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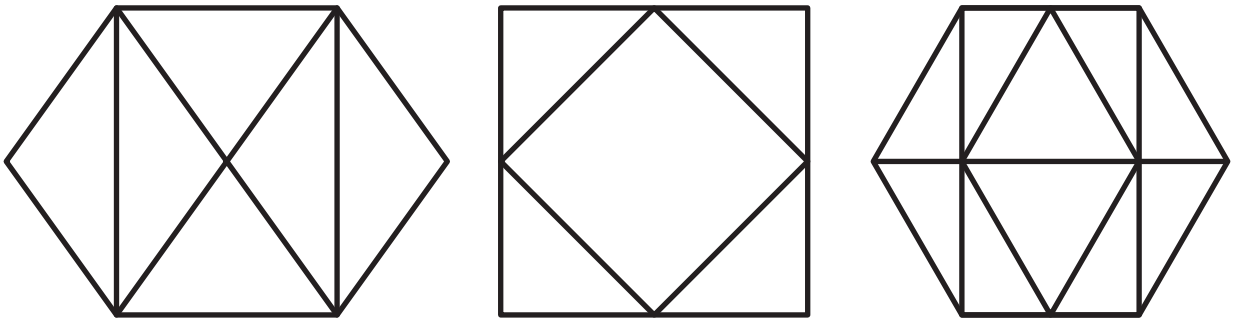

360° video for design, by design

Wo Meijer

360° Video for Design, by Design

360° Video for Design, by Design

Dissertation

for the purpose of obtaining the degree of doctor
at Delft University of Technology
by the authority of the Rector Magnificus, Prof. dr. ir. H. Bijl,
chair of the Board for Doctorates
to be defended publicly on
Wednesday, 22 April 2026 at 15:00

by

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This dissertation is as much an example of my work
as it is a testament to the efforts and support
of my friends and coworkers.

Wo Meijer

We each need to find our own inspiration, Kiki.
Sometimes it's not easy.

Ursula – Kiki's Delivery Service [1]

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Summary

The products and services we use daily – bicycles, laptops, grocery delivery apps – are shaped by teams of designers. These designers need to make decisions about *what* to design and *how* the final product or service should behave. Since these decisions are complex, multi-layered, and holistic, designers seek to understand the context and (potential) users of their design work. The better the understanding designers develop, the better they can make decisions that impact the final design outcome – in short, better understanding of context and users, better products.

This work explores how a novel material – 360° video – gives designers a better understanding of context and people. The ability of 360° video to capture the complete visual context around the camera and give the viewer the affordances of navigating the time and viewpoint of the video enables richer insights. This work demonstrates that designers can develop novel, multi-perspective insights and use the greater immersion of 360° video to develop a richer, more empathic understanding of context and people. However, this work highlights how the complex nature of 360° video complicates the work of designers – complicating the actions of sharing insights and iteratively engaging with source material that are crucial to design work. In order to understand and support the use of 360° video, this work aims to develop the necessary motivation, knowledge, and tools for designers to engage in the novel practice of 360° Video Design Ethnography – using 360° video to better understand people and their context.

To understand the impact of 360° video on the Design Ethnography process, I started with an empirical study (Chapter 2) in which 12 participants used 360° video in collaborative VDE workshops. This demonstrated the key opportunities of 360° VDE – more immersive, empathic, and novel insights through multi-perspective viewing – providing a solid motivation for its adoption by designers. However, the study also showed key challenges that represent barriers for designer – two key challenges: incompatibility with tangible representations which makes sharing insights difficult, and a complex process of re-engaging with 360° video which discourages iterative analysis. Crucially, these challenges align with two key differences between ethnography and design ethnography – the focus on collaborative analysis and the importance of iterations.

Based on this initial understanding and the two key challenges, I engaged in the parallel development and evaluation of two tools – one aimed at each challenge. In this process the tools both embodied design knowledge in their creation and functioned as probes to better understand the possibilities of 360° Video Design Ethnography. The tools are:

> **Tangi** (Chapter 3) – a tool that enables designers to generate tangible artifacts from 360° video frames, thereby enabling them to more easily share their insights during collaborative workshops. The development of the tool is grounded in the impor-

tance of tangibility for collaborative workshops as well as the unique challenges with sharing insights from 360° video presented in Chapter 2. These tangible artifacts support key interactions for collaborative discussions such as pointing, rotating, arranging and acting as a surface for annotations as well as two capabilities specific to 360° video: maintaining spatial orientation within 360° environments and linking specific details to the broader 360° context. Additionally, participants reflected that providing tangible representations of 360° video opens up complex embodied interactions with a previously intangible media, allowing them to modify and create new artifacts with familiar tools and interactions.

D360 (Chapter 4) – a digital tool that embodies three crucial techniques to support iterative engagement with 360° video: 1. providing a lightweight, multi-device viewing interface, 2. creating annotation objects that link to their source 360° video, and 3. integrating into the existing workflow of designers. These techniques provide the basis for further development of 360° video tools for designers.

Using the results from the initial study and both tools, I synthesized the "Framework for Designerly 360° Video Use" (Chapter 5), which provides a way to describe, discuss, and support how designers engage with 360° video. The framework maps actions in Design Ethnography to providing (or removing) the affordances of navigating the time or viewpoint of the 360° video, which allows it to contextualize the two tools I created as well as point out design spaces that are yet to be explored.

Overall the aim of this work is to enable the practice of 360° Video Design Ethnography by providing evidence for the benefits and challenges of 360° Video Design Ethnography, tools to support its adoption, and an overall framework.

Samenvatting

De producten en diensten die we dagelijks gebruiken — fietsen, laptops, bezorgapps voor boodschappen — worden vormgegeven door teams van ontwerpers. Deze ontwerpers moeten beslissingen nemen over wat er ontworpen moet worden en hoe het uiteindelijke product of dienst zich moet gedragen. Omdat deze beslissingen complex, gelaagd en holistisch zijn, proberen ontwerpers inzicht te krijgen in de context en (potentiële) gebruikers van hun ontwerpwerk. Hoe beter het inzicht dat ontwerpers ontwikkelen, hoe beter ze beslissingen kunnen nemen die van invloed zijn op het uiteindelijke ontwerpresultaat — kortom, beter begrip van context en gebruikers leidt tot betere producten.

Dit werk onderzoekt hoe een nieuw materiaal — 360° video — ontwerpers een beter begrip geeft van context en mensen. De mogelijkheid van 360° video om de volledige visuele context rondom de camera vast te leggen, en de kijker de ruimte te geven om door de tijd en het perspectief van de video te navigeren, maakt rijkere inzichten mogelijk. Dit werk laat zien dat ontwerpers nieuwe, multiperspectivische inzichten kunnen ontwikkelen die verschillende elementen binnen één frame van 360° video verbinden, en de grotere immersie van 360° video kunnen gebruiken om een rijker en empathischer begrip van context en mensen te ontwikkelen. Tegelijkertijd laat dit werk zien hoe de complexe aard van 360° video het werk van ontwerpers bemoeilijkt — het delen van inzichten en iteratief werken wordt aanzienlijk ingewikkelder bij het gebruik van 360° video. Om het gebruik van 360° video te begrijpen en te ondersteunen, beoogt dit werk de noodzakelijke motivatie, kennis en tools te ontwikkelen waarmee ontwerpers zich kunnen begeven in de nieuwe praktijk van 360° Video Design Ethnography — het begrijpen van mensen en hun context met behulp van 360° video.

Om de impact van 360° video op het Design Ethnography-proces te begrijpen, begon ik met een empirische studie (Hoofdstuk 2) waarin 12 deelnemers 360° video gebruikten in gezamenlijke VDE-workshops. Deze studie liet de belangrijkste kansen van 360° VDE zien — meer immersieve, empathische en vernieuwende inzichten via multiperspectivisch kijken — wat een sterke motivatie biedt voor adoptie door ontwerpers. Tegelijkertijd liet de studie ook twee kernuitdagingen zien die obstakels vormen voor ontwerpers: de onverenigbaarheid met tastbare representaties, wat het delen van inzichten bemoeilijkt, en het complexe proces van hernieuwd werken met 360° video, wat iteratieve analyse ontmoedigt. Cruciaal is dat deze uitdagingen aansluiten bij twee belangrijke verschillen tussen etnografie en design ethnography — de nadruk op gezamenlijke analyse en het belang van iteratie.

Gebaseerd op dit initiële inzicht en de twee hoofduitdagingen, ben ik parallel overgegaan tot de ontwikkeling en evaluatie van twee tools — elk gericht op één van de uitdagingen. Tijdens dit proces belichaamden de tools ontwerpkennis in hun creatie en functioneerden ze als probes om de mogelijkheden van 360° Video Design Ethnography beter te begrijpen. De tools zijn:

Tangi (Hoofdstuk 3) — een tool die ontwerpers in staat stelt om tastbare artefacten te genereren vanuit frames van 360° video, waarmee ze hun inzichten gemakkelijker kunnen delen tijdens gezamenlijke workshops. De ontwikkeling van de tool is gebaseerd op het belang van tastbaarheid voor samenwerking, en op de unieke uitdagingen van het delen van inzichten uit 360° video zoals gepresenteerd in Hoofdstuk 2. Deze tastbare artefacten ondersteunen belangrijke interacties voor gezamenlijke discussies zoals wijzen, roteren, rangschikken en dienen als oppervlak voor annotaties, evenals twee mogelijkheden specifiek voor 360° video: het behouden van ruimtelijke oriëntatie binnen 360° omgevingen en het koppelen van specifieke details aan de bredere 360° context. Daarnaast gaven deelnemers aan dat het aanbieden van tastbare representaties van 360° video complexe, lichamelijke interacties mogelijk maakt met een voorheen ontastbaar medium, waardoor ze nieuwe artefacten kunnen creëren en aanpassen met vertrouwde tools en handelingen.

