporary VUIs in television follow a similar layout and visual elements, with commercial products setting the standard through two popular graphical VUI models.

The most popular is the creation of a superimposed layer to the existing interface that is activated when using a voice command and shown in the lower section of the screen (figure 1). This new layer upholds the overall visual elements such as typography or color palette but adds new visual components essential for the VUI feedback and

interaction such a microphone icon and call-to-action elements related to the interaction. The visual break created by this over imposed layer allows for the user to focus on the voice interaction being completed, creating the cognitive and visual space for more complex interactions, such as combined searching, multiple voice queries or possibly, in the future, a dialogue with the system. This interface design option keeps the user on the same interface and content he/she was watching, while clearly showing that a new interaction is occurring.

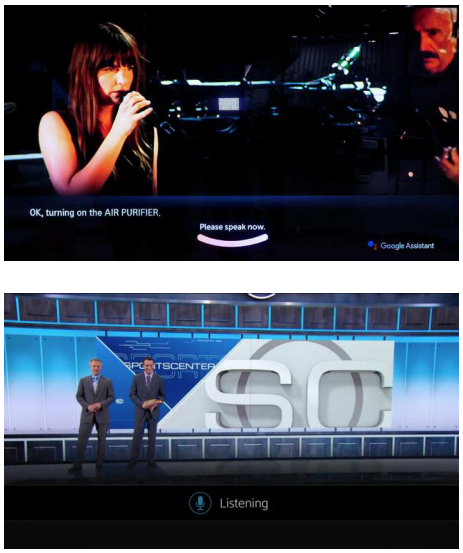

Fig. 1. Examples of superimposed bottom layer VUI models: LG with Google Assistant integration (top), Infinity X1 set-top box (bottom).

A second VUI model for screens can be identified when visual cues are included from the start. In this voice-first approach, products make the voice interaction a priority. Although the design of these products still relies, on some part, on the user's touch and not simply on voice commands, the preferred input was designed to be the user's voice. The designing of screens in this second model differs as the visual cues and components are designed as an integral part of the layout. The visual elements are tailored to the voice interaction, reflecting on this with minimal interfaces through the disuse of menus and emphasis on text, and with visual wording an essential part of the screen by either representing prompts or user queries. Even though this interaction model is in its early steps, commercial products such as the Amazon Echo Show or the Lenovo Smart Display are breaking through in terms of offering new multimodal screens that prioritize voice, establishing the voice-screen combo as products that effectively set expectations [24].

Fig. 2. Examples of voice-first VUI models: Amazon Echo Show (left), Lenovo Smart Display with Google Assistant (right).

4 Trends in Voice User Interfaces for Television

To better understand what the future trends in interactive television VUIs might be, four cases that presented singular VUI solutions in their interaction or visually approaches were selected. These examples display solutions that go beyond current trends by:

- introducing the context of use as an influence for VUI possibilities – Xfinity One;
- presenting a conversational layout and visual elements – LG's Voice Mate;
- their popularity and the increasing number of users, along with the extensive use of data for personalization – Google Assistant and its use on Android TV;
- the growing number of personalization tools for VUIs – Amazon's Alexa and its use on Fire Cube TV.

Following, the four cases are detailed on how user interactions occur and on the graphical elements that support and augment the user's interaction with the system.

4.1 Xfinity

First introduced in 2014, Xfinity's Voice Control[1] (combined with Voice Guidance) was designed to help the users find content through voice-activated search and allow them to set definitions on the X1 set-top box (e.g. programming DVR) with simple voice commands. Xfinity's voice control has been significantly updated in the last couple of years, by adding features such as commands for finding an item through Bluetooth tracker Tile – "Xfinity Home where are my keys?" – or locking a smart lock – "Lock the front door". The control of smart home devices is thus an important part of Xfinity's Voice Control experience, providing a unified domestic user experience through the set-top box, assigning new values to the television [23]. Xfinity provides voice control for an ever-increasing number of user intents and incorporates the user's context to do so. One example showcased by the company is the display of soccer game stats about the game being watched (using the command "Show me soccer stats") with a specially designed sidebar infographic (figure 3 - top). Other examples

1 www.xfinity.com/learn/digital-cable-tv/x1/equipment

included new voice commands to enjoy events such as the Winter Olympics (figure 3 - bottom)– "What Olympic events are on today?" – or voting on America's Got Talent.

