

How People Use 360-Degree Cameras

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ABSTRACT

A variety of new kinds of consumer cameras that capture the full 360-degree surroundings in a single panorama photo or video has recently been introduced to the market. In addition to conventional viewing devices, such as smartphones and computers, the 360-degree photos and videos can also be viewed with a virtual reality headset for a more immersive experience. In this paper, we present a field study where 14 consumers used 360-degree cameras freely in their everyday lives for a period of four weeks. We describe the strategies that the participants applied to capture 360-degree content in different situations and discuss the opportunities, challenges, and limitations of using a 360-degree camera compared to conventional cameras. We identify four common practices of consumer 360-degree camera use: Panorama Capture, Experience Capture, Automatic Capture, and Document Capture. We also report on the participants' habits of viewing, sharing, editing, and managing consumer-captured 360-degree content.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**.

KEYWORDS

360-degree camera, photo, video, immersive, omni-directional, panorama, consumer photography, virtual reality

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1 INTRODUCTION

Camera manufacturers have recently introduced new kinds of consumer cameras that capture the full 360-degree surroundings in a single picture or video clip (see Figure 1). Examples of such cameras include Ricoh Theta, Samsung Gear 360, Nikon KeyMission 360, and LG 360 Cam. These cameras typically have two imaging sensors which take two pictures simultaneously in the opposite directions through wide angle lenses. The pictures are then stitched together



Figure 1: An example of a photo captured with a consumer 360-degree camera.

to produce a spherical 360-degree panorama picture. The pictures can be viewed with conventional devices, such as smartphones and computers, using a special 360-degree viewer application which allows the picture to be freely rotated on the display. Alternatively, the pictures can be viewed with Virtual Reality (VR) headsets, such as Oculus Rift or Samsung Gear VR. The VR headsets completely immerse the viewer in the picture and allow the viewer to experience a strong feeling of presence in the captured situation.

While many people have some experience of 360-degree images and video clips (for example, of “street view” imagery provided by digital mapping services, or of “virtual tours” offered by real estate agencies, hotels, and tourist attractions), a 360-degree camera represents a new capture concept to most non-professional camera users. The camera manufacturers envision many potential uses for 360-degree cameras: capturing memorable moments, such as family parties, holiday trips, sports performances, and outdoor adventures, and reliving those moments later in realistic detail in virtual reality. However, there is little information available about whether ordinary people would be willing to adopt such a capture concept, how would they actually employ a 360-degree camera in different situations of everyday life, and how would the use of a 360-degree cameras compare to the use of conventional cameras.

In this paper, we present a field study on consumer 360-degree camera use. To the best of our knowledge, this is the first study that addresses non-professional use of handheld 360-degree cameras in everyday contexts of use. We provided a group of 14 people with 360-degree cameras and related equipment that they could freely use in their everyday lives for a period of four weeks. The evolving camera usage practices of the participants were tracked with weekly questionnaires and the participants were extensively interviewed about their experiences at the end of the study. Based on the study results, we contribute a rich picture of people’s early practices of capturing and using 360-degree photo and video content. We

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describe the strategies that the participants applied to capturing 360-degree content in different situations and discuss the opportunities, challenges, and limitations of using a 360-degree camera compared to conventional cameras. We identify four common practices of consumer 360-degree camera use: Panorama Capture, Experience Capture, Automatic Capture, and Document Capture. We also report on the participants' habits of viewing, sharing, editing, and managing consumer-captured 360-degree content. Our study continues the tradition of user studies on novel camera technologies in Human-Computer Interaction (HCI) research, focusing on the people's interactions with and through technology. Overall, the results of our study inform the development of future photo and video solutions, applications, and services involving 360-degree content.

The rest of this paper is structured as follows. First, we give an overview of the related work. We then present the study procedure and results, followed by discussion and conclusions.

2 RELATED WORK

2.1 Domestic Photography

Sarvas and Frohlich [20, p. 5] define domestic photography as “the photographic activities of ordinary people taking and using images for non-professional purposes”. They divide the history of domestic photography into three eras: the Portrait Era (1839–1888), the Kodak Era (1888–1990), and the Digital Era (1990–). In the Portrait Era, people purchased photo capture as a service and the photos were primarily personal portraits. In the Kodak Era, the advances in camera technology and the introduction of commercial photo finishing services made it possible for ordinary people to capture their own photos. The subjects of the photos became more versatile, including people (for example, family members), locations (for example, home or holiday destinations), and events (for example, familial rites such as birthdays) that the camera user had a personal relationship with [20, p. 60-63]. Overall, the photography activities were connected to leisure time [20, p. 56]. The photos were carefully captured, selected, and organized to construct an ideal, positive image of one's life [20, p. 7-9]. The photos were primarily shared with family members and friends who knew the persons in the photos, and the sharing involved reminiscing and telling stories about the photos.