D360 (Hoofdstuk 4) — een digitale tool die drie cruciale technieken belichaamt om iteratief werken met 360° video te ondersteunen: 1. het bieden van een lichte, multi-device kijkinterface, 2. het creëren van annotatie-objecten die gelinkt zijn aan hun oorspronkelijke 360° video, en 3. integratie in de bestaande workflow van ontwerpers. Deze technieken vormen de basis voor verdere ontwikkeling van 360° video-tools voor ontwerpers.

Op basis van de resultaten van de initiële studie en beide tools, heb ik het “Framework for Designerly 360° Video Use” (Hoofdstuk 5) gesynthetiseerd, dat een manier biedt om te beschrijven, bespreken en ondersteunen hoe ontwerpers werken met 360° video. Het framework koppelt handelingen in Design Ethnography aan het bieden (of wegnemen) van de affordances van navigatie door tijd of perspectief van 360° video, wat het mogelijk maakt om zowel de twee tools te contextualiseren als ontwerpruimtes aan te wijzen die nog onderzocht moeten worden.

Het uiteindelijke doel van dit werk is om de praktijk van 360° Video Design Ethnography mogelijk te maken door bewijs te leveren voor de voordelen en uitdagingen, tools te bieden voor adoptie, en een overkoepelend framework te formuleren.

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Fortunately my family (Mom, Dad, Fred) are all amazing people who I have been able to get support, love, and energy from. My less literal family is also crucial; Lilian, you are an amazing partner and you have supported me so much in this process[1]. My less biological family; Max, Jaime, and Fred (the friend, not the sister) for being the best friends that a guy could ask for, and supporting me in person and at a distance. Daniela and Radu for being my Family™ and being lovely and dependable friends. Jonas for the mental support, beers, and jokes about bad movies.

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If you were not listed on here, it does not mean that I do not appreciate what you did, it just means that ADHD gives me very strong "out of mind, out of sight", so I will apologize and buy you a drink to make up for it. ;)

[1] I want that documented, even if we do part – sorry Garoa ;).

1

Introduction

If you wish to make an apple pie from scratch
you must first invent the universe.

Carl Sagan

1

Overview

This dissertation addresses a significant gap in design research: understanding how 360° video can enhance the process of Video Design Ethnography (VDE). While conventional video has long been used by designers to capture user contexts and provide temporally rich insights [2, 3], 360° video offers unique affordances – since it captures the complete visual context around the camera, it provides the viewer with the affordance of controlling not only the the time of the video, but also the perspective [4]. Recent studies explore how 360° video enhances conventional ethnography by capturing the complete visual context of an area of study, allowing viewers to take the perspective of different actors within complex interactions [5–9]. However, it is unclear if these advantages directly transfer to Design Ethnography – a distinctly less structured, more iterative, and more collaborative practice than conventional ethnography [3, 10, 11] – and what novel challenges designers would face a clear gap in knowledge.

To address this gap, I conducted an empirical study that provided designers with 360° video in a conventional Design Ethnography workshop format (Chapter 2). This study demonstrated benefits of 360° video that motivate its adoption by designers – greater understanding of context, more "feeling with" empathy, and novel insights through multi-perspective analysis. Additionally, the study elicited two key challenges that underscore why designers might not be willing or able to adopt 360° video: 1. 360° video is incompatible with tangible representations of insights that are used during collaborative analysis, and 2. the complexity of viewing, annotating, and searching 360° video complicates the iterative re-engagement with material found in Design Ethnography.

The findings from this study serve to motivate the development of tools that support designers in using 360° video in Design Ethnography – the advantages underscore why 360° video is an interesting material, the key challenges focus the development of such tools. Therefore I engaged in generative research by developing two tools in parallel - each aimed at one of the key challenges identified in Chapter 2. The first, Tangi (Chapter 3), address the challenge of collaborative analysis with 360° video insights from 360° video by providing tangible representations of 360° frames. The second, D360 (Chapter 4), is a digital tool that focuses on enabling rapid, iterative engagement with 360° videos by providing an annotation interface that . I evaluated both tools through workshops with experienced designers, there the tools acted as probes to enable use, reflection, and exploration of how they impact the designers' work with 360° video. This confirmed the utility of both tools as well as eliciting reflection on novel features, techniques, and processes for future tools to support 360° VDE.

Finally, in the conclusion of this work (Chapter 5) I discuss how the knowledge I developed in this work connects with, and expands on, related literature on Design Ethnography and conventional ethnography that uses 360° video. I also use the work as a whole to extract overall design guidelines for 360° VDE tools and synthesize a "Framework for Designerly 360° Video" that frames the process of 360° VDE in terms of the materiality that designers engage with, how my tools support actions in this framework, and finally how future research and development can leverage it.

In brief, this work identifies 360° Video Design Ethnography as a novel practice, demonstrates that it enables designers to develop richer, more immersive, multi-perspective insights, highlights the key challenges (difficulty sharing and difficulty re-engaging) that present a threshold to its adoption, and provides knowledge in the form of tools that can enable the practice – 360° video for design, by design.

1.1. Background and Motivation

In this section, I outline the research area this dissertation contributes to: Design Ethnography, with a particular focus on Video Design Ethnography. I begin by describing the core principles and methods of Design Ethnography and then introduce 360° video as a technological development that offers new potential for this practice. Finally, I highlight the gap between the promising capabilities of 360° video and its limited adoption by designers as the lack of literature suggests.

1.1.1. Design Ethnography

The products and services we use daily – bicycles, laptops, grocery delivery apps – are shaped by teams of designers. A key aspect of their work is ensuring these designs fit the context of use – first by understanding the real-world context, activities, and needs of who they are going to design for, then using this understanding to generate design ideas, and finally evaluating those design ideas by reflecting on how they would or would not fit into the context [12]. In other words, designers work with "...the assumption [...] that documenting people's practices and products used in their natural habitat could be helpful for design" [10, p.34]. Designers then use this knowledge of the people they design for to both inspiration for solutions [3] *and* as the basis to reflect about the problem they are trying to address [13]. The wide collection of activities designers engage with to form this of understanding the context and the people within it is coined by Salvador, Bell, and Anderson [14] as Design Ethnography.

While this uses the term "ethnography", it is crucial to separate the formal practice of ethnography in social sciences with the practice of *design* ethnography. More *conventional* ethnographic practices aim to produce a "thick-description" – providing a complete analysis of the activity, context, and people being studied – and stops at this description. On the other hand, Design Ethnography is problem-focused, time-bounded, and oriented toward practical outcomes [3, 10, 11] – in other words it is not focused on a complete or thick description, but rather zooming in on what the designers are interested. This also means that the process is different, Crabtree, Rouncefield, and Tolmie [3] discusses how Design Ethnography is unique in that it is: 1. highly collaborative, 2. highly iterative, and 3. does not fixate on methods. These unique points make it challenging to discuss Design Ethnography as a singular method or even set of methods, since the process depends on the methods designers use, how many iterations they feel is necessary, and can even vary between designers in the same team. Therefore it is important to establish a generalizable model of the *phases* of Design Ethnography. For example, both Müller [11] and Crabtree, Rouncefield, and Tolmie [3] frame Design Ethnography with three main activities

– fieldwork (i.e., gathering material), analysis (i.e., consuming and analyzing the material), and output (framed as "reporting" [11] or "informing design" [3]). Nova [10] expands on this by discussing six stages: 1. brief, 2. preparation, 3. research design, 4. field research, 5. analysis, and 6. design intervention – essentially unpacking "fieldwork" into the specific steps of brief, preparation, design, and then entering the field.

While all the steps are important, in this work I focus on the analysis and output phases because these are the steps that are impacted most by 360° video (described in detail in Section 1.1.4). This is due to the fact that recording 360° video (i.e. the fieldwork phase) is very similar to the use of conventional cameras [4]. Once a design team has gathered material through fieldwork, they then "engage" with it – read, view, listen, etc. When engaging with the materials, designers develop "insights" [3, 10, 11] – observations that spark interest, unexpected events, important moments, novel interactions, etc. These insights then feed into an iterative and collaborative process of sense-making [3, 10, 11] where designers work together to make sure the material is "[...] "reduced" in order to allow concepts, categories, patterns, exceptions and/or hypotheses to surface." [10, p.54]. These elements then lead to discussions within the design team who are trying to build a shared understanding of what is important for their design based on the people and context they are designing for [3]. Based on their understanding, designers make design actions that narrow the focus of the design on solving a certain challenge in a certain way [12]. However, since the goals of a design are often not clearly defined [13, 15] but rather latent and intertwined with the context [16], designers reflect on the decisions they make based on their understanding of the context [12]. For Design Ethnography, this means that designers re-engage with the material, for example to negotiating the impact of a design decision based on insights [17] or to elicit new insights [2] based on a new understanding of the design problem. This process of reflectively re-engaging with material is unique to Design Ethnography, since it is part of the larger design process "[...] it is very difficult to distinguish [...] analyses from project ideas, sketching and the mapping of design opportunities" [10, p.54].