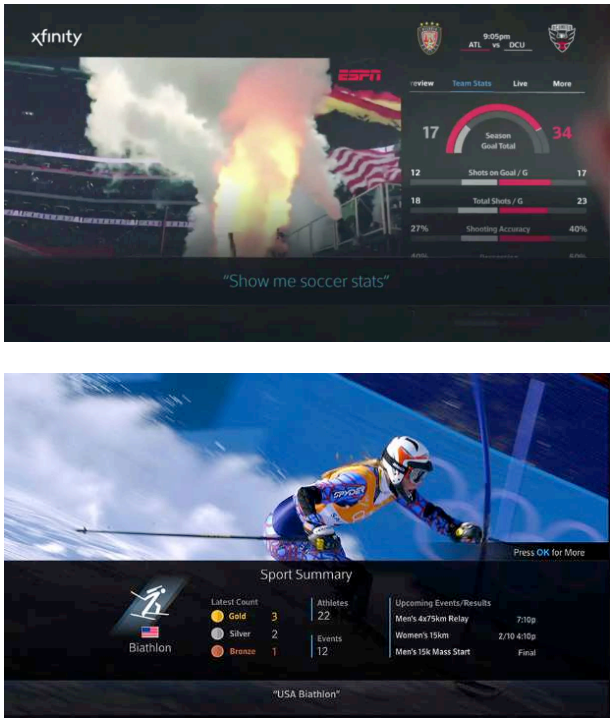

Fig. 3. Context-aware Xfinity VUI for soccer stats (top) and Olympic results (bottom).

4.2 LG Voice Mate (2016)

LG has released several VUIs across models of its smart TVs in the past three years. The 2016 Voice Mate VUI[2] version is visually disruptive, akin to the distinctive look & feel displayed by the graphical user interface [8]. VUI interaction occurs in the bottom right side, differentiating from other interfaces (figure 4). It was designed in a chat-like interface and, although it did not offer a conversational interaction, it clearly visually separates what is the user input and the platform's output. The interaction starts with a speech bubble on the left side with the instruction "Speak now" and an example of a possible command (e.g. "Voice guide"). Command suggestions are continuously changing although they are not related to the context of use. Visually feedback is given when the user speaks and results are shown in the same sidebar by extending it, covering the right half of the screen in a translucent dark layer. This allows the user to keep watching its content without completely replacing the interface while presenting results or further options.

2 www.lg.com/br/suporte/ajuda-produto/CT20096005-1436351544468-others

Although this model was eventually disregarded for a more standardized lower-bottom layer as seen on the previous section with LG's integration of the Google Assistant, the evolution of voice user interfaces and NLU technologies and therefore, more complex conversations between the system and the user, could lead back to a more conversational graphical interface such as the LG's Voice Mate.

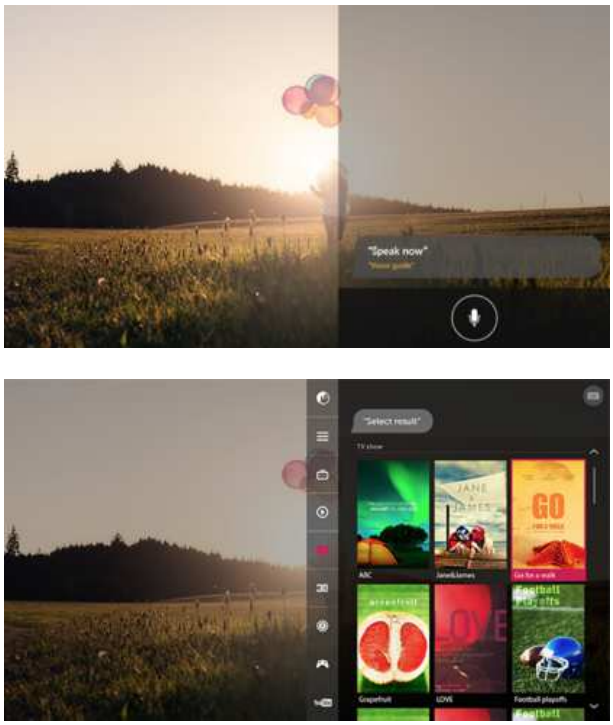

Fig. 4. Voice Mate activated (top), Voice Mate search results (bottom).