In the Digital Era, photography converged with computing and telecommunications, offering a tremendous range of new opportunities for capturing, managing, editing, and sharing digital photos. Still, the first studies on consumer digital photography [3] found that the initial practices of digital camera use closely followed the earlier practices of film camera use. Managing and archiving the rapidly accumulating collections of digital photographs created new needs, especially as few people were found to be willing to invest time on managing their photos [3, 13]. The introduction and wide adoption of cameraphones made the digital camera ubiquitous [11] and provided enhanced opportunities for instant sharing of pictures [19, 25]. Storytelling, editing, and playfulness have been found to be an important part of the people's photo sharing activities [5, 6, 16]. In addition to affective purposes, the cameraphones have also been used for functional purposes such as supporting practical tasks [11]. On-line photo sharing sites [for example, 15]

and social media services [for example, 9] make possible sharing photos with remote friends as well as publishing them to large audiences.

Compared to photography, the consumer practices of video capture have received relatively little attention. Kirk et al. [12] identify two different kinds of practices of consumer video camera use: spontaneous and more planned. In an early study of consumer video capture with cameraphones, Lehmuskallio and Sarvas [14] found that the possibility of capturing video had changed the consumer practices only gradually and the models for capturing video were often taken from traditional photography. In addition to offline capture, the cameraphones have also offered new opportunities for live mobile video broadcasting [8, 24] as well as for two-way interaction and collaboration over live video links [7].

2.2 Omni-Directional Photos and Video

While 360-degree cameras are not a new invention [for example, 2], they represent a recent development in consumer camera technology, and only a few earlier studies have addressed consumer applications of 360-degree photos and videos from HCI perspective. These studies have primarily focused on user interactions for consuming 360-degree content. A common problem in watching 360-degree videos is that viewers may lose track of the subjects which they are intended to attend [26], and in collaborative viewing, people may experience challenges in establishing common spatial references [22]. Several gesture sets have been developed to control 360-degree video viewing [1, 18]. Beyond interactions for consuming 360-degree content, researchers have also explored the use of real-time 360-degree video connections to support different applications, such as remote collaboration [10], video chat [23], and communication between distance separated couples [21]. No earlier studies have addressed non-professional use of handheld 360-degree cameras.

3 OUR STUDY

3.1 Objectives

In our study, we were interested in the practices surrounding the 360-degree photo and video content captured by ordinary people. In particular, we wanted to focus on the capture of such content with consumer-grade 360-degree cameras that have recently been introduced to the market, but we also wanted to understand the later phases of the user-created content lifecycle, including viewing and sharing of 360-degree content with VR headsets and with other more conventional means. We were also interested in how these practices would compare to people's current practices of using conventional cameras. Overall, we wanted to provide a rich picture of people's early practices in capturing, viewing, and sharing user-created 360-degree photos and video clips, in order to inform the development of future photo and video solutions, applications, and services involving 360-degree content.

3.2 Participants

We recruited a total of 14 people (seven female and seven male) living in (removed for blind review) to participate in the study through local mailing lists and social media groups. We decided to select the participants from two demographics of active camera users: seven



Figure 2: Equipment used in the study (from left to right): Samsung Gear VR headset, Samsung Galaxy S7 phone, Benro BK10 tripod, Samsung Gear 360 camera, and Ricoh Theta S camera.

of the participants were young adults (age $M=25$, $SD=3.1$), while the other seven were parents in families with children (age $M=35$, $SD=7.8$). The participants were quite experienced in camera use: on a scale between 1 and 10 (1=novice, 10=expert), they rated their proficiency in photography as 6.9 on the average. However, there were no media production professionals included in the participant group. Five participants had their professional backgrounds in information technology, while the others represented a wide variety of different professions, including architecture, biotechnology, business administration, marketing, and social services. Some participants had tried VR headsets (for example, Google Cardboard or Oculus Rift), but none of the participants had experience in using a 360-degree camera before the study. The participants received small rewards for their participation.

3.3 Equipment

At the time of the study, the user base of 360-degree cameras was still very small and many of the camera owners represented early adopters. Therefore, rather than studying the early adopters, we decided to recruit the study participants from more mainstream user demographics and to provide the cameras to them, following an approach similar to several earlier studies on novel consumer camera technologies [14, 16, 17]. Each participant was provided with the following equipment for the duration of the study (see Figure 2):

- 1. 360-degree camera.** In order to gather richer data about 360-degree camera use and to avoid binding the results to a single camera model, we decided to use two different camera models in the study: eight participants used a Ricoh Theta S camera, while the remaining six used a Samsung Gear 360 camera. Both cameras offered the same basic functions and features: they supported the capture of panoramic 360-degree still photos, video clips, and timelapse videos. Both cameras could be triggered with the camera button, or by using the self-timer or remote control. The cameras differed slightly in the implementation details: for example, they represented two different form factors and there were some differences in the picture quality.

- 2. Samsung Galaxy S6 or S7 smartphone.** The smartphone could be used to control the camera with a remote control application provided by the camera manufacturer. Additionally, it could be used to view the captured photos and videos on the phone display. The participants could also use their personal phones with the Ricoh camera, but the Samsung camera required a Galaxy phone to be used.