Eventually this iterative process finds an end due to saturation (no new insights), pragmatic concerns (running out of time or money), or external forces (natural disasters, change in composition of the design team). The insights developed during the collaborative sense-making process are presented as outputs – either for the design team themselves or as a boundary object [18] that represent the importance and nuances of design decisions to be further developed by engineers [17]. Nova [10, p.60] defines three different categories of outputs: description (a list of noted events, objects, attitudes, etc.), modeling (an initial model of person, context or problems formed into a typology, set of themes, etc.), or prescription (actionable design principles, design spaces, etc.). Since these outputs are used to communicate ideas and insights with people who might not have access to the original material they must strike a balance between "brevity and richness" [10, p.60], which again means a reduction in richness from the original material. For example sharing an entire video is rich, but lacks brevity – using a set of important frames of the video keeps visual richness and increases the brevity – a bullet point list of important moments

based on the video would remove all the richness of the video, but be brevity at its finest. Since it is simpler to decrease the richness of material in successive steps of the Design Ethnography process but not to increase the richness (without gathering more material), it is important to work with a material that is sufficiently rich to begin with.

1.1.2. Video Design Ethnography

In this dissertation I focus specifically on Design Ethnography that uses video – Video Design Ethnography (VDE) – this is because video enables designers to easily captures complex, dynamic interactions [2, 17, 19]. Video accomplishes this by giving the viewer two affordances[19, 20]; visual and temporal. These two affordances allow viewers to understand how individual moments (using the visual affordance of a frame of video) are related in time (using the temporal affordance of having a series of frames). Unlike putting a designer in a room full of people, cameras allow less obtrusive [2, 21] observation that can travel along with people while they move through a space, enabling naturalistic capture of complex, dynamic activities and situations. Furthermore, once videos are captured, anyone on the design team can view a video with the same experience [16] – unlike media such as notes or photos, where the person recording it has fixed the time or not captured the visual richness of a moment. These attributes make video a very important material for design teams, enabling them to observe, share, and iteratively engage with video [2, 3].

The additional affordance of video compared to static materials such as photos and field notes can lead to deeper analysis [2, p.20], and thus richer insights – understanding the temporal relationship of events that would not be possible with other media[1] However, the affordance of temporal navigation also introduces challenges for collaborative analysis – it is difficult to discuss a video while it is playing [22], and sharing control over the time of a video is non-trivial [23]. One way to over come this is to use simple representations of insights – key-frames – that serve as an indicator for a more complex sequence, at the cost of "throwing away" the affordance of temporal navigation. One technique to overcome this loss of temporality is the sophisticated software created by Wasson [16] which enabled members of a design team to create multiple key-frames that also served as links back to the full video – but only using a digital interface. In similar thread, Buur and Soendergaard [24] discuss the "Video Card Game Method" of collaborative analysis which uses tangible key-frames along with annotations. These cards enable designers to discuss insights with a simple representation that hints at the full video, allowing designers to focus on the in-person discussion and manipulation of these insights as tangible elements [25, 26] – rather than engaging with digital systems, which can break the flow and interactions of a collaborative discussion, thus reducing the effectiveness of the design team [24].

However, this simplification is only possible if the resulting cards provide enough information for the discussion, and if they do not the Video Card Game method requires the design team to re-engage with videos when relevant to the discussion [2,

[1] See Ylirisku and Buur [2] for a specific examples of how video benefits design.

p.108], helping align their understanding and showing members of the team new (to them) footage. Not only does this limit designers' overall immersion in the context [3, p.86] it also presents a pragmatic challenge of finding and viewing the video clip that is being discussed – interrupting the discussions central to collaborative workshops [17, 23, 24].

1.1.3. Research on VDE

As a consequence of the wide variety of methods designers use [3, p.54], a bulk of the research on (Video) Design Ethnography focuses on descriptive analysis of what designers *do*. For example, Ylirisku and Buur [2] provide descriptions of how designers use video to understand a variety of activities such as skiing, injecting insulin, wastewater treatment, and cooking amongst others – focusing on how designers engage with, and get insights from, videos during collaborative sense-making activities such as the Video Card Game method. Similarly, Nova [10] provides detailed descriptions of the processes used by different designers in Design Ethnography – helpfully abstracting the variety of methods into a set of six steps: brief (the initial design task), preparation (using second sources to develop initial focus), research design (preparing to go into the field), field research (exploring and documenting the field), analysis (reducing the data to insights), and finally design intervention (delivering a design artifact). While ostensibly providing a non-prescriptive set of recommendations for conducting Design Ethnography, Crabtree, Rouncefield, and Tolmie [3] argue that formal and theoretical ethnographic methods should be disposed with, and designers should engage in ethnography based on their needs in the design process and how their understand evolves along with their analysis.

While these works provide a good *descriptive* overview of how designers engage in Video Design Ethnography, other research explores a more *generative* understanding of VDE by developing and evaluating tools to support it. Wasson [16] discuss how creating custom software that supports annotating videos allows design teams to assemble relevant videos, an idea further explore by Mackay and Pagani [27] with a system for creating Video Mosaics – using simpler elements with fewer affordances (storyboards, annotations) in order to edit together a video that might combine multiple insights or act as the output of a VDE process. More focused on the use of video in collaborative sense-making workshops, Buur and Soendergaard [24] developed a system that enables designers to "pull-up" videos based on printed screenshots, which reduced the burden of finding the original video but the interaction still interrupted discussions. Developing the idea further, Buur, Jensen, and Djajadiningrat [22] used a "video wall" that enabled designers in a workshop to collaboratively engage with videos rather than simpler representations – enabling designers to collaboratively use the affordance of navigating time that video gives in order to understand and gather insights. Finally, Buur, Nakamura, and Rye Larsen [28] explore how designers can use scale models of forklifts to recreate the actions observed in videos in a more tangible way – taking the temporal affordance of video and translating it to tangible objects that can be manipulated and viewed by designers during a workshop. Common to this type of research on VDE is the

development and evaluation of tools (a strategy which I will use) that are aimed at supporting designers when they face the challenge of balancing the richness of video for greater insights with the challenge of collaboratively engaging with videos.

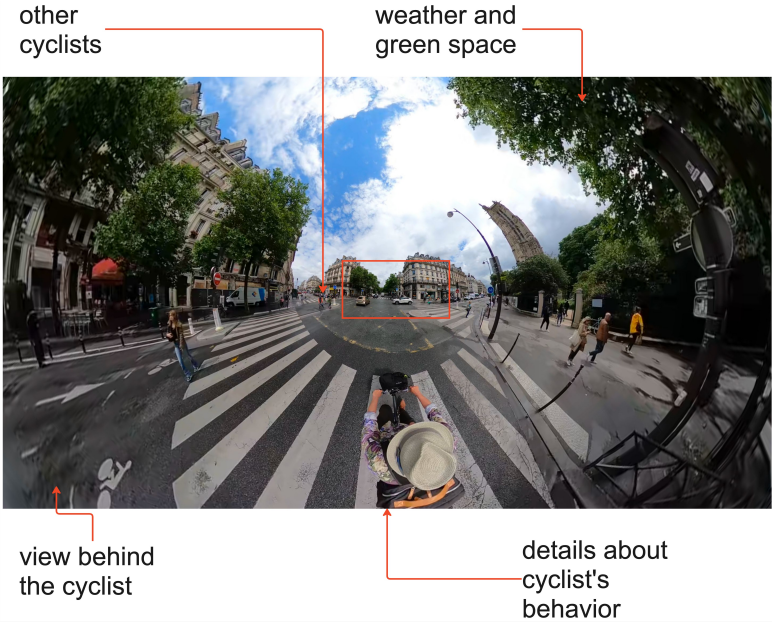


Figure 1.1.: An example of the additional information that 360° video can contain compared to conventional video (center red rectangle). Video from Velo Mondial - CC BY 4.0.

1.1.4. 360° Video

While video provides a rich source of information for designers, it only provides it with a set viewpoint, after all;

> "Observations are always intentional. We cannot see everything. Our biological make-up does not allow us to see the world in 360°" – Müller [11, p.46]

But what if our cameras *could*? By using a 360° camera, designers are able to capture a sphere of video around the camera, providing a unique affordance – being able to navigate viewpoint with the frame – to Video Design Ethnography. Figure 1.1 provides an example of how a frame of 360° video provides additional visual information beyond the viewpoint of conventional video (center) which, when viewed with appropriate software, enables a viewer to navigate the viewpoint within the complete 360° space. This allows viewers to "[...] select the subject and the viewpoint that they wanted to focus on" [4] *after* recording rather than before. This

means 360° video provides *two* affordances for the viewer – the ability to navigate the temporal dimension of the video (similar to conventional video) and the ability to navigate the viewpoint – expanding the flexibility of video by viewing an moment from multiple viewpoints, or finding elements in the context that would be out of frame with a conventional video.

Researchers have used this to study complex activities such as dye making [5], berry picking [7], fire-fighting [29], and running [8]. For example, when Porcheron *et al.* [9] leveraged 360° video to understand how cyclists interact with technology – phones, bike computers, etc – they were able to use the affordance of navigating the viewpoint of a 360° video to connect how elements of the context in front of the cyclist caused the cyclist to interact – which is simply not possible with a conventional camera. It is because of this unique affordance that 360° video has so much potential to enable designers to understand complex, multi-perspective iterations, which in turn leads to richer insights from analysis.

