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Extending the field of view: a human-centred design perspective on 360° TV

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Omnidirectional video (ODV) is a type of video that presents viewers with a new type of interactivity. It enables people to look around in a 360° view of the recorded dynamic scene as if they are controlling the camera themselves. ODV presents opportunities for new interactive television formats. The development of such new formats, however, is accompanied by challenges in terms of user experience and technical and creative development. In this article, we discuss issues and opportunities tied to televising ODV from a user perspective. These findings are the result of a human-centred design study. In this study, we introduced 20 potential users to ODV, as this was new to them. We gathered their feedback on the demonstration, and then encouraged them to envision suitable ODV-based enhancements of television genres. This article offers a discussion of both the methodology (including a form of laddering) applied in the study and the user research findings. We found that people see an added value in ODV under certain conditions (e.g. enabling exploration), but that there are also a number of bottlenecks such as the concern to miss key parts of a television programme while looking around.

Keywords: omnidirectional video; television; participatory design, user research

1. Introduction

Most of us are familiar with 360° imagery in one way or another. While using Google Streetview, we can rotate our view to see different parts of the street. In a panoramic theatre, we turn our heads to admire the full stellar constellation displayed above us. When we play games in 3D environments, we control our view to check for clues or opponents surrounding us. While watching television, however, we do not have this possibility to adapt the viewing direction, although many of us may have experienced a point in time when they wished they could have a peek at what was happening to the left or the right of the screen.

Omnidirectional video (ODV) is a form of video that has been captured so that it affords exactly that what was described above: the viewer can look around in a 360°, camera-registered, moving image. There are several terms in use to refer to ODV. Synonyms include panoramic, 360°, spherical and surround video. In essence, people can freely choose the viewing angle while the ODV plays, as if they are turning and controlling the camera.[1] As such, ODV provides viewers with a new form of interactivity.

Although combinations of the two are possible, ODV has to be distinguished from multi-angle video. In the case of multi-angle video, users have the opportunity to choose between alternate video streams, often showing a single event (e.g. an explosion) from different viewpoints (recorded by cameras standing at different positions). With regular ODV, viewers can choose their viewing direction from a given viewpoint, but cannot change the viewpoint itself. This extended field of view is the result of either using a single-camera solution with curved lenses/mirrors or a multi-camera system in which each camera registers part of the surrounding space and images are stitched together afterwards (Decock *et al.* 2011).

ODV can be displayed in various ways. In a spherical or cylindrical cave(-like) environment,[2] for example, users can look around by means of natural eye and head movement. When people wear a head-mounted display to view ODV, the viewing area is restricted to a display in front of the eyes. Users look around by moving their head, as their head movement is picked up by sensors. This is applied in the theatre performances of one of our project partners, in which visitors become part of the experience.[3] In case of more common displays (such as television, computer and tablet displays), again only part of the 360° scene can be shown and developers have to either capitalise on the existing interface or provide new interaction devices/modes (see, for instance, the example in footnote 1).

ODV provides an opportunity to create, develop and distribute new television formats that exploit its affordances. However, establishing ways to accomplish this is not straightforward. Already in the early 2000s, television was identified as an interesting, yet challenging application domain for ODV (see, for instance, Fritz 2004). Today, the question how to successfully implement ODV in a television context is still a subject of research, illustrating that it

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is by no means a trivial process. It requires not only technological innovation (e.g. to improve image quality and video distribution), but also conceptual development and investigating how users may perceive and deal with this new way of interacting with television content.

Indeed, whether new interactive services fulfil their promise, does not merely depend on tackling technical challenges. The switch from analogue to digital television and the introduction of cross-media interactive platforms has clearly taught us that there are other obstacles. Producers wish to retain authoring control, while many TV viewers at the same time appear satisfied with the current types of 'lazy interaction' (e.g. pausing and voting) that do not really call for high involvement (Van den Broeck and Pierson 2008).

For example, experiments with interactive services such as access to additional content (e.g. accessing diary of a TV-presenter and contestants in a reality show, watching behind the scenes movie clips) showed that these features were only appealing to those viewers that already liked the specific programme (Van den Broeck and Pierson 2008). With regard to interactive narrativity, a Dutch study showed that viewers had little interest in choosing between alternative endings for a particular programme (Van Zoonen and Aalberts 2005). TV is still mainly considered as a storytelling medium (Gerbner 1997) and viewers tend to want to leave this storytelling to the professionals.

The concern that considering technical challenges in isolation does not provide us with a complete picture is echoed in the work of Steen (2008) who warns for the risk inherent to purely technology-driven innovations. When user needs and wishes are neglected, innovations may well lead to a product that is quickly abandoned, or not even adopted at all. He argues for human-centred design as an alternative to technology push, in which an active attempt is made to bridge the world of users on the one hand, and researchers, developers and engineers on the other.

The user study presented here forms part of the explorative television (xTV) research project. In this project, Steen's argumentation is taken into account, as the main goal is to address the complex challenge of televising ODV in an interdisciplinary way. Within the project, we do not merely focus on technological research, but also consider concept creation and user experience. The particular study we report on in this article fits in this approach and attempts to involve users in the design process. The study was conducted in the fall of 2011 and its specific aim was to inscribe potential users of televised ODV in the development process. Treating users as equal, knowledgeable partners, we engaged in a dialogue with them on what characteristics, if any, would make television programmes suitable for use in conjunction with ODV.

In what follows, we will first describe the methodology of this human-centred design study and then discuss users' perspective on televised ODV (for convenience dubbed ODTV or 360° TV). This will encompass both users' concerns as well as perceived opportunities.

2. Methodology

This study should be seen as one step in a broader research and design process in which we worked together with content creators and engineers to iteratively drive, refine and evaluate the design of ODTV production experiments and research prototypes with the help of users. In each step of our user research, including this study, the goal is to gather empirical evidence on user experience to inform the design process.

In the initial stage of the project, *prior* to this study, we conducted a literature review, and consulted with experts and with users (visitors to a ODV-based theatrical performance, see Bleumers *et al.* 2011). This was done in order to conceptualise users' experience with ODV and to outline a first set of requirements for the project team to take into account. The *current* study's main focus is idea generation in which we stimulated participants to envision suitable ways in which ODV could be part of their television viewing experience, again leading towards recommendations for the design team. *Following* this study, a research prototype was developed, which again allowed us to make recommendations, this time based on user-centred prototype evaluation.

The specific set-up of the study, and the process it is part of, is in line with the human-centred design approach, which in 2010 was formalised as a standard for user experience (referred to as ISO 9241-210).

Steen (2008) describes how human-centred design can be situated across two dimensions. The first dimension describes the tension between designing 'with' users and designing 'for' users. In certain approaches, the user is positioned as a knowledgeable partner in the design/research process, while in other approaches researchers and designers seek to enhance their knowledge of users to feed into this process. The second dimension describes the tension between the concerns for what is and for what ought to be. Certain approaches focus on studying the current situation of the user, while others focus on imagining a future situation.