- 3. Samsung Gear VR headset.** The smartphone could be attached to the headset for immersive viewing of the photos and video clips in a virtual reality environment.

- 4. Benro BK10 mini-tripod.** A small tripod that could also be used as a selfie-stick.

3.4 Method

The study consisted of three phases: (1) briefing session, (2) four-week study period, and (3) final interview. The purpose of the briefing session was to provide the participant with the necessary information and equipment for the study period. We also collected some background information about the participant and their practices of conventional camera use. The participant then started the four-week study period during which they could freely use the provided camera and related equipment. The participant was advised to use the equipment like it were their own—no specific instructions or tasks were given. During the study period, the participant answered to weekly questionnaires about their experiences with the camera during that week.

At the end of the study period, the participant was interviewed about their experiences with the camera and related equipment. During the interview, two or three concrete cases where the participant had used the camera were discussed in detail. More general questions were asked about various topics, including captured content, different pieces of equipment, and differences between 360-degree capture and conventional photo and video capture. The duration of the final interview was approximately one hour. The interviews were video recorded.

For each interview, the researcher who made the interview wrote notes about it based on the video recordings. The interview notes were combined with the data from the weekly questionnaires. The researchers then analyzed the data and built an Affinity Diagram [4] in a series of interpretation sessions. Based on interpretative content analysis, the notes were grouped based on similarity. The groups were then further clustered to broader categories that were identified from the data and jointly revisited, discussed, and refined. In the end, the categories were processed into more general findings that form the core of the Results section.

4 RESULTS

4.1 General

On the first week of the study period, the participants were very excited and curious about the 360-degree cameras. They experimented with the cameras in many kinds of situations and environments and captured large numbers of photos and videos. During the following weeks, the level of use normalized and more regular practices of using the camera started to form. A total of 1,493 360-degree photos and 218 video clips were captured by the participants during the study. On the average, each participant used the camera on

20 different occasions during the study period and captured 107 photos and 16 video clips. There was some variation in the activity of use between the participants. The two most active participants used the camera more than 35 times, while six participants used the camera on 5-14 occasions only. The remaining six participants used the camera 15-25 times each. The level of activity of an individual participant could vary greatly between different weeks of the study, with, for example, the number of social gatherings and other special events or the weather conditions impacting the activity.

4.2 Motivations of 360-Degree Camera Use

The most common motivation for using a 360-degree camera was to capture the overall experience and atmosphere of the situation as a memory. Another common motivation for using a 360-degree camera was entertainment—playing with the camera for fun. As a piece of novel technology, 360-degree cameras fascinated the participants and inspired experimentation. The participants used 360-degree cameras also for many other purposes, such as for documenting places (for example, architecture), for communicating experiences to persons who were not present, and for self-expression, creativity, and art.

Overall, most participants (9/14) said that 360-degree capture was best suited for special, exceptional places and events that one wanted to record and possibly share with others, for example, trips and holidays, social gatherings and parties, ceremonies such as weddings and graduations, and concerts and other performances. The young adults found few everyday life events inspiring enough to be worth capturing in 360-degrees. While the 360-degree cameras were considered to be quite small and lightweight to carry, none of the young adults said they would like to carry a 360-degree camera always with them in everyday life. The parents were more interested in capturing moments of everyday life, and most of the parents (4/7) could consider carrying the camera always with them.

4.3 Capturing Full 360-Degrees

The main difference to a conventional camera, as observed by the participants, was that a 360-degree camera captured the whole surroundings. This had many benefits. A single 360-degree picture recorded a lot of information—it could combine the information of many conventional pictures into one panoramic picture. “[Y2] *The beach of black sand... these [three] pillars that are naturally formed... and also the stone that reaches out to the sea. So it is basically five things in a single picture.*” A 360-degree camera captured a realistic picture of the whole situation as it was, including the environment and the persons and their faces and gestures. “[P6] *Here you can see all the dishes that people are eating, and also each person, just like they were at that moment.*” This made a 360-degree camera also a practical tool for documenting things, for example, for work purposes. “[P3] *At the workplace we thought that a 360-degree camera could be very useful for planning renovation projects and documenting old buildings. It would be convenient as you would need to take only a single picture in every room.*”

An important difference compared to a conventional picture was that the viewer of the 360-degree picture, not the camera user, could then afterwards select the subject and the viewpoint that they wanted to focus on. It was possible to discover new things

and surprising details, for example, secondary events that occurred in parallel with the main event. “[P4] *What I like most is to explore the pictures... to be in this particular moment and see the people’s facial expressions and what was going on... See what was happening behind your back.*”

However, in some cases, a 360-degree camera could capture too much. Most participants (9/14) thought that sometimes a 360-degree picture lacked focus or subject. “[P6] *If I take a picture of my son going to school with a normal camera, he will be in focus. But a 360-degree camera captures also our house and car and everything else.*” In a way, the 360-degree pictures were pictures of everything and of nothing at the same time. Half of the participants (7/14) also thought that a lot of the information captured by a 360-degree camera could be meaningless and uninteresting. “[P2] *Often the view behind your back was quite useless information in the picture.*” Some of the parents (3/7) were worried that 360-degree pictures, for example, pictures taken at home, could reveal too much. “[P1] *In the pictures taken at home, you can see all the mess, and it is difficult to frame it out of the picture.*”