However, initial research on 360° video also points to potential challenges, specifically ones that make its use challenging for Design Ethnography. First, because it captures a greater field of view than we deal with biologically, it challenges an assumption that many of our tools have – that the materials we interact with are "flat", such as paper, computer screens, etc. While it is possible to show 360° content on flat media using projections such as the one used in Figure 1.1, Koenderink and van Doorn [30] highlight how these projections are difficult to understand – causing confusion about the spatial relationship between people and objects in different parts of the frame. Therefore if designers want to consume and share 360° media in a workshop, they need to make a choice: 1. preserve the full visual context of the 360° video with heavy distortion, or 2. only look a segment of the 360° video using viewing software or with a VR headset [4]. Since the first option causes distortions that make spatial relationships difficult to understand [30], it directly conflicts with a key advantage of 360° video, understanding interactions and perspectives of different people around the scene. The second option means that viewers can miss (or feel like they are missing [31]) important interactions, events, or people that they might not be looking at in specific moment. Furthermore, especially important for Design Ethnography is the viewing tools require a viewer to control *both* the time and the viewpoint, they are challenging to use collaboratively [32, 33]. Finally, specifically for collaborative analysis in Design Ethnography, adding complex digital interactions in order to share insights complicates and potentially blocks essential in-person discussions [22, 24].

1.1.5. Lack of 360° Video in Design Ethnography

Literature has explored how 360° video can benefit ethnographic practices by enabling viewers to immerse themselves in the context and take different viewpoints [5–9]. However, there is a lack of literature about the impact of 360° video on *Design* Ethnography specifically. While on the surface it might seem easy to transfer the findings directly onto Design Ethnography, previous literature does not discuss in detail the impact of *360°* video on viewing, sharing, and re-engaging with the material – crucial actions in VDE [2, 3, 10, 11, 24] that Jokela, Ojala, and Väänänen

[4] suggests are complicated by 360° video.

Neubauer *et al.* [34] is one of the few examples of giving designers 360° video as user research material in order to familiarize designers with the International Space Station – a great context to study with 360° video as it is difficult to visit in person and hard to predict where interactions happen. While Neubauer *et al.* [34] describe the benefit of 360° video for this reason, and hint at a positive impact on empathy, they do not provide a detailed description of how 360° video challenged designers, instead noting simply that "[o]ne participant at a time explored the virtual space, while the others observed".

Here we find the *gap* in knowledge – while 360° video provides richer insights for ethnography [6], the impact (both positive and negative) specifically on Design Ethnography is unknown. Furthermore, if even if the impact is known, the lack of adoption, as well as known challenges with easily viewing and sharing 360° video [4], point to the need for the creation of tools that support designers in engaging in 360° Video Design Ethnography.

1.2. Research Aim

This work is aimed at both bridging this gap in knowledge – i.e., defining the benefits and challenges of 360° video for Design Ethnography through empirical study – and enabling the wider practice of 360° VDE – i.e., by developing tools and knowledge to support the activity of 360° VDE through generative methods. To address these objectives, I formulate a set of four research questions. The first two are aimed at understanding the impact of 360° video on Design Ethnography, and are addressed by the work in Chapter 2. These first two questions help motivate and scope this work as a whole, they provide directions for what to emphasize in the 360° VDE process as well as what to improve – in other words the provide input to the third and fourth research questions. Questions 3 and 4 are thus more generative, seeking to understand strategies, techniques, and impacts of specific parts of the 360° VDE process that is enabled by this research. The research questions that structure this work are as follows:

1.2.1. Research Questions

RQ1: How can 360° video benefit Design Ethnography?

This question examines how the unique affordance of 360° video – being able to control the viewpoint – benefits and enhances the process and results of Design Ethnography. It seeks to bridge the gap in knowledge between the benefits for conventional ethnography – richer, more immersive insights that connect multiple perspectives [5–9] – and how transferable those are to the uniquely iterative, collaborative, and unstructured [11, p.37] process of Design Ethnography. Globally, it seeks to **motivate** research into, and adoption of, the novel practice of 360° Video Design Ethnography.

RQ2: What challenges do designers face when engaging in 360° Video Design Ethnography?

This question aims to understand what barriers designers face when trying to engage with 360° video. While 360° video presents inherent challenges – such as requiring specific software or tools such as a VR headset to view [4] – it is important to understand *how* these challenges impact Design Ethnography specifically. This is especially important since the impact of 360° video on the highly iterative and collaborative workflow of Design Ethnography is not discussed by previous literature [34]. On a broader level, this question asks why designers are not able to use the current tools and processes for 360° video?

RQ3: How can tangible representations of 360° video support collaborative sense-making?

Chapter 2 demonstrates that one of the primary challenges designers face when using 360° video is its incompatibility with printed screenshots – the tangible representation of insights that serve as the basis for collaborative sense-making [24]. However, the possible methods for creating tangible representations and their ability to support collaborative sense-making remains unclear. This question explores how such novel tangible representations of 360° video can support these kinds of discussions – confirming the capability of different approaches to representations can support collaborative sense-making as well as understanding how tangibility might enable designers to more deeply engage and work with 360° video.

RQ4: How can digital tools enable iterative engagement with 360° video?

My work in Chapter 2 illustrates that 360° video is challenging to iteratively engage with – once a 360° video insight is made, returning to its origin requires finding the correct file, timestamp, and perspective, a process made challenging due to 360° video's "low searchability" [6]. This means that 360° video exacerbates the challenges with iteration in Video Design Ethnography discussed by Wasson [16] and Buur and Soendergaard [24] – friction in re-engaging with the original source material during the VDE process makes the process slower and discourages iteration. Inspired by the digital tools made by Wasson [16] and Mackay and Pagani [27], this research question explores the design concepts that digital tools can leverage in order to support designers in iteratively engaging with 360° video.

Overall these four questions frame the goal of my work: to understand the impact of 360° video on Design Ethnography to motivate its development and understand its limitations – and then to develop tools that embody techniques to overcome these limitations. This approach provides both theoretical knowledge about the process of 360° VDE and practical tools – a workflow that designers can engage with now – providing value to both designers and design researchers.

1.2.2. Method

To address these Research Questions and to make contributions to both research and practice, I take a multi-phase approach that applies different methods to different

questions. The first two research questions ask what the impact is of a certain change (360° video compared to conventional video) on a previously established process (Video Design Ethnography) – justifying an empirical approach that seeks to observe and understand this change. Research Question 3 on the other hand requires a generative approach – in order to understand the how tools that do not exist when starting the research supports a process that is not widely used because of a lack of such tools. Therefor this work is bifurcated in two phases, each with a different research method:

(1) Empirical Study of 360° VDE: in order to understand the impact of 360° video on the complex and ill-defined process of Video Design Ethnography, I start the research by conducting an empirical observation of exactly that – the impact of 360° video on a conventional VDE workshop. In Chapter 2, I conducted 16 workshops (12 individual sessions, 4 group sessions) with designers based on the Video Card Game method discussed by Buur and Soendergaard [24]. By having experienced designers engage with 360° video in a Design Ethnography process in a controlled "lab" [35] setting, I was able to observe their behavior – how they consumed 360° video, how they discussed their insights in a group, etc. – as well as elicit their reflections on the process – how did they feel about certain tools or experiences, what would they have liked to bring into the workshop. This combination of observation and reflection *about* the process of 360° Video Design Ethnography by actual designers provided insights about behavior and impact of 360° video on the process far beyond the details of previous work [34, 36]. The empirical data from this study helped demonstrate the benefits of 360° video for designers – richer, more immersive insights that would not be possible with conventional video – as well as two key challenges: incompatibility with tangible representations which makes sharing insights difficult, and a complex process of re-engaging with 360° video which discourages iterative analysis.

(2) Research through Tool Design: to move beyond *simply* describing the impact of 360° video on Design Ethnography to supporting and understanding it as a complete practice, it was necessary to switch to a generative approach. In this phase I engaged in a more focused variation of Research-through-Design [37, 38] – by engaging in a process of creating tools that support 360° VDE, I was able to elicit knowledge about how and what to support and to use the tools to elicit new directions for 360° VDE. This approach resulted in the parallel development of two tools – First, a tool that supports designers sharing insights from 360° video by creating tangible artifacts (Chapter 3). Second, a tool to support designers with annotating and re-engaging with 360° video through a digital interface and integration with white-boarding software commonly used for analysis by designers (Chapter 4). On their own, these tools embody knowledge – they reflect design decisions that resulted from the empirical work in Chapter 2 as well as implicit decisions necessary to go from that knowledge to functional tools. Furthermore, these tools served as a probe for engaging with experienced designers – here I expand from a conventional RtD approach – I used these tools in workshops with designers who have experience with 360° video in order to understand the tools *utility* [39]. These workshops serve as a mix of evaluation (i.e., getting confirmation that they provide novel utility for

the designers) and as tools for generative knowledge (i.e., as objects for reflection and envisioning the future).

Case Study: Understanding Cycling with 360° Video

To help structure the dissertation I use a single common throughout all the chapters – using 360° video to understand and design for cycling experiences. Beyond the benefit of focusing my scope of the work, cycling is an interesting case study for this work due to three major reasons: First, I worked as a bicycle designer and have first hand experience with the process and methods for applying Video Design Ethnography in the design of new bicycles. Second, my PhD was part of a consortium focused on the development of "smart" e-bikes, necessitating the design of new bikes – which in turn benefit from knowledge and tools that give designers a richer understanding of cycling experiences. Finally, since "...the experiences that make cycling meaningful are fleeting, ephemeral and corporeal in nature and do not lend themselves to apprehension by language alone" [40], it is an activity that almost *necessitates* study with video [40–42]. Even more importantly, the experience of cycling depend on the goals, experiences, cultural background, familiarity, and emotional state of the cyclist **and** the dynamic set of events that happen during the actual trip, which means that understanding the full context – say with 360° video – is important to understand the complete experience of cycling. Figure 1.1 serves to illustrate how much additional visual context – and in turn how much potential for additional insights about context and interactions – 360° video captures compared with conventional video. These attributes make cycling an ideal case study for exploring how 360° video impacts Design Ethnography, and thus serves as the example case study used in the rest of the dissertation.