In the current xTV study, our main concern is envisioning a realistic future situation. Television formats using ODV do not exist yet and as such, the users are not yet defined. This does not mean that the current situation is not important. When thinking up new formats, the generated ideas will be shaped by people's actual context and TV experiences.

Second, in the xTV project, we want to involve users and other stakeholders as knowledgeable partners in the development process. The rationale for this choice is not simply the belief that this will benefit the development process, as other human-centred design approaches can accomplish the same. It is the belief that users and other stakeholders should

be given a voice, should be empowered within the design process. We note, however, this is not the same as positioning them in the role of designers and researchers. What is key to us is treating their expertise as equally important.

2.1. Set-up and data collection

2.1.1. Overview

Our main research question for this study was: What characteristics make a TV-programme suited for enhancement with ODV according to adult digital TV viewers? In addition to our main question, we decided to investigate an additional research question (as a subtopic): Do gamers and non-gamers have different ideas and preferences with regard to enhancing television through ODV?

The choice for this subtopic was informed by our observations at the start of the project that hinted at gamers and non-gamers having different expectations about ODV. That gamers' extensive experience with games as interactive media, with navigation through virtual environments, and with game concepts and mechanics may trigger different needs and perceived opportunities appeared to be a plausible hypothesis worth exploring further. Figure 1 shows the set-up of the sessions (one per participant), lasting about 1 hour and 30 minutes, that we conducted to address the above-mentioned research questions.

In total, 20 people participated in this study.[4] Participants were recruited via two channels: (1) an existing representative user panel in Flanders (Belgium) and (2) an additional call for participation. All participants were selected so that they had access to and watched digital television at home. We did this because we wanted to work at this point with people who already had affinity with digital television, and who would not reject the concept of 360° TV-based solely on their disinterest for watching television.

Half of the participants played games on average about three hours or more a week and half played less than three hours a week or not at all. We will refer to them as the gamer group and the non-gamer group, respectively. The gamer group consisted of five females and five males. The average age in this group was 32.6 (range: 22–54, SD = 10.93). The non-gamer group consisted of four females and six males. The average age in this group was 32.3 (age range: 22–48, SD = 8.96).

Most participants were professionally active with the exception of three persons: a university student, one person recently graduated and one disabled participant. Although we did not inquire into this, it was apparent from participants' job positions that the majority held a college or university degree. While most participants used several platforms to consume digital content, all but one participant had never heard about ODV.

Each participant took part in an individual session. As can be seen in Figure 1, sessions consisted of three phases, which we will describe in more detail below.

2.1.2. Introduction and intake phase

In the introduction and intake phase, participants first signed an informed consent form. Next, we briefly interviewed participants to be able to contextualise our findings. Questions addressed current television viewing behaviour (e.g. viewing times, programme preferences, use of interactive digital television services and social viewing) and, for the gamer group, also their gaming practices (e.g. amount of play, game preferences and platforms played).

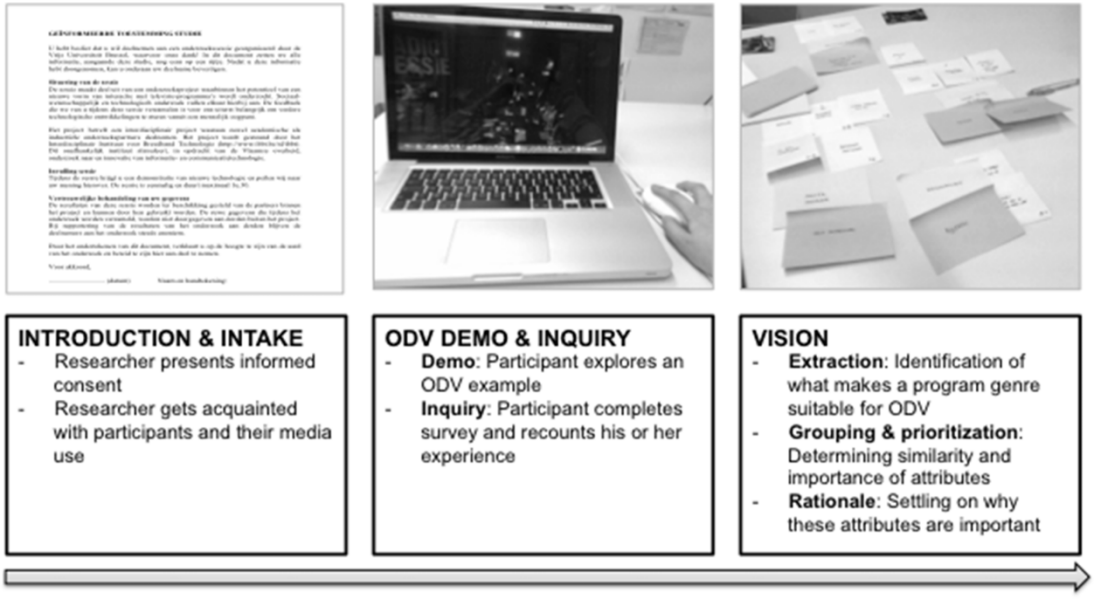

Figure 1. Overview of the session in which each user took part individually.

2.1.3. Demo and inquiry phase

In the ODV demo and inquiry phase, we first familiarised participants with omnidirectional viewing by letting them look around in an ODV fragment, featuring a concert by a Belgian music artist. A link to the publicly available version of this sample can be found in footnote 1. Each respondent viewed the content on a laptop and controlled it by means of a computer mouse. Participants were explained how they could change their viewing angle and zoom in and out, as the main aim of this phase in the research was to give them experience with the technology rather than to investigate usability issues.

After the demonstration, participants were asked to complete a short survey. This was followed by a brief discussion of their responses, to get a better idea of how participants had experienced the demo and how they conceived of possible television use of ODV based on this experience.

The survey used to inquire into the experience of the ODV demonstration contained ten statements. Participants had to indicate to what extent they agreed with the given statements (on a 5-point scale ranging from 1 = 'don't agree at all' to 5 = 'completely agree'). The statements, originally in Dutch, were:

(1) *Fun*: I enjoyed looking around in the image.
(2) *Ease of use*: Looking around in the image went smoothly.
(3) *Interactivity (Control)*: While the movie was playing, I was able to decide what to look at.
(4) *Presence*: I had the feeling that I was in the same place as the artists and the audience.
(5) *Interactivity (Exchange)*: There is an exchange between the viewer and the form and/or content of the image.
(6) *Quality*: The visual quality of the movie was good.
(7) *Interactivity (Synchronicity)*: While watching the movie, the image adapted without any delay.
(8) *Directing*: While watching the movie, I felt like I was directing it.
(9) *Story*: I missed a story line while watching the movie.
(10) *Identification*: I identified with people in the audience.

Items pertaining to interactivity (items 3, 5 and 7) were based on items from the Interactivity Scale developed by Liu (2003), which consists of three subscales: Active control, Two-way communication and Synchronicity. The item pertaining to presence (item 4) refers to physical presence and was based on an ITC-SOPI questionnaire item (Lessiter *et al.* 2001). Finally, the identification item was derived from a player identification scale (Van Looy *et al.* 2010).