4.4 Capturing the Camera User

As the 360-degree camera captured the whole surroundings, it usually also captured the camera user in the picture. “[Y7] *It felt really weird that every time you take a picture, you are always included in it.*” In a way, every picture captured with a 360-degree camera was a self-portrait. This was often good as it allowed the camera user, who is normally left out of the picture, to be present in the picture. Many participants (5/14) considered selfie and groupie pictures as an important use case for a 360-degree camera. A few participants (3/14) were particularly concerned how they looked like in the pictures and said that they were posing and smiling for the back camera when taking pictures. Especially capturing long video clips could feel awkward as the camera was recording also the camera user who was staring at the camera back lens and did not know how they should behave. “[Y2] *The problem with videos is that you don’t really know what to do. When you shoot videos with DSLR, you can pan and zoom and focus, but with this you just start the video and stand there and do not know what to do.*”

Most participants (8/14) wanted that in some cases, for example, in scenery or nature pictures, it should also be possible to exclude the camera user from the picture. Further, many participants (6/14) were concerned that in pictures captured with a handheld camera, the camera user’s hand was clearly visible and covered a large area at the bottom of the picture (see Figure 1). Solving these problems was possible with the equipment used in the study but required additional effort: the participant had to position the camera on a tripod, possibly hide themselves, and then use either a remote control or a timer to trigger the camera. Another option was to use only a single lens to capture a 180-degree picture. However, that option was rarely used as the participants said that the whole point of the 360-degree camera was to take full 360-degree pictures. For pictures with a limited field of view, they could have equally well used their normal cameras with better results.

4.5 Aiming the Camera at the Main Subject

While the camera captured a 360-degree view, interestingly, most participants (9/14) still aimed the camera at the main subject. Naturally one reason for this behavior was that it was a habit inherited from conventional cameras, but there were also several other reasons. In many cases, even a 360-degree picture had a main subject and the participants wanted it to be at the center of the front lens. The direction of the camera could be used to guide the attention of the picture viewer, as the viewer applications initially showed the front camera image at the center of the view when a new picture was opened. In many applications, the front camera image was also used for previews and thumbnails of the captured picture. Finally, by pointing the camera at the most important subject, it could be ensured that it was not positioned on the stitching seams at the lens borders where the image quality was not as good as at the center of the lens. However, the very symmetric physical shapes of the cameras made it sometimes difficult to differentiate the front and the back lens, resulting in, for example, pictures where the main subject was located behind the viewer.

4.6 Strategies for Capturing 360-Degree Content

The participants developed many strategies for capturing photos and video clips with a 360-degree camera. A common strategy used by half of the participants (7/14) was to try to position the camera so that there would be something interesting to watch in several directions. “[P3] You take advantage of the 360-degrees—you are shooting in every direction.” It was felt that otherwise the picture did not fully use the capabilities of the camera and the resulting pictures were not interesting to watch. Many participants (5/14) captured pictures of groups of people in ring-like formations, for example, sitting around a table. “[P6] At the café, I selected a round table on purpose and put the camera in the middle of the table.” One participant had developed a microphone-boom-like camera setup where the camera was upside down on a selfie-stick and could be easily dropped at the center of a group of people for a quick 360-degree picture. The picture was then automatically turned to correct orientation based on the camera orientation sensor data. A few creative users (3/14) specifically tried to find camera positions that provided unusual viewpoints, for example, very small or very large scales, or places where a man could not easily go. “[P2] On a cliff, I used the selfie-stick to put the camera over the edge and took a picture. When you see the treetops and a 20-meter drop below you, that really stuns people!”

Another common strategy (6/14) to capture 360-degree pictures was to position the camera so that it provided a realistic view as experienced by the camera user. Such pictures were often intended to be viewed with a VR headset to re-experience the situation as it was at the moment of capture. In these pictures, especially the height of the camera was considered to be important—ideally, the camera should have been at the eye level. “[Y6] That is the natural perspective, the experience you want to share. If the camera is above you head, it does not feel authentic.” If the camera was positioned too high, the pictures gave the impression of a giant looking down from the heights. If the camera was on the table or at the chest level, it was too low, giving a child-like perspective. In particular,

the faces appeared unnatural if they were not at the same level as the camera.

A novel and innovative strategy used by some participants (5/14) was to place the camera on a stand in advance and then use the remote control to take pictures whenever something interesting happened. “[P4] [At the birthday party] I placed the camera at the kids’ table near the sunflower. It was almost invisible. . . . I took pictures when the kids started to play or talk around the table.” This strategy was most commonly used when capturing events, for example, celebrations and parties, but one participant also used the setup to capture moments of everyday life at home. Often the camera was positioned in a discreet way, allowing more natural pictures of people to be captured. The 360-degree camera enabled the camera user to be in the captured pictures and to focus on participating in the event instead of using the camera. “[P4] I don’t have to be with the camera. I can be with the important persons I want to be. . . . I can be in the pictures even if I take them. It gives new possibilities for the photographer.”