1.3. Contributions

To reiterate, this work is aimed at contributing to both research about, and the practice of, 360° Video Design Ethnography. This is embodied by the following major contributions of this work, which are further contextualized and expanded upon in Chapter 5.

- **Empirical Understanding of 360° VDE:** Chapter 2 provides a detailed description of the behavior of designers engaged in 360° VDE as well as their reflections. This information serves as the basis for defining the opportunities of 360° VDE – more immersive, empathic, and novel insights through multi-perspective viewing – as well as the key challenges – incompatibility with tangible representations which makes sharing insights difficult, and a complex process of re-engaging with 360° video which discourages iterative analysis..

- **Tools to Enable 360° VDE:** I provide two open-source tools along with peer-reviewed papers that describe their motivation, underlying design decisions, and evaluate their utility for professional designers:

  - Tangi (Chapter 3) – a tool that creates tangible artifacts that support the documentation, sharing, and collaborative analysis of 360° video insights by a team of designers.
  - D360 (Chapter 4) – a digital tool that supports designers in iteratively engaging with 360° video by providing a web-based viewing interface that inserts insights in an online white-boarding tool along with embedded links that return to that moment and viewpoint in a 360° video.

- **Conceptual Framework for Designerly 360° Video Use:** in Chapter 5 I synthesize a framework for how designers engage with the materiality of 360° video that helps other researchers and designers understand, discuss, and develop new methods for supporting 360 VDE.

1.4. Dissertation Structure

This dissertation is based on three research papers that are included largely unchanged. As these are self contained works, each chapter can be read on its own – at the cost of some repetition between the chapters. Below is a summary of each chapter to aid the reader in understanding the narrative of the dissertation:

Chapter 1 – Introduction (this chapter):

Provides background knowledge about (Video) Design Ethnography, the potential positive and negative impacts of 360° video on Design Ethnography, and points to the gap between the potential benefits and lack of wide spread adoption. Additionally, it presents the Research Questions that frame this work, the overarching research approach, and this overview of the later chapters.

Chapter 2 – Opportunities and Challenges of 360° VDE:

This chapter presents the empirical study of how designers use 360° video in Design Ethnography workshops (addressing RQ1 and RQ2). I describe the 16 workshops conducted, the observations of designers' behaviors, and the thematic analysis of the benefits and challenges encountered. This chapter provides the key opportunities of 360° VDE – more immersive, empathic, and novel insights through multi-perspective viewing – as well as the key challenges – incompatibility with tangible representations which makes sharing insights difficult, and a complex process of re-engaging with 360° video which discourages iterative analysis. These findings motivate the need, and provide initial design directions, for new tools. This chapter is based on W. Meijer *et al.* "Sphere Window: Challenges and Opportunities of 360° Video in Collaborative Design Workshops." In: *Nordic Conference on Human-Computer Interaction*. NordiCHI 2024. New York, NY, USA: Association for Computing Machinery, Oct. 2024. DOI: 10.1145/3679318.3685407.

Chapter 3 – Tangi:

This chapter presents Tangi – a tool that enables designers to generate tangible artifacts from 360° video frames, thereby enabling them to more easily share their insights during collaborative workshops. The development of the tool is grounded in the importance of tangibility for collaborative workshops as well as the unique challenges with sharing insights from 360° video presented in Chapter 2. Through evaluation with 9 designers who have experience with 360° video, I demonstrate the utility of Tangi in providing designers multiple tangibly representations of 360° video insights to suit their needs in a discussion. Furthermore, this chapter discusses how providing designers with tangible representations of 360° video opens up complex embodied interactions with a previously intangible media, allowing them to modify and create new artifacts with familiar tools and interactions. This chapter is based on W. Meijer *et al.* "Tangi: a Tool to Create Tangible Artifacts for Sharing Insights from 360° Video." In: *Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction*. TEI '25. New York, NY, USA: Association for Computing Machinery, Mar. 2025, pp. 1–14. DOI: 10.1145/3689050.3704928.

Chapter 4 – D360:

This chapter presents D360 – a digital tool that enables designers to iteratively engage with 360° video. Specifically, D360 provides an easy to access web-based interface enables designers to view and annotate 360° video. These annotations are inserted in Miro, an online white-boarding tool that is widely used by design teams to analyze user research materials. These annotations also contain a link which enables designers to quickly open up the D360 viewer to the corresponding file, timestamp, and orientation. Evaluation with 6 experienced designers confirmed the utility of D360's annotation workflow – designers were able to access 360° videos, create annotations, use those annotations in a familiar analysis environment, and quickly return to the 360° videos – all crucial steps that were previously seen as major barriers to iteration. Furthermore, the evaluation highlighted the importance of being able to combine 360° video with other sources of information in a Design Ethnography process, as well as the need for simplifying how designers can modify and create new elements from 360° video itself. This chapter is based on W. Meijer, T. Dingler, and G. Kortuem. "D360: a Tool for Immersive, Iterative, and Collaborative Design Ethnography using 360° Video". In: *Proceedings of the 2025 ACM Designing Interactive Systems Conference*. 2025. DOI: 10.1145/3715336.3735793.

Chapter 5 – Conclusion:

Finally, this chapter summarizes the key contributions of this work as a whole. It then provides answers to the Research Questions defined in this chapter, as well as discussing how the work as a whole connects and expands related work. Next, it presents the Framework for Designerly 360° Video Use that provides a way to describe, discuss, and support how designers engage with 360° video. Finally, it reflects on some loose ends and discusses the limitations of this work and how future work can address these and move beyond it.

2

Opportunities and Challenges of 360° Video in Design Ethnography

Previous research has demonstrated that 360° video can enhance ethnography by providing the viewer the affordances of navigating time (as is the case with conventional video) *and* navigating the viewpoint, allowing viewers to explore the complete visual context around the camera and take the perspective of different people. However, it is unknown if these advantages transfer to the less structured, iterative, and more collaborative practice of Design Ethnography, and what challenges designers would face when using 360° video. This chapter addresses this gap in literature using an empirical study where 12 participants engaged in a conventional Video Design Ethnography process while using 360° video. The results show the benefits of 360° video for designers – greater understanding of context, more "feeling with" empathy, and novel insights through multi-perspective analysis. Additionally, these workshops elicited two key challenges that underscore why designers might not be willing or able to adopt 360° video: 1. 360° video is incompatible with tangible representations of insights that are used during collaborative analysis, and 2. the complexity of viewing, annotating, and searching 360° video complicates the iterative re-engagement with material found in Design Ethnography.

This chapter is based on W. Meijer *et al.* "Sphere Window: Challenges and Opportunities of 360° Video in Collaborative Design Workshops." In: *Nordic Conference on Human-Computer Interaction.* NordiCHI 2024. New York, NY, USA: Association for Computing Machinery, Oct. 2024. DOI: 10.1145/3679318.3685407

2.1. Introduction

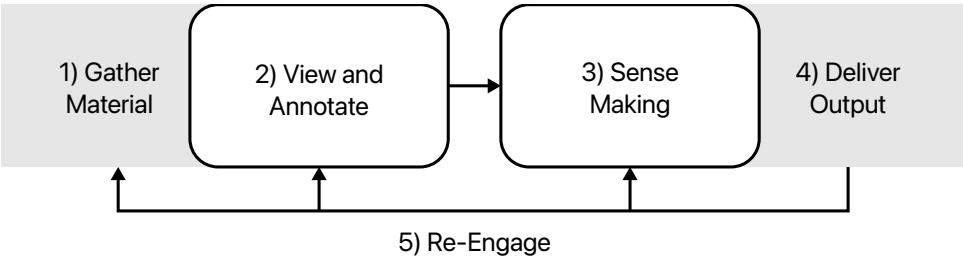


Figure 2.1.: A generalized model of the process of Video Design Ethnography consisting of 5 actions designers take: gathering material, viewing and annotating it, sense-making, sharing the results, and the iterative step of re-engaging with previous steps.

Recently, consumer cameras capable of capturing 360° video [1] have become increasingly common, allowing casual users of cameras to easily capture their full visual context [4]. Viewers of 360° video can control both the time (e.g., pause, play, rewind) and perspective (e.g., what section of they see) of 360° video to immerse themselves in the world of the video and explore it from multiple perspectives. This combination of capturing the full visual context, immersion, and perspective taking has been used to create dynamic and detailed documentation of different environments [4, 46] and create empathic narrative experiences [47, 48].

360° video is particularly interesting to designers who use video for user research – specifically Video Design Ethnography (VDE, shown in Figure 2.1), an iterative process of viewing, annotating, and collaboratively sense-making of videos in order to develop rich insights, inspiration, and empathy for their users [2, 10]. Video enables designers to *see* and *hear* contexts that might be difficult or dangerous to observe in person, such as heavy logging equipment [49], industrial climbing [50], or urban exploration [51]. In this situation, 360° video can eliminate the fundamental challenge of needing to aim the camera at the activity being studied [6], as well as the challenge of not capturing the full context of an interaction (as described by [49]), all while providing designers with a more immersive viewing experience [36].

However, it is uncertain what challenges 360° video would bring to VDE. For example, how the complications of sharing 360° video described by Jokela, Ojala, and Väänänen [4] could impact the collaborative analysis core to VDE [2, 10]. For example, the description of designers using 360° video by Neubauer *et al.* [34] sidesteps the potential challenges of sharing 360° video by simply not sharing the video between designers. Studies of 360° video using more formal ethnographic methods, such as the work of Vatanen *et al.* [7], do not engage in the same kind of iterative, collaborative interpretation as design ethnography [10] and thus do not address the specific challenges that 360° video could introduce for designers.