2.1.4. Vision phase

In the final phase, the vision phase, we prompted users to envision possible opportunities for future usage of the new technology, letting them think about enhancements of existing types of television programmes with ODV. The previous phases can be seen as a warm up for this phase, making participants aware of their own TV viewing and gaming experience and practices and familiarising them with the new technology.

In this phase, we used 'laddering' as a research method. Laddering was first introduced in consumer research to capture consumers' perception of a product so that marketing could be matched to this perception (Reynolds and Gutman 1988, Reynolds and Olson 2001). It is based on Means-End Theory (Gutman 1982), which states that consumers choose certain products because they believe that the products' attributes result in consequences that support their personal values. The goal of laddering is to reveal these perceived attribute–consequence–value chains or 'ladders' through interviewing and content analysis.

Laddering, as explained by Reynolds and Gutman (1988), starts with establishing which product attributes are important for the person that is being interviewed. Often these attributes are elicited by letting participants compare existing products, express their preference and explain what it is about the preferred product that makes it better. When a substantial list of attributes is extracted, it is suggested to let participants prioritise attributes (Reynolds and Gutman 1988). The researcher then proceeds to prompt the participant to explain why he or she believed each particular attribute to be important (making sure the most important ones are covered).

Given our human-centred design approach detailed earlier, it may seem a bit unconventional to use a method that was developed in a marketing context. However, we believed that provided some adaptations as explained below, we could retain the method's merit – extracting perceived links between product attributes, product experiences and personal values – while putting it to use in a human-centred design approach.[5] In what follows, we describe this in more detail. We note that we tested our approach in two pilot sessions with one gaming and one non-gaming respondent to assess whether it was viable.

To help participants express what programme characteristics they thought could be important, we first let participants compare television genres (one pair at a time, see Figure 2). Instead of asking them their preferred genre, which is typically done, we asked them:

- For which of these two types of programmes do you think ODV would be more suitable?
- What is it about this type that makes it more suitable? (and/or) What is it about the other type that makes it less suitable?

The TV genres we asked participants to compare were drawn from the list of genres used by Geerts *et al.* (2008). They deployed it to investigate the impact of programme genre on social interaction during and after TV viewing.

Figure 2. Example of a pair of cards.

Table 1. List of genres used in our visioning phase.

Card No.	Genre	Card No.	Genre
1	News	11	Stand-up comedy
2	News magazine	12	Reality show
3	Weather report	13	Comedy series
4	Documentary	14	Quiz
5	Debate programme	15	Music programme
6	Sports programme	16	Hobby programme
7	Drama series	17	Action series
8	Soap	18	Consumer magazine
9	Docu-soap	19	Human interest
10	Talkshow	20	Touristic programme

They compiled this list by selecting popular genres from the content classification scheme issued by the European Broadcasting Union (2007).

We omitted animation and movies from the list as out of scope for the current study, but added consumer magazine, human interest and touristic programme, which we felt were missing. This yielded a list of 20 genres (such as news, documentary and comedy series), which we illustrated on cards with well-known Flemish TV programmes (see Table 1 for the full list). The specific illustrations are available on request.

Each elicited attribute was written down on a post-it by the facilitating researcher. Once all card pairs had been compared, we asked participants to group post–its describing essentially the same attributes. We added this step to avoid redundancy. We then had participants prioritise attributes.

Following prioritisation, the researcher proceeded by moving the participant gradually up the ladder from 'attributes' to 'consequences' and finally to 'values' by asking the following:

- Why do you find this programme characteristic is important? What consequences do you think it has for your viewing experience?
- Why is this consequence important? Which personal values does it support?

Similar to the attributes, elicited consequences and values were noted down on post-its. The session was ended with the question whether the participant felt a genre that would be particularly suitable for ODV was not mentioned.

2.2. Analysis

2.2.1. Analysis of the demo feedback

We tested for significant differences between the ratings of the non-gamer and gamer group by applying two-tailed *t*-tests for unpaired samples per survey item. Significance level for these tests, α, was set at .05. The discussions following the survey were categorised according to the survey items and then summarised.

2.2.2. Analysis of the vision phase results

The direct results of a laddering interview are analysed in two phases: a qualitative and quantitative phase (Reynolds and Gutman 1988). The user session that we organised yielded a set of unstandardised chains of attributes, consequences and values. These unstandardised ladders formed the main input for a first qualitative analysis phase:

(1) All unstandardised ladders were listed in Microsoft Excel, including corresponding interview notes.
(2) Summary codes (i.e. standardised labels) were created and numbered. Interview notes and recordings helped establish which raw labels refer to the same concept.
(3) The ladders were re-coded, using the summary codes, yielding standardised ladders.

The standardised ladders (63 ladders, average ladder length of 3.14 elements) were then entered in the LadderUX tool[6] (Vanden Abeele and Zaman 2009) for the quantitative analysis of the laddering data. This tool automates the following steps:

(1) *Construction of summary score matrix*: This contains all participants' ladders.
(2) *Construction of implication matrix*: This specifies the strength of all the code links registered.
(3) *Construction of the hierarchical value map*: This is a graphical map of dominant links between attributes, consequences and values.

Dominant links are determined by the cut-off level. This is the number of links needed to call a link dominant. We set this level at 3 in LadderUX. This resulted in 79% of perceived links being above cut-off level and hence being represented in the hierarchical value map.

Table 2. Insights in participants' TV viewing and gaming practices and preferences.

	Practices	Preferences
Viewing	The living room is the prime location for watching television for most participants, with the bedroom as an alternative The sample is an almost equal mix of people mainly watching TV together with others and those primarily watching alone TV viewing predominantly occurs in the evening (dependent on work/commuting times during the week and social agenda) Reported hours of TV viewing range from 4 hours to 30 hours per week	Participants primarily report watching series and news. Several mention watching reality programmes to relax and have a laugh Documentaries (historical/nature), sports and quizzes were also reported several times, albeit less frequently This content is not always consumed via digital TV-services. In some cases, the TV-set only functions as a screen to display the content or TV-content is viewed via laptop/PC, on and offline
Gaming[a]	Compared to TV viewing, gaming is less routinised; game-play is more occasional and increases when new titles are discovered Reported hours of gaming per week range from 3 hours to 12 hours per week	Genre preferences strongly vary, including strategy, management, shooter, social network and physical exertion games Participants enjoy multiple genres. For about half of them casual (puzzle and tetris-like) games are among the genres played The desktop or laptop computer is most commonly referred to as the platform of choice, although various game consoles (fixed and portable) are also reported

[a]Findings refer to the participants belonging to the gaming group.

3. Findings

3.1. Viewing and gaming practices and preferences

Table 2 presents an overview of the main insights we gathered during the interview in the introduction and intake phase. It is interesting to note that as we enquired about participants' TV viewing practices and preferences, people tried and sometimes struggled to delineate what is meant with digital TV and TV viewing.