A practical limitation of capturing pictures with a 360-degree camera was that the camera captured well only subjects that were within a distance of a few meters. Any subjects further away rapidly became very small and difficult to see. “[Y1] If you are on a mountain, the scenery around you is very beautiful. But if you take a picture of it with [a 360-degree camera], the only thing you can see is the stone that you are standing on in a gigantic size.” Half of the participants (7/14) experienced problems in situations where they could not move close to the subject to capture a picture, for example, in weddings and other large celebrations, in concerts and sporting events, or when capturing outdoor action, wild animals, or nature. A probable explanation for the phenomenon is that unlike conventional cameras, the 360-degree cameras used in the study had no zoom capability, and that the resolution of the cameras and VR headsets was too low. On the other hand, the limitation could also be exploited to frame unwanted subjects “out of the picture” by moving the camera a few meters further away.

4.7 Limitations of Expressive Capabilities

Almost all participants (12/14) considered that a 360-degree camera lacked capabilities for artistic expression compared to conventional cameras. “[P3] With a normal camera, you have to think how to frame the picture and to make sure that the composition makes sense. It is more complicated, but it captures the moment in an entirely different way. A good photograph has many dimensions that you cannot reach with a 360-degree camera.” The 360-degree camera user could not frame or compose the picture as with conventional cameras, and it was not possible to focus on a specific subject or to capture details. It was only possible to select the place and time when to capture a picture. “[Y4] The main creative point of this camera is to find a good location. Where you put it.” One of the few tools to control the importance of the different subjects in the scene was the distance to the camera. “[P3] Some things are always closer than others. In that way you can of course highlight certain things.”

The participants also felt that a 360-degree camera lacked versatility compared to conventional cameras. All the pictures captured with a 360-degree camera looked too similar. “[Y6] In photography, you need to vary the style, the focal length, and other parameters,

in order to keep the pictures interesting.” One participant compared capturing pictures with a 360-degree camera to capturing pictures with a DSLR using a fisheye lens—a few photos captured with a fisheye lens make a photo set interesting but using it for every photo is too much. On the other hand, the participants also felt that 360-degree cameras could offer new expressive opportunities—they just had to be discovered first.

4.8 Capturing 360-Degree Content in Social Situations

The 360-degree cameras used in the study were small, they did not look like conventional cameras, and they did not have to be directly pointed at the subject of capture. The participants (9/14) reported that in many situations the other people present in the capture situation did not notice that they were being captured with a camera. This allowed the participants to take more natural photos and videos of people. “[Y1] *The best thing was that people did not understand that it was a camera. Especially on the back side you could catch so natural expressions as [people] did not understand that [the camera] recorded in that direction also.*” But the 360-degree camera also made several participants (5/14) concerned that they could unintentionally capture pictures of unknown persons while these persons did not even realize that they were captured. Especially the parents (4/7) were worried that they could capture pictures of unknown children, for example, in a park or on the beach. “[P5] *It is just not appropriate to take pictures of other people’s kids.*” Because of this, many participants felt it somewhat uncomfortable to use a 360-degree camera in a place with unknown persons. They would have wanted to be able to somehow frame the unknown persons out of the picture, as they were used to do with conventional cameras.

On the other hand, many participants (8/14) reported that in some situations using a 360-degree camera attracted other people’s attention. “[Y5] *There were some people that were surprised and did not know what the camera was. They were looking with a curious face—what is that? I guess I looked like an alien with the camera.*” The 360-degree cameras attracted attention because they were not yet widely known and had unusual appearance. Also using a tripod with a 360-degree camera made it easier to notice. Some participants (5/14) said that they occasionally hesitated using a 360-camera in public, especially in formal situations, because it did not look like a real camera and they did not want to appear strange, nerdy, or disrespectful using it. “[P5] *I would not use it in a funeral. ... It would not be a respectful enough way to record.*” Still, most people were positively interested in the 360-degree camera as it represented exciting new technology. This offered opportunities for social interaction with friends, or for forming new social contacts with passers-by. Most participants (8/14) showed the camera to their friends or family and had fun together taking pictures with it. In some cases, the camera even provided a reason to meet distant friends. Having a novel device that the others did not have was also a way to impress others. However, the novelty effect of the 360-degree camera faded away quickly.

In a situation with a large number of people present, the other people could block the view of the 360-degree camera in many directions. This made capturing 360-degree photos and videos challenging as the participants had to keep track of the other people

and try to find a position with an open view, or even ask the other people to move. When taking pictures with a conventional camera, the other people could see where the camera user was aiming at and spontaneously move away from the camera field of view.