[1] In this paper, we use the term "360° video" to refer to video that captures an entire sphere around the camera, also known as "spherical video."

In this paper, we present challenges and opportunities that surface when introducing 360° video into an existing VDE workshop structure. Specifically, we raise the following questions:

1. What ways do designers engage with 360° video in VDE?
2. What challenges do designers face when using 360° video in VDE workshops?
3. What do future opportunities support the use of 360° video in VDE workshops?

To address these questions, we conducted 16 design workshops (12 individual sessions, 4 group sessions) based on the "video card game" method [24], a VDE workshop format described in Section 2.2.2. During these workshops we asked designers to address the fictional design task of creating a list of features for a "smart" electric bicycle [2] by using 360° video.

Our analysis shows that 360° video enhances VDE workshops by enabling designers to explore and immerse themselves in their users' context. However, adopting VDE to 360° video is not a trivial; annotating and sharing insights from 360° video are unaddressed challenges. Therefore, we call for future HCI work to study how 360° video impacts the design process beyond VDE workshops, as well as explore two opportunities to support the use of 360° video during collaborative VDE workshops: 1. tools that better support the rapid and iterative viewing and annotation that designers engage in, and 2. the creation of 360°-specific screenshots to enable the sharing of rich insights in workshops.

2.2. Background

2.2.1. Video in Design

Designers[3] use video for a wide variety of tasks: studying users, sharing information, prototyping, and sharing their insights and ideas with other designers and stakeholders [2, 23]. In this study, we focus on Video Design Ethnography (VDE) – i.e., how designers use video as a user research material to develop: **insights** into the user, their context, and their behavior [10, 13, 52], **inspiration** for design requirements [53, 54], and **empathy** for (or understanding the internal state of) the user [55–57].

2.2.2. Example: Video Card Game Method

As opined by [10], designers and design teams often lack a structured and repeatable approach, and are rarely documented in scientific literature. While the conceptual process described in Section 1.1.1 describes *what* designers do, it does not describe *how* they do it. In order to provide a concrete, well described method that has been used by others Ylirisku and Buur [2] and Lucero *et al.* [25], we can turn to the "Video Card Game Method" described by Buur and Soendergaard [24].

[2] An electric bicycle that changes its behavior based on input from the cyclist, the environment, and other data sources.

[3] In this paper, we mean "those engaged in the process of designing a new product or service".

Prior to the card game, designers need to gather video material and split the material into predefined clips (either at random or with a specific predetermined focus) and print out a "card" for each clip. This card contains a screen shot of the clip and gives participants in the game a place to write down annotations.

Once this material is prepared, the game consists of the following steps:

1. **Dealing the cards:** the cards, which represent a video, are randomly assigned to participants.
2. **Reading the cards:** participants view their assigned videos and annotate their insights.
3. **Arranging your hand:** participants group their cards into families (themes).
4. **Collecting card families:** participants select their favorite family and share it with the other participants.
5. **Discussing the card families:** participants iteratively discuss card families, and "...since none of the players have seen all the clips, it is important to return to the video at this point" [2, p.107].

The Video Card Game aligns with the important actions of VDE: viewing and annotating video clips in step, engaging in sense-making (individually in step 3, collaboratively in steps 4 & 5) and re-inquiring in the video in step 5. Additionally, the Video Card Game demonstrates shifts in fidelity; videos get reduced to clips and then screenshots, participants further reduce these clips to a set of annotations and then to themes, finally going from low to high fidelity by going from these themes back to the videos themselves in the final stage. Here the Video Card Game provides a well defined example that shows how designers make the moves of VDE and thereby shift between different levels of fidelity.

Potential Impact of 360° Video

Based on the generalized model of VDE shown in Figure 2.1, it is possible to discuss the potential impact of adopting 360° VDE. Stage 1 involves gathering video material and thus requires designers to switch to 360° cameras. Jokela, Ojala, and Väänänen [4] show the use of 360° cameras do not present a significant challenge, in fact simplifying the process of capturing the full visual context. This largely aligns with Tojo, Oto, and Niida [6], who do indicate challenges with privacy (i.e., the risk of capturing *everything*) and some logistical issues with memory size. In other words, stage 1 either benefits or remains the same when adopting 360° video.

The impact of 360° video on Viewing and Annotating is not clear – 360° video is more immersive and detailed, which can enhance designers' individual exploration of the video, and has the potential to increase empathy (See 2.2.2) – both of which would benefit the VDE process.

However, sharing 360° video (necessary for collaborative Sense-Making) is challenging [4, 33] since sharing the entire 360° video frame leads to heavy distortion. The alternative is to only view a segment that is roughly equal to a human's

perspective, at the cost of throwing away the additional visual context that is the advantage of 360° video in the first place. While Neubauer *et al.* [34] demonstrated that designers using 360° video could develop detailed insights into the lives of astronauts, the designers in the study did not attempt to share 360° visual material. Thus, the exact advantages and challenges of using 360° video in the analysis stage of VDE remain uncertain.

Empathy in Design and 360° Video

Watching 360° videos can lead to increased perspective-taking and empathy [47, 58], which is a desired outcome of user research in design [2]. Importantly, empathy is not a single, well-defined construct [57] – therefore, in this work, we focus on two modes of designerly empathy described by Kouprie and Sleeswijk Visser [56]: “feeling with” the other and “feeling as” the other. This distinction helps frame criticism of empathy in design since a designer “feeling as” they were the user can lead to ignoring the lived experience of the users themselves [55, 59]. Previous work on the impact of 360° video on empathy often frames empathy as “feeling as” [58] or does not make the distinction clear [47], which points to the lack of clarity around the potential advantage of 360° video to enhance designers’ empathy during VDE workshops.

2.3. Method

While there are many ways to use video in the design process [2], we selected the goal of defining design requirements for a future product, thereby reducing the domain-specific knowledge expected of participants. Additionally, we grounded the study in the context of “creating a set of features for a future electric bicycle” as a fictional design case. We chose the context of cycling since it is a highly contextual and multi-faceted experience (changing with location, weather, speed, familiarity, etc.) [60, 61], which plays to the benefits of 360° video for design ethnography. Furthermore, Porcheron *et al.* [9] showed that, using a handle-bar mounted 360° camera, enables viewers to explore how the context around a cyclist (e.g., the changes to the street in front of the handlebars) influenced the actions of the cyclist (happening “behind” the camera).

2.3.1. Workshop Material

We selected three sets of 360° videos based on three distinct urban contexts: 1. South East Asia (SEA, e.g., Manila, Bangkok, Jakarta. 2. north-eastern North America (NA, e.g., New York City, Toronto. 3. and Western Europe (WE, e.g., Paris, Milan. We used the method described by Nielsen *et al.* [62] to gather a collection of 16 videos (SEA: 5, NA: 5, WE: 6), listed in the Appendix A.1.2. Videos were collected on YouTube by searching for "cycling [context]" and using the 360° video filter. Videos that were not naturalistic, not of an urban context, or were of poor quality (i.e., not stabilized, low resolution) were removed.

Participants were provided with three devices: a desktop or laptop (a 2020 MacBook Pro 13-inch), a mobile phone or tablet (a 2022 iPhone SE2), and a VR headset (an Oculus Quest 2). All devices used YouTube [4] to show 360° video - all devices provided a similar Field of View and participants were able to control the perspective and time of the video and take screenshots.

2.3.2. Participants

Twelve participants were recruited using personal networks and snowball sampling. While most participants had experience with design and design ethnography, we were unable to recruit participants who had previous experience with 360° video in VDE – reflecting the novelty of 360° video in user research noted by Tojo, Oto, and Niida [6] and discussed in Section 2.5.4. Participants were randomly assigned to a group and one of the three contexts during individual sessions. We elected to not recruit additional participants after the first twelve due to reaching saturation when analyzing the themes described below. Table 2.1 shows information about the participants, which context they viewed during the individual stage, and which group session they participated in.

		Experience (years)		
Participant	Context	Design	VDE	Cycling
1	SEA	10	5	5
2	NA	5	5	25
3	WE	10	3	23
4	SEA	3	3	22
5	NA	8	8	20
6	WE	0	0	3
7	NA	7	7	21
8	WE	6	6	24
9	SEA	10	10	27
10	NA	7	7	25
11	SEA	17	2	20
12	WE	7	2	23

Table 2.1.: An overview of the participants, the context they viewed during the individual session (South East Asia, North America, Western Europe), and their self-reported years of experience with design, design ethnography, and cycling.

2.3.3. Workshop Structure

The two-session workshop are based on the "video card game" workshop described in Section 2.2.2. The workshops were piloted two times with experienced bicycle

[4] The MacBook used Google Chrome to access YouTube, while the others used their respective YouTube Apps.

designers to adjust the timing and explanations of the tasks. Both the individual and group sessions are one hour long, split between design activities and data gathering. The format of the workshops, data collection, and data storage procedures were approved by the university ethics board. Participants were offered coffee, tea, and snacks during each session.

Individual Session:

1. The overall workshop structure (individual and collaborative parts) was described to the participant.

2. The participant completed an informed consent form and a free-response survey about their familiarity with design ethnography, design, cycling, and 360° video.

3. The participant was described how to use the three tools to view the 360° video (including how to take screenshots).

4. The participant was then instructed to "Use any of the tools provided to find interesting moments / interactions / events that you would like to share with the other designers to develop an intelligent e-bike concept".