This has partly to do with different modes of engagement with the TV. TV can be a primary activity when one is actively involved with watching the TV-content (TV in the front), but TV can also be a multitask activity (e.g. ironing in front of TV, reading, Internet surfing – this can be referred to as TV on the side. TV can also serve as background noise (TV in the back). These different levels of engagement with TV can shift during the day (Van den Broeck *et al.* 2006). For example, some participants noted they turned the TV on as they came home from work until bedtime, only sometimes watching it actively, asking whether they should count that time as TV viewing.

In addition, it was not straightforward for participants to define digital TV-viewing within the more complex media ecosystem that the TV has become part of. For instance, is watching a downloaded TV-series on the TV-screen via the Microsoft Xbox digital TV viewing?

To the gaming practices and preferences listed, we add that most of the reported game-play occurred in a domestic context, rather than on the move (with a few exceptions reporting playing while commuting or travelling).

3.2. Feedback to ODV demo

In this section, we describe participants' feedback to the ODV demo. Figure 3 shows the response distributions for each of the ten statements that they were asked to judge.

Table 3 shows the average ratings per item in the survey following the demo. Recall that the highest rating (5) refers to strong agreement with a given statement. For example, a high mean rating for fun means that on average participants found ODV usage a fun experience.

The descriptive statistics have been collapsed across gaming groups as statistical analyses showed no significant differences between the average ratings given by the gamer and non-gamer group. Nevertheless, we did find a marginally significant effect for synchronicity ($p = .054$). This item was on average rated lower in the non-gamer group.

3.2.1. Fun

While most participants enjoyed the ODV demo, there was disagreement on whether such content would continue to be entertaining and on whether one would like to have television programmes with the opportunity to look around. In this regard, some respondents expressed sceptical arguments, which bring to the fore their views on what underlies an optimal television viewing experience and what may compromise it.

One such argument was that the affordance of ODV may threaten the viewing experience as a relaxing experience, given that it is perceived as requiring substantial cognitive

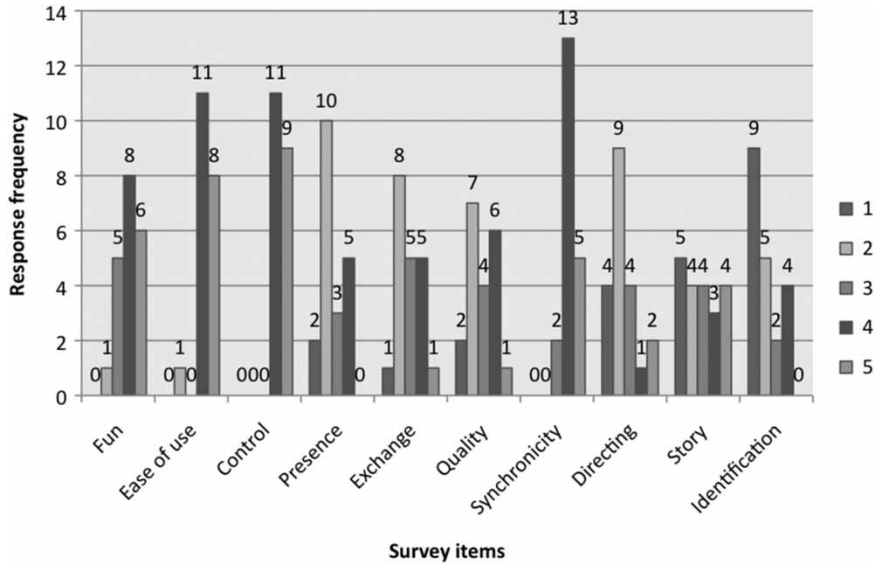

Figure 3. Response distribution per survey item. The legend categories correspond with the points on the 5-point scale for rating the statements ranging from 1 = 'don't agree at all' to 5 = 'completely agree'.

Table 3. Mean rating and standard deviation per survey item.

Item	Mean	Standard deviation
Fun	4.0	0.89
Ease of use	4.3	0.73
Control	4.5	0.51
Presence	2.6	1.00
Exchange	2.9	1.04
Quality	2.9	1.14
Synchronicity	4.2	0.59
Directing	2.4	1.19
Story	2.9	1.50
Identification	2.1	1.19

involvement. Related to this, some argued that specifically in programmes with an elaborate narrative (e.g. fiction) looking around could hamper narrative processing; causing viewers to lose focus and miss the essence of the programme (cf. TV as storyteller, see supra). ODV was expected by some to also hinder watching television together on a single screen. Indeed, conflicts may arise over how the television programme is watched and over who controls the ODTV. Finally, a participant in the gaming group noted that interest in looking around should be meaningfully triggered. When there is no clear purpose in looking around (unlike games), one might easily get bored with this viewing activity.

Thinking about the implications of 360° TV, some participants also voiced privacy concerns that might negatively influence their live experience of an event, ultimately making it less enjoyable. They did not like the idea that as a member of the audience in an event (e.g. performance, show or sports event) that is recorded and broadcasted in ODV format, one could be observed continuously by viewers.

3.2.2. *Ease of use*

The demo was overall considered easy to use. Extrapolating this to television, however, some points were raised that should be taken into account in order to improve ease of use.

Participants felt ease of use could be improved by having pre-set viewpoints, enabling viewers to jump between points of interest, instead of having to continuously drag the image. This could include jumping back and forth between the personally selected and the directed view. In addition, one of the gamers noted that it was impossible to zoom in/out and look around simultaneously. This could be enabled to improve viewing efficiency.

As mentioned, the ODV demo was controlled by handling a computer mouse. When asked what type of control would be considered easy to use on television, several respondents suggested control by hand gesturing would be most intuitive (cf. Microsoft Kinect). They were concerned that the current remote control would not give them enough precision, and they disliked the idea of having to hold a device all the time. They were least interested in purchasing and using a separate device specifically for controlling ODV on television.

While participants watched the demo on a single screen, we also asked about the possibility of watching a directed view on one screen and ODV on a second screen (e.g. tablet or laptop), either simultaneously or successively. Participants expect synchronous viewing of a primary and secondary view to be complex. They also worry that co-located viewers will perceive using a second screen as asocial behaviour. Successively viewing television-related ODV content on a secondary platform (e.g. computer, handheld) appeared to raise more interest.

3.2.3. Interactivity

Overall, participants felt highly in control over what they could look at by being able to choose the viewing angle. They did note the potential relevance of being able to control viewpoint as well, for instance, during a sports game. In addition, they tended to experience a high degree of synchronicity between their actions and the image update.

In terms of perceived exchange, viewers felt they exerted influence on the images they saw, but that these same images did not strongly compel them to look in certain directions (cf. absence of triggers). As a result, ratings for this item varied around the midpoint of the scale.

3.2.4. Directing

Most participants did not feel as if they were directing the video, given that they only had control over the viewing angle and not over other factors (i.e. viewpoint and scene content). Those who gave a low rating for this item (i.e. the majority) noted that they felt more like a cameraman/woman or a voyeur, rather than a director. The few people that did give a higher rating for this item, referred to feeling part of the performance (i.e. presence) or to the possibility of customising the video fragment.

3.2.5. Presence and identification

Ratings of presence and identification varied substantially across individuals, yet people tended to recount both experiences in a similar fashion and there was a tendency to give a low rating.