4.9 Image Quality

While the participants identified many imperfections in the photo and video quality, most participants were still quite satisfied with the captured content, taking into account the small physical size of the camera. Especially the quality of the photographs viewed on a smartphone display was considered good. The most commonly complained problems included the low resolution and lack of zoom (10/14) (especially when viewing videos on a VR headset), problems with dynamics and exposure (7/14), geometry distortions (5/14) (especially faces), stitching issues (5/14), and focusing problems (4/14). The participants adopted different strategies to improve the image quality, for example, aiming the camera so that no important subjects were on the lens borders to avoid stitching problems, or adjusting the camera settings manually to solve exposure problems.

4.10 Photos vs. Video

Despite the 360-degree cameras being strongly marketed for video capture, the participants took approximately nine times more photographs than video clips. There were many reasons for favoring photos over video. Most participants (8/14) thought that video provided no additional value if there weren’t any interesting events taking place. Half of the participants (7/14) said that they had a personal preference of taking pictures over video. Many participants (6/14) also considered photos to be easier to capture, manage, present, and share than video clips. A few participants (3/14) were fascinated by how a photo recorded a frozen moment in time.

Video was preferred for richer capture of longer stories, as it recorded also movement and audio (7/14), provided more realistic and immersive capture (6/14), and enabled recording of complete events (5/14). However, capturing good quality videos proved challenging to many participants. Typically, the participants’ first experiments in 360-degree video capture resulted in videos with strong camera movements, resembling videos captured with conventional handheld cameras. Such video clips where the camera was not stable were practically impossible to watch with a VR headset as they rapidly caused cybersickness in the viewers. “[P1] *It was difficult to watch video clips with the glasses, because a video clip that was shot in motion was shaking too much and it hurt my eyes.*” The participants quickly learned that they had to avoid camera movements and stabilize the camera, for example, by using a tripod. When viewing video clips on the smartphone display, camera movement was not such a large problem. Most participants (9/14) considered that the audio track was an important element of the overall experience and thought that the camera provided good audio quality. A few participants (3/14) were excited about the possibility to capture 360-degree timelapse videos that compressed a long time period into a short video clip. Common subjects for timelapses included hastened videos of long activities such as painting a wall or playing a game of baseball, or summaries of daily life at home or on the street. A practical problem in capturing long timelapse videos was the limited battery life of the cameras.

4.11 Managing and Editing 360-Degree Content

Managing 360-degree photo and video content was more complicated and required more manual work than managing conventional photos and videos. The primary reason was that the standard photo and video management solutions that the participants were used to did not properly support 360-degree content, and the participants had to manually copy, convert, and organize the media files. While there were some 360-degree specific content management solutions available, the participants considered those as too primitive and preferred the standard tools. The captured 360-degree content was most commonly archived on a computer or an external hard disk. Typically, 360-degree content was considered special and stored separately from conventional photos and videos, even if they were captured in the same situation. A few participants (4/14) expressed their interest in printing 360-degree pictures, for example, framing panorama pictures and hanging them on the wall.

Only a few of the 360-degree photos and videos captured during the study were edited. Many participants simply did not feel a need to edit the content they had captured: they were either satisfied with the content as it was, or did not believe the content could be significantly improved by editing it. Another reason for not editing the captured 360-degree content was the lack of suitable tools. The most commonly requested editing operations were cropping, adjusting colors (for example, with filters), and straightening the horizon. Also, cutting video and special effects (for example, the “Little Planet” effect) were requested. One participant would have wanted to use a 360-degree photo as a background of a 3D graphics model. The few participants who edited their 360-degree photos and videos used both standard tools (for example, Photoshop) as well as 360-degree specific tools (such as the Ricoh Theta+ smartphone application). They felt that editing greatly expanded the utility and the applications of the camera and the captured content.

4.12 Viewing 360-Degree Content

While we provided all participants with VR headsets, the participants most commonly used conventional devices with flat displays, such as smartphones and computers, to view the 360-degree content they had captured. On the weeks 2-4 of the study, 360-degree content was watched on conventional displays in 69% of the cases, while only in 31% of the cases a VR headset was used. Viewing 360-degree content on a smartphone display was the most common approach, as it provided the quickest, simplest, and easiest way to see the content. Watching the captured 360-degree content on a computer display required more effort, but it allowed the participants to see more details and enabled easy management and organization of the content. Typically, standard image viewers and video players were used. They provided no proper support for 360-degree content and presented it incorrectly as geometrically distorted.

The initial reaction to head-mounted VR headsets was very positive, and the VR headsets were considered exciting and fun. However, as with the 360-degree cameras, the initial excitement typically disappeared quickly. Still, most participants (10/14) commented that a VR headset provided a superior experience for viewing 360-degree content. “[Y3] In my opinion, you really need to have [a VR headset] to enjoy [360-degree] photos and videos.” A VR headset was

considered as “the true way” to view 360-degree content (7/14). It offered a large image size and allowed the participant to naturally select the viewpoint and to control what was shown (6/14). A VR headset also supported strong immersion and feeling of presence (5/14). However, the VR headsets had many practical problems and shortcomings which hampered their use in everyday situations. The most commonly reported problem (9/14) was that viewing user-captured content on a VR headset was too complicated and required too much effort. “[P3] Using VR glasses is easy as such, but it is still so troublesome that if you consider their entertainment value you usually don’t bother.” Another common problem (9/14) was that using a VR headset made the viewer feel sick. “[P4] [The VR headset] is a good concept—you can really feel the situation. But I couldn’t use them, two minutes, no more.” As already discussed, the cybersickness was particularly a problem for the video content captured by the participants. Many participants (5/14) also considered that the image quality should have been better. Some participants (4/14) complained that the VR headset blocked the awareness of the environment and prevented multi-tasking, while others (3/14) were concerned that wearing a VR headset was isolating and embarrassing in social situations. In families, small children would have been the most enthusiastic users of VR headsets but ironically, the safety instructions of the device vendors prohibited children from using them.