5. The participant was then given 15 minutes to use the various tools (see section 2.3.1) to explore the randomly assigned context. During this session, participants took screenshots and other notes as they saw fit.

6. Next, the participant took a short break while the screenshots from each device were printed on A4 paper.

7. The participant was then given 15 minutes to document their findings using the printed screenshots, sticky notes, extra sheets of paper, and a variety of pens. This material was placed in a folder and kept by the researchers until the group session.

8. Finally, the participant engaged in a semi-structured interview based on their overall experience, their use of the 360° nature of the videos, their perception of the impact of the video on their empathy, and any features they were missing. The semi-structured interview questions are included in the Appendix A.1.1.

Group Session:

1. Three participants, who each viewed one of the three contexts, were brought together and given 5 minutes to review their findings from the previous workshop.

2. The participants were then given 15 minutes to share their insights and address the design question: "Using the insights you have gathered, create a list of features for a new e-bike."

3. Participants engaged in a 20-minute group reflection facilitated by the lead researcher. Here, participants reflected on the process of sharing and ideating with the results of the individual sessions.

4. Finally, participants engaged in a 20-minute ideation session with the lead researcher to generate a set of features for a future 360° video workflow for designers. Inspired by Sanders and Stappers [63], participants first individually documented ideas, then took turns sharing their ideas and adding new ones during the discussion.

Data Collection:

During the sessions, we collected the following data was collected to analyze the behavior, impact, and future directions: 360° video (used to capture all members of a group session with one camera) recordings of all sessions, structured notes by the lead researcher, recordings and transcripts of the individual and group semi-structured interviews, and the design output of the ideation session.

2.3.4. Analysis

The analysis focused on two main facets of the workshops: 1. how did participants use the 360° nature of the video during the workshop, and 2. how did participants reflect on using 360° video. We followed a reflexive process based on reflexive thematic analysis [64, 65]:

1. The lead author familiarized themselves with the data by reading transcripts, session notes, ideation output and viewing each video, and began initial coding.

2. Using the initial codes, the lead author developed a set of observations and themes from reflections.

3. Co-authors checked the codes and themes for consistency and suggested additions.

4. The observations and themes that were not unique to the impact of the 360° nature of the videos (e.g., reflections of the overall use of video in design, the use of hands and pens to indicate movement over time) were removed.

5. Finally, the resulting observations, themes, and grouped ideation output were defined and described in Section 2.4.

2.4. Results

In this section, we present the themes from our analysis of the workshop recordings, research notes, and ideation output, grouped using the three research questions:

1. What ways do designers **e**ngage with 360° video in VDE?

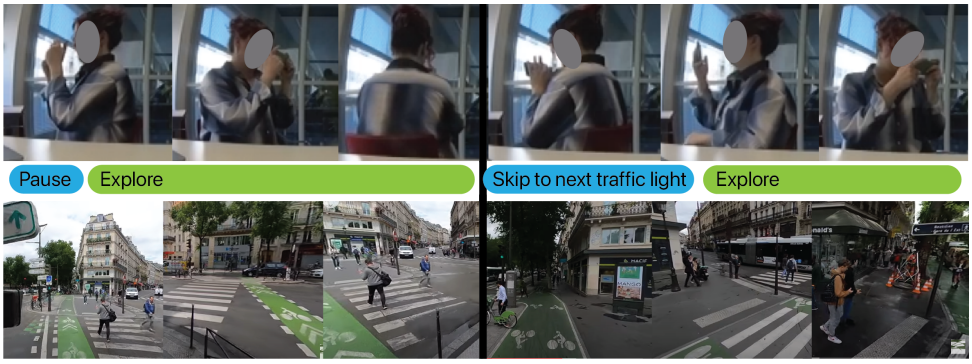


Figure 2.2.: Participant 3 using both the affordances of time (by pausing and skipping forward) and perspective of the 360° video. This gave them the ability to understand a single interaction from multiple perspectives. Video from Velo Mondial - CC-BY.

2. What **c**hallenges do designers face when using 360° video in VDE workshops?

3. What do future **op**portunities support the use of 360° video in VDE workshops?

2.4.1. How designers engaged with 360° video

E1 **Navigating through both time and perspective: (P1, P2, P3, P5, P7, P9, P10, P12)** Like with conventional video, participants skipped forward and backward through the videos. With the affordance of being able to change perspectives, participants tended towards two *modes* of viewing the 360° video: exploring and analyzing. While exploring, participants tended to look around or *"skipped the boring and predictable parts [of the video] to get to something interesting"* (P9). When analyzing a specific moment, participants skipped back to a moment that stood out to them to review a moment from different viewpoints; continuing or reversing the video with a different perspective than the one that triggered the decision to review a moment, for example, P3 exploring the interactions around traffic lights shown in Figure 2.2.

E2 **Understanding the full context (P1, P3, P4, P5, P8, P9, P12):** Participants took advantage of the main affordance of 360° video: changing the perspective to explore and understand the "space" of the full 360° video. *"There's a lot of things going on the periphery, which the 360° gives an option of exploring"* (P5). Besides the slight reframing, participants (P1, P3, P4, P5, P8, P9) also took advantage of the ability to look up and down completely to look at the cyclist (as seen in Figure 2.3), other vehicles, the condition of the road, or even at buildings and the sky. Notably, participants used the 360° video to explore *"...also look at the nice things that are happening around [the cyclist]."* (P1) such as well as negative things such as *"the sidewalk, the garbage on the streets [...] construction areas"* (P2) to better understand the context around

the cyclist at one specific moment in time, which would not be possible with conventional video.

Figure 2.3.: 360° video allows viewers to understand complex interactions (E3); for example, the screenshots on the left show the action (top) of people carrying glass across the bike path and the reaction (bottom) of the cyclist who starts to brake. Video from Velo Mondial - CC-BY.

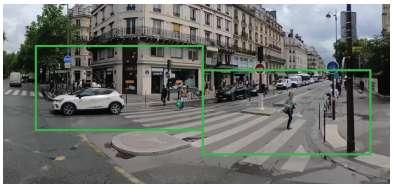
E3 **Seeing action, reaction (P2, P5, P8, P12):** Besides looking around, the 360° video enabled participants to see the action and reaction of events in the video, P2 used the affordance of looking around the 360° video to understand why a car honked at the cyclist while at a stop light. *"[The cyclist] had the mirror on in the New York video, so you could see behind him and realized, oh, OK, because there's no cars behind because riding a bike is a 360° experience that you're reacting to things behind you in front of you to the side"* (P8). By being able to see both the actions around the cyclist, and how the cyclist's reaction, participants were able to understand the decisions and reasoning of the cyclist, and how they would have reacted differently.

E4 **The immersion - analytical spectrum (P1, P2, P3, P4, P5, P9):** when contrasting the different tools, there is a spectrum; on one hand the VR headset is considered the most immersive but difficult to use. On the other hand, the laptop is more practical, familiar (P4, P5, P7), easier to take screenshots with (P1, P2, P9), and more *"forensic"* (P3). *"... one moment where I had seen something interesting on the phone video, but I'm struggling to really pinpoint it. So then I went to the laptop, found that same moment in the video and then was able to really zoom in, get a proper look"* (P3).
Many participants viewed the phone as a middle ground; navigating the video

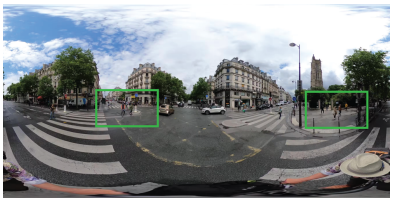
was seen as more intuitive than the laptop because of how the movement of the phone (and thus the participant's arms or whole body) maps to panning around, but less immersive than the VR headset because of its small size and poorer video quality (P1, P2, P5, P9).

E5 **"Feeling with" rather than "Feeling as" (P1, P2, P3, P5, P7, P8, P9, 11):** While P2 and P5 did talk about feeling as if they "were" the cyclist - primarily when wearing the VR headset and facing forwards - others (P1, P3, P7, P8, P9, P11) clearly felt as if they were an outside observer or companion to the cyclist, rather than being the cyclist themselves. *"So I think I felt like somebody [...] riding a tandem bike basically"* (P8). As external observers, participants still resonated with (their impression) of the feelings of the cyclist, expressing the urge to be *"protective"* (P3) or mirroring the frustration they thought the cyclist faced when waiting for a bus to move after a traffic light turned green (P8).

2.4.2. Challenges faced by designers



(a) A composite screenshot, multiple overlapping screenshots are combined to show a larger area of a 360° video.



(b) A scattered screenshot, multiple screenshots from different perspectives show insights that happen across the view of the camera.

Figure 2.4.: Examples of two ways participants used multiple screenshots to share insights that resulted from being able to change perspectives within a single frame of 360° video. Video from Velo Mondial - CC-BY-4.0.

C1 **Creating pseudo 360° screenshots:** Since the screenshots taken by all the devices match the current view, a single 360° video screenshot is the same as a screenshot of a conventional video. While the 360° viewing tools were available, none of the participants used the tools when explaining and contextualizing their insights due to the perceived time cost of finding the correct video, time, and viewing angle (P2, P3, P7, P8, P11).
Instead, participants shared 360° *specific* insights using two distinct techniques that combined multiple screenshots. One method was to create **composite screenshots** (Figure 2.4a), where multiple overlapping screenshots allowed participants to capture a larger field of view than one screenshot. This enabled them to capture how the cyclist reacted to traffic in front of them, or to document interactions between pedestrians and cars. The other method was

to take **scattered screenshots** (Figure 2.4b), multiple screenshots from different perspectives to indicate interactions that happen "across the frame". For example, showing traffic in front of and behind the cyclist or how the cyclist reacted to oncoming obstacles.