A number of factors were suggested to influence these experiences. Some of these factors relate to the medium and the way the content is captured. For instance, some participants believed a larger display or a surround display (and surround sound) would enhance their sense of presence. A few participants noted the camera was not at the eye-level position. Because of this, it seemed as if one was hovering somewhat above the audience instead of being part of the crowd.

Other factors were mentioned that refer to the participants' attitude towards what was demonstrated. As such, some participants noted that they tended to focus on the technical aspect of the demo. They believed that one's attitude towards the demo, sometimes referred to as willingness to suspend disbelief (Lombard and Ditton 1997), affected their sense of being there. Furthermore, certain participants did not like the music(ian) and claimed that because of this they could not identify with and feel part of the crowd that was enjoying the concert. Thus, they stressed the importance of content appreciation in relation to presence and identification.

3.2.6. Quality

Overall, image quality was perceived as neither exceptionally poor nor great. One of the reported quality issues was the occurrence of stitching artefacts. At certain moments, participants perceived slight errors in how the video image segments were stitched together. In addition, some participants noted a blind spot, that is, the absence of an image at the position of the actual camera.

While the above issues were not considered major issues, most participants did feel that zooming in and out had a detrimental effect on perceived image quality. The resulting resolution drop and image distortion were considered troubling; participants felt that quality should be maintained constant across the zooming range.

While these quality issues were reported by participants to affect their overall quality of experience, it must be noted that participants differed in terms of how problematic they found these artefacts to be. Figure 3 illustrates these individual differences by revealing how varied the quality ratings were.

3.2.7. Story and content

Participants' opinions differed mostly with respect to the statement that probed whether they had missed a story line while watching the demonstrated fragment. Several participants mentioned that they had not really missed one, noting that for a concert the story line is limited. It was acknowledged, however, that narrative could have helped to contextualise the viewing experience (e.g. situating where it is taking place) and potentially even stimulate a sense of presence (e.g. through character identification).

In addition, several participants argued that the presented content could not fully illustrate the added value of ODV as viewers tend to focus on musicians and the directed version thus shows what the viewer wants to see. Discussing what might constitute more appropriate types of content, participants referred to content where the viewer and director are likely to have different opinions on what constitutes an interesting view (e.g. broadcast of live events). They also emphasised that the risk of missing essential content when looking around should be minimised.

3.3. Envisioned opportunities

The vision phase yields a set of ladders, i.e. attribute–consequence–value chains, that illustrate how people believe that existing formats can be enhanced using ODV and why they find such enhancements meaningful. This set is visualised in Figure 4.

In what follows, we will describe each ladder structure separately. Specifically, we will point out per ladder what characteristic is considered to make a television programme suitable for omnidirectional viewing (i.e. attribute component), which desirable impact ODV is believed to have on the viewing experience (i.e. consequence component) and why this is considered meaningful on a personal level (i.e. value component).

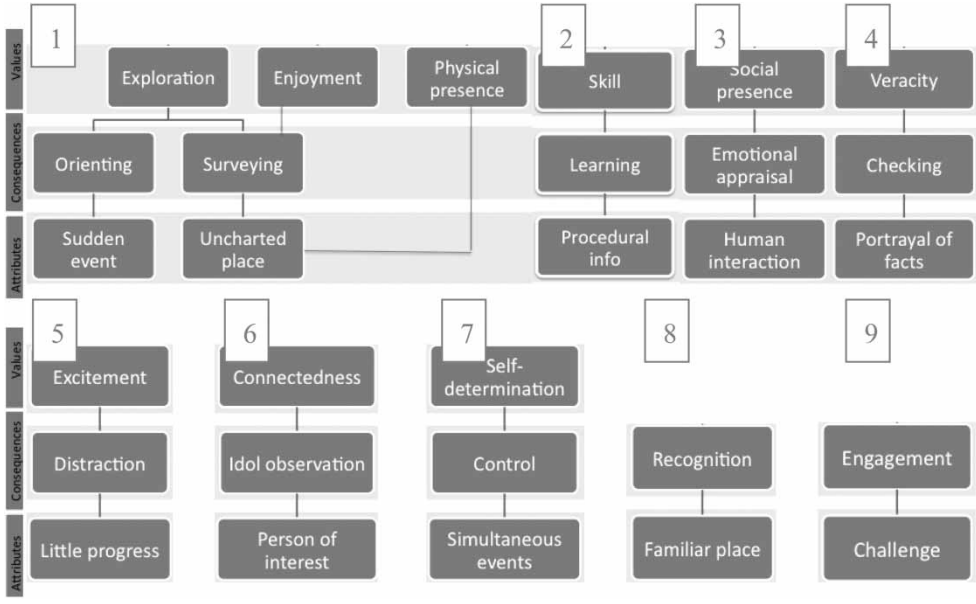

Figure 4. Overview of ladders derived from the data gathered during the vision phase. The lower level of each ladder is the attribute level, the middle level represents the consequences and the upper level represents the values.

As will become evident from the discussion, some of the preferred programme characteristics can be linked to particular genres, while others appear to be more generic and can be applicable to various programmes.

3.3.1. From the uncharted to exploration

Programmes featuring an environment previously not (well) known by the viewer are considered suitable for omnidirectional viewing. ODV is believed to give viewers an opportunity to survey the displayed space, getting a bigger picture of what is going on. This fulfils the desire to satisfy one's curiosity and be informed. ODV was also seen as something that allowed participants to feel physically present in the mediated space.

Exploration can be self-initiated or triggered. On the one hand, viewers may seek to enjoy the beauty of a space or pursue other goals such as planning a trip. On the other hand, they may be triggered to attend to a sudden event featured in the programme (e.g. a sound originating from outside the given view).

In essence, when showing places is key to the programme itself, ODV could enable viewing behaviours that support exploring the environment from within. In this respect, programme genres such as documentaries, touristic programmes, but also programmes featuring houses and interior design are considered to be particularly suitable for ODV-based enhancements.

3.3.2. From procedures to skill

In programmes that show how certain procedures are performed, viewers expect that omnidirectional viewing will allow them to observe components of the procedure more closely and thus will facilitate learning about it. This supports the interest they might have in mastering a certain skill or to at least have knowledge about how something is done.

Genres that tend to feature this procedural information, according to participants, are hobby programmes (e.g. cooking programmes). Some participants, however, also expressed interest in gaining knowledge about the procedure of making a programme. To watch such 'a making-of', the ODV camera would need to be placed alongside the commonly used camera-setup. Interest in seeing this creation process is not tied to a specific programme type. Instead, people's preference was linked to what they already enjoy watching. Participants also considered this to be a feature that they would use only once. Once they have seen the process, they know it.

3.3.3. From human interaction to social presence

When human interaction plays a central role in a programme, omnidirectional viewing is also potentially relevant. Commonly, when human interaction takes place, the focus is usually on the human actor who is speaking, leaving others literally out of the picture. ODV is thought to provide the possibility to look around at will and assess the emotional, non-verbal response of others that are part of the interaction, yet (momentarily) in a more passive role: the audience, quiz candidates, participants in a debate that are listening, and so on. This emotional appraisal supports the need to capture and interpret human emotion, to understand people's intentions and the social situation as a whole, and in some cases even feel part of it.