4.13 Sharing 360-Degree Content

For sharing 360-degree content with other people co-located in the same physical space, the most common approach was simply to show the content on a smartphone display. As for personal viewing, it was the fastest and easiest method, for example, in capture situations when the other people wanted to see the photo or the video clip immediately after capture. Another approach was to show the content on a television or other large display. This allowed a larger group of people to watch the content together. However, there was still a limitation that only one person at a time could control the viewing device, for example, to pan the image and select the viewing orientation.

Most participants also used VR headsets to show 360-degree content to others. Showcasing a VR headset provided an entertaining activity in social situations, for example, in parties. “[P2] I showed photos and videos to my relatives on VR glasses. The response was very positive. Everybody was interested.” As a piece of novel technology, VR glasses were considered as interesting and amusing. VR headsets did not support social viewing well, as only one person at a time could view the content, and the person who was wearing the VR headset was isolated from the other persons in their real environment.

Overall, only a very small fraction of the captured 360-degree content was shared online. The most common sharing channel used by most participants (10/14) was Facebook which supported both 360-degree photos and video clips. The participants also tried many other channels, such as Instagram, WhatsApp, and cloud storage services, but at the time of the study, none of these services provided support for 360-degree content. The participants constantly had to worry if the recipients could successfully view the shared content, that is, whether they had proper applications and devices

for viewing 360-degree content, or did they even understand in the first place that the content was 360-degree content and not just an ordinary photo or video clip. The first shared 360-degree photos and videos generally received positive feedback (13/14). “[P1] *The first reactions were fun, as everybody was so excited. Nobody had seen such photos before.*” Publishing 360-degree content provided a way to amaze others and to attract attention due to the novelty of the technology. In two cases, sharing 360-degree content online resulted in a face-to-face meeting to view the content together with a VR headset.

5 DISCUSSION

5.1 Practices of 360-Degree Camera Use

Based on the study results, we can identify four different practices of consumer 360-degree camera use: (1) Panorama Capture, (2) Experience Capture, (3) Automatic Capture, and (4) Document Capture. We will next discuss each of these practices in detail.

Panorama Capture. In the practice of Panorama Capture, the 360-degree camera is applied to conventional domestic and hobbyist photography in a straightforward manner. The 360-degree camera is simply seen as a special camera that makes it easier to capture panorama pictures, replacing panoramic photo apps, fisheye lenses, and special camera heads used with conventional cameras. It is considered as a useful addition to the photographer’s toolbox, as it enables more versatile pictures to be captured. Capturing of pictures is often motivated by self-expression, creativity, and artistic goals. The situation and camera position are carefully selected, often aiming to provide novel viewpoints, in order to capture beautiful and interesting pictures. The pictures are typically intended to be viewed with conventional devices and shared through traditional social media and messaging channels. The pictures are often edited after capture.

Experience Capture. The practice of Experience Capture resembles the visions and marketing materials of the 360-degree camera manufacturers. The 360-degree camera is used as a tool to capture pictures of important moments, places, and experiences that the camera user wants to remember or to share with others. The camera captures the situation in full 360 degrees, recording a lot of information and details, which helps in recalling a rich memory of the moment and related stories. The pictures also often reveal new aspects, such as missed details and parallel stories. The camera is positioned so that it records an authentic first-person perspective—in particular, the height of the camera is considered as important. The pictures are often intended to be viewed with a VR headset for an immersive experience.

Automatic Capture. As a 360-degree camera captures in all directions, there is no need to aim the camera like a conventional camera. In the practice of Automatic Capture, this capability is exploited to automate the recording of important events. The camera is set up in advance in a position that provides a good view of the event but makes the camera preferably unnoticeable in order to avoid disturbing the subjects and to capture more natural pictures. During the event, the camera user can then simply trigger the camera with the remote control to capture a picture when something interesting happens. Alternatively, continuous video or timelapse

recording can be used for the duration of the entire event. This approach enables the camera user, who traditionally has been forced to focus on using the camera and who therefore has “missed” the event, to participate in the event and also to be recorded in the pictures about the event. In a way, the 360-degree camera acts as an “automatic cameraman” that captures third-person pictures of the event. The camera user can then later select the best pictures, and optionally crop them to create conventional photos or video clips. Automatic Capture is a novel practice that was observed only in a few situations during the study.