4.3 Google Assistant

The Google Assistant[3] was first introduced in 2016's I/O, Google's annual conference. It aims to create a new personal user experience, combining advanced AI with an ever-enhancing conversational persona and creating an ongoing two-way dialogue. The Google Assistant can be used to control an interactive television in different ways: using a Google Chromecast to receive commands via other devices (i.e. smart speakers like Google Home) or natively installed in smart TVs or media centers (e.g. Android TV). This allows for different interaction methods, as it can be accessed using the wake-up sentence "Hey/OK, Google" in hands-free devices, on remotes or the smartphone app. The importance of the Google Assistant usage is exponential, as the number of

[3] https://assistant.google.com/

Android devices continues to grow, increasing the potential for its use with television-related commands [25].

Home assistants like Google Home allow for a hands-free interaction using a simplified interface with auditory signals and minimalist animations with 4 dots. The integration with the Google ecosystem also allows the user to search outside the TV platform or perform many commands with Google Actions (third-party "apps" for Google Assistant). Therefore, although it is not context-related, it provides widespread access to any information needed and displays it on the bottom of the TV screen (figure 5).

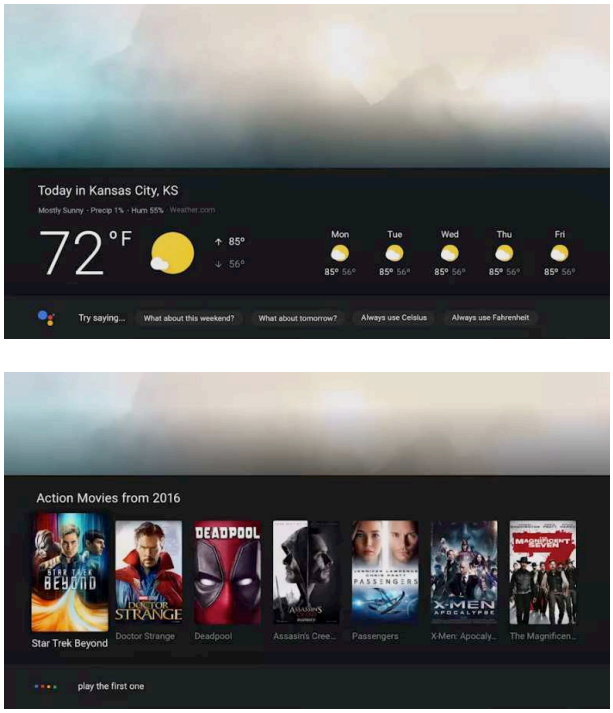

Fig. 5. Google Assistant VUI on Android TV - Weather results (top), search results (bottom).

4.4 Amazon Alexa

Amazon Alexa[4] was announced in 2014 alongside the smart speaker Amazon Echo. In recent years, Alexa has been adapted to provide results visually with smart displays like the Amazon Echo Show and on the TV with devices such as the Amazon Fire Cube. Therefore, interaction with Alexa can be initiated both by a wake-up word (e.g. "Alexa"), on a remote or on a smartphone. The number of different Alexa-enabled devices is increasing (surpassing 20.000 compatible devices) but there is still the need for the user to have an external device with Alexa support. Furthermore, Alexa skills (third-party "apps") are growing at an exponential rate, with more than 50.000 skills listed worldwide [25].