As apparent from the previous paragraph, programmes that were often linked up to this preference structure are debate programmes and quiz formats. Also mentioned were consumer magazines in which there is a test audience, stand-up in which the comedian heavily interacts with the audience, and music contests with several jury members.

3.3.4. From portrayal of facts to veracity

In the case of programmes featuring events that are portrayed as facts, yet leaving the viewer uncertain about whether the events are actually staged, participants were also interested in having an omnidirectional view. They believed that this would allow them to verify what is going on. Such viewing behaviour would be in line with the desire for truth and authenticity.

Programmes that are seen as operating on the border of fact and fiction are reality shows, docu-soaps and human-interest programmes. Aside from these typical examples, there was also mention of a blurred boundary between fact and fiction in other genres such as in news reports.

Interestingly, while participants considered this opportunity, some started to reflect on the impact ODV might have on the television production process. While some believed that ODV might lead to a more authentic way of televising content, others felt that producers would likely find a work-around to 'manipulate' viewers.

3.3.5. From little progress to excitement

Omnidirectional viewing was considered to provide some distraction in programmes that are slow paced in nature or momentarily exhibiting little progress. As such it would be a way to keep one's mind occupied and to avoid boredom. Looking around could be an alternative to changing channels, with the advantage that the viewer can still hear what is going on and return to a more focused, linear view when the pace picks up again.

This ladder cannot be linked to a particular programme genre. Dull moments can be experienced in any programme. Long conversations during soaps, debates and talk shows, slow pace in documentaries, sports and music programmes were mentioned to trigger distraction-seeking. Even participants that were highly sceptical about ODV on television felt that slow content provided an opportunity. This does require that there is something visually interesting available. Otherwise, people would turn to other activities (e.g. doing dishes) while using the television as a radio.

3.3.6. From persons of interest to connectedness

Programmes that feature a person of interest to the viewer are seen as potentially suitable for omnidirectional viewing. In this case, ODV could afford observing this person and his/her context from a first-person or even from the idol's perspective. Such viewing behaviour would meet people's need to understand (the context of) the people they relate to better, to feel more connected to them.

Genres that are likely candidates in this regard include sports programmes (featuring a sportsman of interest), music programmes (with one's favourite musician playing in a band), programmes in the style of MTV 'Cribs' (featuring an idol who showcases his or her house) and fiction series (featuring one or more characters that one relates to).

It must be noted that most participants considered fiction series to be problematic genres for ODV-based enhancements, fearing they could miss essential story elements or associating fiction with a lean-back experience. However, it was noted that as a fan of a particular fiction series one could make use of ODV when watching an episode again.

3.3.7. From simultaneous events to self-determination

When a programme features several events at the same time, omnidirectional viewing allows the viewer to choose for themselves which event is of more relevance. This supports the viewer's interest in having freedom of choice.

This preference structure emerged explicitly in the context of sports programmes such as omnisports (such as the Olympic games) or cycling (e.g. different events going on among pack vs. front runners). It is apparent, however, that the value of self-determination is also implicitly present in the other preference structures as well.

3.3.8. From familiar places to recognition

Unlike the ladder structures discussed so far, the analysis yielded also two partial ladder structures (i.e. attribute and consequence only) that will be described in the current and in the following Section 3.3.9. The lack of a value element in these ladders seems to be due to the fact that these ladders were mentioned less and the fact that they were associated with divergent values.

A small number of participants pointed out that if a place was featured on television that was familiar to them, they would appreciate looking around for landmarks, elements in the landscape or cityscape familiar to them. In the case of the place where they live, it would be a way to feel more connected to it or look at it in a different way. In the case of a place they once visited or lived in, it would be a way of finding out how much the place had changed over time. This is in line with the current success of the Google Street View service that enables users to look around on a map.

3.3.9. From challenge to engagement

A few participants pointed out that when the programme features a particular challenge (e.g. solving a murder mystery), ODV would allow participants to be more actively, cognitively engaged, as if rising to the challenge themselves. For some, this would support the desire for creative thinking, as they found that clues in current crime series are

often displayed too obviously. Others saw an opportunity for joint fun, competing against or playing together with others.

3.3.10. Final remarks

We conclude this section with two final remarks, namely on the outcome of the comparison of gamers' versus non-gamers' preferences and on the outcome of this laddering exercise as a whole.

In both the gamer and non-gamer group, there is a ladder structure leading up to the need for exploration. Orienting to sudden events, however, was only mentioned by the gamer group. A possible interpretation for this result may be that, due to their gaming experience, this group may be more inclined to think of triggers as a relevant way of encouraging exploration.

The remaining ladders that reach the value level are different for the two groups. In the non-gamer group, the ladder structures leading up to the social presence and connectedness described earlier resurface. In the gamer group, the ladders leading up to skill, excitement and veracity reappear. This suggests that the non-gamers we interviewed were more drawn to the social affordances of ODV, while the gamers were more occupied with its individual affordances. We do want to emphasise that this comparison should be treated with caution, given the relatively small number of participants per group (i.e. 10).

The laddering results as a whole, in fact, should be understood as specific to the given sample that was involved. The study allows us to identify a number of ways in which ODV can be perceived to offer an added value during television viewing, yet, it does not permit us to make generalising statements about the prevalence of these perceptions among the general TV-viewing audience.

The opportunities for ODV-enhancement identified in this section are based on an aggregate of the individual laddering data and represent the dominant perceptual orientations for the given sample. They reflect reoccuring relationships across the data for the entire participant group, in which each member had particular interests and preferences.

Participants would often refer to their (general and TV) interests and viewing habits during the cards exercise in the vision phase. For instance, one participant confronted with the choice between 'Drama series' and 'Soap', explains his choice for the latter despite his preference for Anglo-American fiction series, by stating that in the former case, he wishes to follow the director's choice to be immersed in the story. Soaps, on the other hand, often move at a slow pace in his opinion and provide time for looking around. This example also illustrates our observation that the selection of one card over the other does not always match participants' genre preferences.

In any case, the goal of the card pair comparison is not to reveal which genre is more suitable for ODV than the other. Instead, it serves to establish what it is about one type of programme that makes it seem more appropriate than the other and to then gain understanding of why this attribute is important to the participant (in terms of consequences for the viewing experience and in the light of his or her personal values).

4. Discussion

4.1. Summary of our findings

In this paper, we describe the results of a human-centred design study in which we encouraged potential users, gamers and non-gamers, to envision suitable enhancements of television genres based on ODV. Specifically, the study was driven by the following primary and secondary research questions:

- What characteristics make a TV-programme suited for enhancement with ODV according to adult digital TV viewers?
- Do gamers and non-gamers have different ideas and preferences with regard to enhancing television through ODV?