Document Capture. In addition to affective purposes, the 360-degree camera can also be used as a practical tool to support pragmatic tasks. It enables efficient documentation of spaces, for example, for architectural, interior, or scenic design purposes. Compared to a conventional camera, which requires several overlapping pictures to be captured, using a 360-degree camera is much faster and easier. The camera user does not have to worry that something is missed as the camera automatically captures everything.

5.2 360-Degree Camera vs. Conventional Cameras

The study participants considered the 360-degree camera as a new kind of a device that was different from the conventional cameras. Of the existing camera categories, the 360-degree camera was closest to a pocket camera—it was a simple, small, and inexpensive camera that you could take with you in situations where you wanted to take special pictures. Compared to a cameraphone, the most important differences were that a cameraphone was always available, enabled better image quality, and allowed instant sharing. DSLRs, on the other hand, provided superior image quality, versatility, and long-distance capture compared to 360-degree cameras.

Considering the traditional practices of domestic photography, the 360-degree camera is a powerful tool for recording and sharing memories as it captures the full surroundings and also the camera user in a single picture. The 360-degree camera is well suited for capturing many of the traditional subjects in consumer photography, including indoor and outdoor scenes such as home interiors, tourist attractions, and urban and nature landscapes, as well as family gatherings and other events with large groups of people. As an interesting new technology, the 360-degree camera matches well the nature of domestic photography as a leisure time activity and gives a positive and modern image of its user. However, the 360-degree camera makes it more difficult to control what is captured and to construct pictures that give a desired image of one’s life, which has been traditionally important in domestic photography. The 360-degree camera is also not so well suited for capturing individual subjects such as persons, objects, or details, as the pictures may lack focus and capturing the 360-degree surroundings may add little value. Finally, the current VR headsets support poorly the traditional practice of social viewing with reminiscing and telling stories about the pictures, as typically only one person at a time can view the pictures and the viewer is separated from the other people around them. This problem could be addressed by novel viewer applications supporting collaborative exploration of 360-degree pictures in a virtual reality environment.

In their current form, the 360-degree cameras complement the existing cameras rather than take their place. The 360-degree cameras provide new kinds of possibilities and can be used for different purposes than the conventional cameras, but in many applications the current 360-degree cameras cannot fully replace the conventional cameras. The development of omni-directional, virtual reality, and volumetric capture technology continues at a rapid pace, however, and in the longer term, these novel technologies may disrupt the currently dominant digital camera technologies. In the Kodak era, the Polaroid film cameras were predecessors of today's digital cameras as they eliminated the need for an external development service and allowed the users to instantly see the captured photos [20, p. 11]. Similarly, the current 360-degree cameras may allow us to take an early peek to the future of virtual reality consumer camera technology and the novel photography practices that it may enable.

5.3 Future Work

We believe that many of our findings represent fundamental aspects of 360-degree capture and will continue to be valid beyond the current first generation of 360-degree cameras. We were also able to identify some new emerging practices of camera use, such as Experience Capture and Automatic Capture, that already take advantage of the unique capabilities of the 360-degree cameras. As such, our study provides a good foundation for further more focused user research on specific sub-topics, user groups, applications, and contexts of 360-degree camera use. It also informs the development of novel application, service, and device prototypes involving user-captured 360-degree content. Still, it is clear that many of the observed practices reflect the earlier practices that the participants were used to with conventional cameras and were also influenced by the novelty and immaturity of the current technology. Over time, as the technology becomes more mature, as the users gain more experience and their skills in using the 360-degree cameras improve, and as the amount of user-captured 360-degree content increases and the content covers a longer period of time, entirely new practices of capturing and using 360-degree content may emerge. Identifying and understanding such new practices provides an exciting direction for future research.

6 CONCLUSION

We have presented a field study on consumer 360-degree camera use. In this study, 14 people used 360-degree cameras freely in their everyday lives for a period of four weeks. The study results indicate that 360-degree cameras represent a new approach to domestic photography and that they complement rather than replace the conventional cameras by enabling new capture possibilities. The primary difference between a 360-degree camera and a conventional camera was that a 360-degree camera captured the whole surroundings in a single picture. This was often good as the pictures recorded a lot of information and also included the camera user, but sometimes the camera could capture too much, resulting in uninteresting pictures without focus. Overall, the 360-degree camera transferred control from the camera user to the viewer: capturing became more passive and viewing more active. Compared to a conventional camera, a

360-degree camera was seen as less versatile and lacking capabilities for artistic expression. 360-degree content was most commonly viewed and showed to others on legacy 2D displays, especially on smartphones. VR headsets provided superior viewing experience but their use was hampered by the numerous practical problems of the current headsets. Based on the study results, we identified four different practices of consumer 360-degree camera use: Panorama Capture, Experience Capture, Automatic Capture, and Document Capture. These practices, however, represent people's early practices of 360-degree camera use, and over time, more novel practices that take fuller advantage of the capabilities of 360-degree cameras may emerge. Identifying and understanding these new practices provides an interesting direction for future research.

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