[4] https://amazon.com/Amazon-Echo-And-Alexa-Devices/

While using a smart speaker the interaction follows a minimalist approach with a blue gradient LED light as visual feedback. If integrated into the TV, that same visual signifier is adapted into a horizontal line on the top of the TV screen (figure 6). Additionally, Alexa commands not related to the control of the TV intents generate new interfaces that occupy the entire screen as seen on the figure 6 (e.g. weather, movies showing in cinemas). Visual affordances are regularly available and are adapted to the user's context (e.g. Try "Alexa, scroll right").

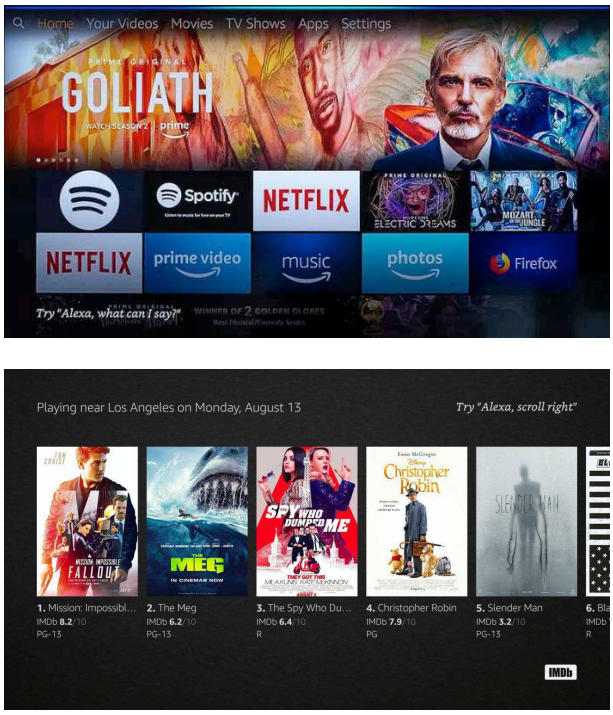

Fig. 6. Wake-up word activated Alexa VUI on Amazon Fire Cube (top), Alexa VUI results for movies showing in cinemas (bottom).

5 Conclusion

VUIs can become the interaction model that truly offers a new television experience, reinventing the regular use of the remote-control and bringing interaction to the flux and open space that is the living room. Screens like the television can "become the canvas for conversational AI" [26], providing visual output for voice-activated inputs. While voice by itself cannot single-handedly offer an optimal user experience, the combination of both voice and remote control is a solution adopted by many.

The introduction of voice activated commands into Smart TVs, STBs or through the control of smart assistants is increasing, allowing users to replace the remote control

with their voice with an impact on their television-related behaviors. However, the addition of voice interaction to an already designed and tested system should be made intentionally and carefully. Because it will introduce a new interaction model into one already known by the user, the VUI designed for a commercial interactive television should become a part of the original's "look and feel" while asserting a new space without disrupting the existing design system.

The analysis showed that two main models are becoming the standard for the design of VUI for television. The first introduces a super imposed layer that does not disrupt the user experience and maintains the interface's look and feel, allowing the user to make a smooth transition between interaction methods. The second model responds to a voice-first approach, where voice is the main input method and the design of the interface validates that by focusing on providing the user with textual and auditory cues.

Visually coherent models have been developed and are deployed in most devices. However, the use case analysis reveals that the VUIs should not follow a one solution fits all approach. Context-aware VUI and conversational interfaces in interactive television can adopt different visual outputs, taking advantage of a bigger screen and the multimodal interaction with a remote-control.

In the future, a more personalized experience can be provided by taking the interaction further beyond the use of a couple of commands, to proactive solutions that should work continuously as a service to help the user with his individual needs and take advantage of the contextual and user data. UX designers face important challenges to work on VUIs in interactive television that integrate, in a balanced way, visual and auditory signifiers with privacy, context, and content.

The analysis reported on this paper attends the more common approaches in VUIs in interactive television and distinctive visual elements and interactions. However, further research has been developed towards identifying what is becoming standard, outlining guidelines based on industry applied interaction patterns and models. Subsequently, this research will support a preliminary stage of an industry and academic R&D project that aims to develop an interface for a natural language understanding (NLU) solution for a broadcaster's set-top box.

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