To address these questions, we first familiarised participants with ODV and then applied a method called laddering tailored to a human-centred design approach. During laddering, we asked participants to choose between programme genres and discuss what made them prefer it for ODV and why. The underlying rationale is elicited by prompting participants to make expected positive consequences explicit, as well as the values these are thought to support. We believe that any television study that aims to provoke an in-depth discussion with viewers on which characteristics make a TV programme suitable for a particular interactive service (if any) can benefit from this approach.

One could argue that by opening up genre conventions for personal interpretation through dialogue, we also subscribed ourselves to a cultural approach to understanding genre (Mittell 2001). The attribute–consequence–value chains that we elicited in fact acknowledge that a genre cannot be defined on the basis of programme characteristics alone, but are coupled to personal, social and cultural values. In this respect, we believe that laddering may also be a fruitful approach to studying people's interpretation of genre.

What did our findings tell us? With regard to our main research question, we found that certain genre-specific content elements can make a programme suitable for ODV from a user perspective. For example, the confrontation with an unfamiliar space typically found in touristic programmes can trigger the desire to explore. Hobby programmes are likely to trigger interest in mastering the displayed skills. Debate programmes may elicit the wish to understand the social situation. In each of these cases, it is anticipated that

ODV may enable viewing behaviours and experiences that satisfy these needs.

Aside from these genre-specific characteristics, more generic, and circumstantial elements could potentially also make ODV viewing worthwhile. When there is little progress in the programme, viewers can seek temporary distraction. When a person of interest or well-known region happens to feature in a programme, viewers can actively act upon the connection they feel with this person or place.

With regard to our secondary question, the answer is nuanced and tentative. In giving feedback to the ODV demo, gamers would refer to their specific experiences, including their gaming knowledge to explain why they did or did not like something about the demo. However, they did not rate the demo significantly different from the non-gaming group. The analysis of the vision results suggests that gamers were more prone to pick up on the individual benefits of ODV on television, while the social benefits were more apparent to the non-gamers. However, further research with larger group sizes is warranted to validate this.

That participants see potential in 360° TV may be surprising, given the evidence on viewers' limited enthusiasm with regard to interactive television services (see intro). We note that we did see sceptical arguments from older studies on interactivity resurface. Participants, some more than others, feared that interactivity might compromise watching television as a social, relaxing and compelling experience. Nevertheless, by comparing various genres, participants picked up on opportunities where ODV could contribute to their viewing experience, instead of detract from it. They may not always want to look around, but do foresee occasions where their own interest in terms of what to look at may differ from what the director believes people want or should see.

The reader may ask to what extent participants' overall viewer preference played a role. Given that we asked about participants' current viewing preferences at the start of the session, we are able to establish that participants indeed also took their general viewing preference into account when deciding in which programme they would prefer to look around and zoom in. A genre they strongly disliked was not a likely candidate for ODV viewing. This is in line with earlier findings on the link between viewer preference and interest in interactivity (see supra). However, it does appear that mild disinterest could be turned around.

4.2. Related work

Seeking to relate our findings to previous work, we observed a dearth of user research concerning ODV. Since its conception, panoramic video has been applied to various domains. Takács (2011) discusses examples in surveillance and security, spatial mapping, teleconferencing, entertainment, health care, education and his own work on mobile delivery of cultural content. Pea (2006) considered possible usage of ODV-based instruments for learning as well as learning research, envisioning also how mobile technology would accelerate the use of ODV for expressive communication.[7]

With regard to television, several broadcasters have experimented and continue to experiment with providing supplementary ODV material online.[8] Research seems to have focused primarily on the conceptual and technological challenges particular to the different application domains.

Work that goes beyond anecdotal user data is that by Rizzo *et al.* (2003) and Chen (2010). Rizzo and colleagues (2003) outlined a series of diverse scenarios, which they subjected to production experiments and user evaluation, ranging from therapeutic to information and entertainment applications. This body of work has mainly focused on viewing panoramic video by means of HMD.

Chen (2010) conducted user research, i.e. requirement elicitation and prototype evaluation, to inform his work on capturing and online delivery of enhanced ODV content on a virtual zoo website. His investigation was highly specific to the given application domain and the envisioned system that also supports annotation and navigation between viewpoints.

Given that the limited user research that is available on ODV has considered its use in other domains and as part of different interfaces, it is difficult to relate our findings to previous work. We do see a correspondence with the user needs that emerged from our inquiry and the requirements that Neng and Chambel established and confirmed throughout the process of designing and evaluating an online 360° hypervideo[9] player (Neng and Chambel 2010, Neng 2012).

Some of our participants noted they would rather look around in retrospect, when they knew what to expect. This is in line with Neng and Chambel's observation that users need an overview of the video content. The concern that one would lose interest in looking around when not triggered corresponds with Neng and Chambel's requirement to hint people about where interesting information (in their case: links) might be. Finally, the desire to have pre-set reference points to jump to, in our view, does not only reflect a desire for efficiency but also the need to orient and know where you are looking in the image as identified by Neng and Chambel. This need was also pointed out and addressed by Chen (2010).

The Surround Vision project (Alfaro 2010, Alfaro and Bove 2011) does not deal with ODV, yet it shows interesting similarities with our own project that make its results highly relevant to us. Within this project, a second-screen prototype was developed and evaluated that enables users to look at what happens outside of the viewing area confined by the television box by using a tablet. By holding the tablet in front of them and moving it to either side of the screen, users get to see different parts of the represented scene (left, middle and right) and can literally look 'outside the box'. To achieve this, video content from three different cameras present throughout the making of a programme is used.

During the Surround Vision user test sessions, participants spontaneously suggested applications that bear strong resemblance to the opportunities identified in our own study. They saw benefits in sports, where they could switch between main and side action. They proposed 'Discovery channel type' programmes where they could explore spaces and they also mentioned the opportunity to catch 'unseen expressions' of people participating in a debate or interview (Alfaro 2010, p. 50).

While it was not the central focus in this study, the possibility to watch ODV on a second screen was indeed touched upon during our discussion with the participants. From this discussion, concerns emerged regarding the cognitive complexity and social implications of using a second screen. Recent research shows that 54% of Belgians are online while watching TV, showing that this has become a habit for a large group of people. Furthermore, 16% of the time spent watching TV, people are online at the same time. Interestingly, however, only in 21% of the cases, the online consulted content is related to the content watched on TV (IAB Europe 2012). A possible explanation, in line with our results, could be that only a minority of people want to invest the cognitive effort it requires to divide their attention across multiple devices when viewing TV(-related) content and to integrate the various forms of information.

4.3. Follow-up research

Overall, our results show that viewers foresee both problems and opportunities for 360° TV. Some of the anticipated issues were particular to the given ODV player and content used during the demo and can be tackled by technical improvements, adjusted content selection and platform adaptations. In fact, at the time of writing, some of these issues have already been addressed by technical improvements. Other matters, however, represent current attitudes about what it means to watch television alone or together and of which it is unclear how they will interact with future solutions once introduced. This brings us to the final part of this discussion: the steps we have taken since this study and steps planned to continue this research.

Indeed, while our approach was successful in capturing user attitudes towards and expectations of 360° TV, follow-up work was needed in three respects.

4.3.1. Concept development

As the attitudinal data do not yield actual solutions, we planned workshops in which the expertise of viewers and the skill of professional stakeholders are joined to generate new formats based on ODV. This resulted in the organisation of five short brainstorms with students and professionals ($n = 31$), mainly studying or working in television production, to whom we presented results of the current study.

Facilitating the brainstorm participants to come up with ideas in which ODV could add or improve people's viewing experience, we found that many of the proposed solutions were in line with the meaningful ODV-based enhancements proposed in the current study. One particular idea, that was not foreseen by users was the social usage of ODV footage where one could, for example, tag and share interesting viewpoints with others.

Future steps could include more extensive workshops in which both stakeholders in television production as well as external professionals with relevant expertise such as interaction and game designers are included. A facilitating technique for this workshop could be letting participants map out a user journey (Parker and Heapy 2006).

4.3.2. Large-scale attitudinal survey

The given methodology cannot tell us how widespread these attitudes are. This requires a large-scaled survey to assess interest in ODV at the level of the general population. Thus far, we have organised five online surveys ($n1 = 78$, $n2 = 720$, $n3 = 38$, $n4 = 38$, $n5 = 91$) tied to particular production experiments where ODV content (recorded footage and/or live streaming) was provided online.

The various surveys consistently point out that, on average and under the online viewing circumstances, people enjoy watching the ODV fragments, find the medium easy to use and feel in control of what they watched. While omnidirectional viewing was expected by the developers to result in a strong sense of presence, which was also considered valuable by some of the participants in the current study, the average ratings show that this is an area for improvement. The same holds true for image quality.

4.3.3. Prototype evaluation

Finally, this study addressed what people hope and fear about how ODV might influence their television experience at home. In this sense, our study is limited, as participants were not able to actually experience how the ODV interaction would play out when watching television.

Since the current study, we have been able to test a second-screen research prototype within a home-like lab environment. While watching television, participants could explore synchronised ODV imagery of the same event on a tablet device (i.e. indoor concert, festival performance, cycling contest, soccer match and the introduction of a new TV studio for a childrens' TV channel). In total, 20 people participated in these lab-based user tests.

Generally, participants in the lab tests, who were all tablet users, welcomed most of the ODV-based enhancements identified in the current study. Opinions strongly diverged, however, with regard to the possibility of being able to appraise people's emotions on TV or seeking distraction through omnidirectional viewing.

A key finding that emerged from this follow-up study was that participants saw great added value in an extended application that would support integrated access to several

information sources related to a television programme. In such an application, omnidirectional footage would be only one of those sources. A recurring example was a cycling race app where one would have access to (1) visual information on the immediate context of a rider of interest (via ODV footage), (2) more information on other visible riders (hyperlinks in ODV footage) and (3) information on the race as a whole (e.g. track elevation).

In the future, a longitudinal study could address actual appropriation of a prototype introduced at people's home in order to investigate actual user practices for a longer period of time (after the 'novelty effect' has faded).

4.4. Requirements for design and research

Based on our findings, we propose the following general requirements for future ODTV prototypes and applications:

- *Adaptability*: Make the set-up adaptable so that ODV content can be displayed on the television screen or on a second screen depending on the social situation.
- *Convenient access*: Provide quick access to regions of interest by working with pre-set viewing directions and viewpoints (set by producers or users).
- *Precise interaction*: Capitalise on devices already present in users' media ecosystem that enable them to interact with ODV with a satisfactory degree of precision.
- *Detail and overview:* Test what zooming range is adequate for users and ensure image quality remains constant across this range so that people can use the zooming function to analyse details or obtain an overview of the given situation.
- *Physical presence*: Ensure that the camera is positioned at eye-level, in line with a first-person perspective, when the goal is to give viewers a sense of being inside the mediated space through ODV.
- *ODV plus*: Explore how each of the opportunities identified earlier can be pursued by combining ODV with other functionalities that support information-seeking and understanding, for example, hyperlinked ODV.
- *Interactive narrativity*: Conduct further experiments to discover how ODV may be meaningfully incorporated in TV storytelling. This involves considering at which point – over the temporal course of a programme, as the story unfolds – TV viewers would appreciate an extended view and could be given a trigger (e.g. through spoken narrative) and time to do so.

These requirements demonstrate that ODV cannot be understood as a mere add-on to current processes of television production and TV viewing. The different stakeholders involved (content creators, engineers, researchers, users, etc.) will need to reflect on how ODTV as a medium can be fitted into these processes, as well as on how these processes can be adapted themselves.

4.5. Final reflection

Overall, our work reflects a human-centred design approach. On a meta-level, it can be considered as a specific form of 'embedding use knowledge with design knowledge' (Peine and Herrmann 2012, p. 1504). By letting potential users envision future possibilities, we actively and creatively engaged them in the innovation process and strived for *their* voice to be heard. Thus, we hope to have made a first step towards describing the promises and challenges related to 360° TV from a user perspective.

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Notes

1. To experience ODV for yourself, please consider the following example provided by our project partner iMinds-EDM (UHasselt): http://www.360video.org/eva/keizern.html. This is a publicly accessible version of the content shown to the participants in this study.
2. An example of 270° spherical projection environment can be viewed here: http://20203dmedia.wordpress.com/2011/11/17/270-degree-mobile-projection-environment/.
3. Our project partner CREW has and continues to use ODV material in their performances. Spectators wear a head-mounted display via which the ODV material is presented and thus become active participants in the performance. Their website containing samples of their work: http://www.crewonline.org/art/projects.
4. Sixteen of the 20 sessions involved face-to-face contacts. We also conducted 4 remote sessions following essentially the same procedure but via Skype (for interviewing) and Google Docs (for facilitating the post-survey and the vision exercise).
5. In fact, we are not the first to use laddering in a design and development context. Laddering was previously also adapted for product likeability evaluation (Zaman 2008, Vanden Abeele and Zaman 2009).
6. This online software tool, LadderUX – Laddering the user experience, is available on request. See: http://www.ladderux.org.
7. A vision that appears to be coming true as there are now relatively inexpensive ODV cameras for smartphones on the market, GoPano micro and Kogito Dot, which come with an online platform for sharing user-generated content.
8. Examples include BBC's Oceans 360 degree experience (http://www.bbc.co.uk/oceans/360/lemonsharks), CNN's special 360° coverage on the Haiti earthquake (http://edition.cnn.com/interactive/2010/01/world/haiti.360/index.html), and Net5's reality show with 360° streaming (http://www.secretstory.nl). A few months ago, Channel 5

enabled viewers of the Gadget Show to have a dual-screen experience where they were able to synchronously explore the studio in 360° on their mobile or tablet (http://www.xs2theworld.com/en/our-work/channel-5).

9. In contrast with regular ODV, 360° hypervideo also contains links that users can click to access additional information such as related content elsewhere on the Web or other scenes in the video.
10. A complete description of the xTV project and a list of partners involved in it can be found here: http://www.ibbt.be/en/projects/overview-projects/p/detail/xtv-2.
11. This software tool for displaying ODV content, developed by Philippe Bekaert, iMinds-EDM is called iv-viewer.

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