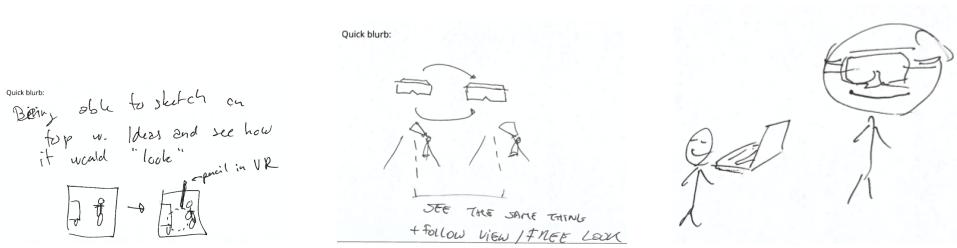
C2 **FOMO, Fear Of Missing Out (P1, P3, P6, P8, P10, P11):** Some participants noted that there was too much to look at, which gave them a sense of "FOMO" on important moments that might be happening at the same time. *"I also had this feeling of ohh something over here. I'm missing something here. I've been looking down for too long. Did I miss? Like this feeling of missing out"* (P1). Some (P6, P8) expressed frustration at being unable to see everything and replayed the same moment from different viewpoints. Others (P1, P3, P10, P11) were more concerned they could be watching the same video multiple times but still miss other interactions they had not seen.

	Viewing Time (Minutes)															Num. Screenshots		
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	L	P	V
P1				V				P		L					P	6	5	2
P2	L			P						V						4	0	8
P3	V					P								L		8	31	0
P4	P				L						V					9	8	5
P5		L				P			V					L		10	0	8
P6								L								12	-	-
P7	P		L				V						P			8	0	3
P8			L					P					V			3	3	4
P9	L			P							V					0	2	9
P10		L		P				V					P			2	7	10
P11						L							V			7	-	12
P12			L					P					V			2	2	2

Figure 2.5.: The timeline showing how [P]articipants switched between different tools (Laptop [L], Phone [P], and VR headset [V]) to watch the 360° videos. Additionally, the number of screenshots taken with each tool during the entire process is shown.

C3 **Switching between tools and avoiding some:** Some (P2, P3, P6, P9, P11) used one tool for nine or more minutes (Figure 2.5), while the other participants split their time more evenly. This presented a challenge when trying to continue a video between two tools, as participants had to select the same video, find the same time, and navigate to the same perspective to continue in the same place.
Additionally, participants avoided or stopped using tools. For example, some saw the VR headset as *"the most fun"* (P7), and immersive (P2, P4, P8, P9, P11, P12) some (P1, P2, P5, P9, P10, P12) switched from VR headset to the other tools due to motion sickness or general discomfort. The phone was also seen

as an intuitive way to navigate the 360° video, allowing participants to explore and understand the space: *"with the phone format because you [...] move around, move the screen, move the phone around physically to pan around the video [...] that really gave me a sense of the space, A feeling for what it was, what it would be like to be there"* (P3). However, participants switched to other tools because of the small screen size (P2, P5, P9).



(a) P2's suggestion for being able to "draw in VR".

(b) P9's suggestion for asynchronously viewing the same 360° video.

(c) P11's suggestion to enable asymmetrical viewing with a VR headset and a laptop.

Figure 2.6.: Three example sketches of directions for future tools from participants.

2.4.3. Designers' vision of future tools

To understand what features participants envisioned in future tools that would support the use of 360° video in VDE workshops, we labeled and grouped suggested features from the discussion and output of the ideation sessions.

F 1 **Improved annotation workflow:** Participants came up with several ways to annotate 360° videos more quickly: being able to label screenshots as they are taken (GS1[5], GS2, GS3, GS4), having a library of previous labels used for annotations (P2, P5), and being able to group annotations into families/themes (P2, P5). Participants also pointed out better inputs for labels P1 and P5 both suggested recording voice annotations: *"...I tried to talk out loud about what I was seeing, but also why I was taking certain screenshots to be recorded somewhere because I felt like I was going to forget"* (P1). In addition, participants suggested adding "visual notes" by highlighting certain areas of the video (GS1, GS3), drawing on the video (GS1, GS2, GS3, GS4), or creating a "virtual piece of paper" (P2, Figure 2.6a) that allows designers to take conventional notes while immersed in VR.

F2 **Asymmetric Viewing:** Because of the different viewing tools, it is possible for designers to collaborate "asymmetrically" (GS1, GS2, GS3), e.g., one viewing footage in a VR headset while the other views it on a phone. This could help

[5]GS indicates collaboartive output from the Group Session.

balance the different levels of immersion between devices (E4), as well as share different areas, views, or things to focus on between designers to reduce FOMO (C2).

F3 **Asynchronous Viewing:** Videos can also be viewed "asynchronously" by compiling a collection of annotated clips on an online platform (GS1, GS3, GS4), by showing what others have viewed or annotated during a video (GS1, GS2, GS3), or by showing a "third person view" of someone else's annotation process (GS2, Figure 2.6b). This would allow designers to understand the reasoning behind others' annotations in context (GS1).

F4 **Reducing FOMO:** Participants suggested several ways to reduce FOMO: encouraging viewers to look at previously unseen areas when (re)viewing a video (GS1, GS2), or encouraging viewers to look for specific objects or interactions using machine vision-based tools (GS1, GS4). A more specific way to prevent FOMO, suggested by P7, was to include a rearview mirror for the video, making what is happening "behind" the viewer more obvious and less mysterious.

2.5. Discussion

Our work presents the first well-documented description of how designers view and engage with 360° video in collaborative sense-making workshops. We demonstrate how designers engage with 360° video, using both the time and perspective (E1) to understand the visual context (E2) and interactions within the video (E3) - which is not possible with conventional video. Additionally, our work reveals challenges specific to the use of 360° video for design ethnography: the viewing device changes the interaction and attitude of analysis (E4), and the ability to explore the context clashes with the goal to develop a complete understanding of the situation, leading to a fear of missing important moments (C2). Crucially, our study highlights how 360° video "breaks" the fundamental process of sharing insights during collaborative sense-making workshops (C1), providing clear directions for future research to help designers integrate 360° video into their workflow. In this section discuss two opportunities to support the future use of 360° video in VDE, how our findings add to existing literature about 360° video, and discuss the transferability and limitations of this work.

2.5.1. Opportunities

By combing the challenges and envisioned future features that surfaced during the analysis of the workshops, we synthesized two opportunities to support the use of 360° video in VDE:

Op1 create 360° video viewing tools specifically for VDE, and

Op2 create 360° specific screenshots for sharing insights during and after VDE workshops.

Op1 360° Viewing Tools: Designers could benefit from 360° video analysis tools that support the iterative and messy nature of VDE [10] while simplifying the creation of annotations (F 1). Since these annotations are captured by the viewing software, it would be possible to share the annotations and viewpoints of others to form a better shared understanding of the content [66]. This asynchronous collaboration (F3) helps to balance the benefits of collaborative annotation of 360° videos [7] with the flexibility of individual viewing.
The tool should work on laptops, phones, and VR headsets so that viewers can seamlessly switch between them, both for their comfort (C3) and to take advantage of the different viewpoints offered by the tools (E4). This allows for asymmetric annotation where one viewer uses the more immersive VR headset while another uses the more "forensic" view provided by the laptop. This notion of asymmetric interaction has been used to help annotate virtual environments [67] or create storyboards for VR stories [68], as it allows one person to remain immersed in a VR headset while the other performs more detailed tasks (e.g., sketching, typing, or highlighting specific areas).

Op2 360° Screenshots: To enhance the way designers use the sharing of flat, physical screenshots during collaborative workshops with the contextual richness of 360° video, we propose the creation of "360° screenshots. These screenshots could include additional information about the 360° frame in which they were taken by including a 360° thumbnail, as well as a perspective overview and timestamp. A QR code linking to this video would drastically reduce the hassle of switching to the 360 video and allow designers to share not only the full 360 video, but also the motion, sound, and insights that led up to the annotation.
More specifically, an annotation tool should support the creation of "composite" or "scattered" multi-screenshots (C1) so that designers can document and share insights based on multiple parts of a single frame of 360° video. Further exploration of different 360°-specific screenshots (e.g., different types of projections, overlays, or multi-screenshots) could lead to a new visual language for discussing and sharing 360° video, similar to the manga-inspired methods for sharing video explored by Uchihashi *et al.* [69].

2.5.2. Adding to Existing 360° Video Literature

By providing a detailed analysis of the use of 360° video in VDE workshops, we can confirm that several findings from other domains apply to how designers use 360° video, namely: designers felt immersed and developed empathy for the users [47, 48, 58], designers were able to explore and understand the context around the user [4, 9], the main challenge of using 360° video was sharing it [4, 33], and the affordance of changing perspective also lead to a fear of missing out [31]. Crucially, our work points to differences in viewing behavior between designers and casual viewers of VR videos and a clear appreciation for multiple viewing devices– both of which are not reflected in research on the use of 360° video. Additionally, the type of empathy designers formed for the subjects of the video differs from findings on narrative uses of 360° video. Here, we will describe these differences in more detail.

Differences in Viewing Behavior

Importantly, our results show that current research on 360° viewing behavior is not transferable to VDE. Our participants often paused and observed multiple viewpoints (E3) and looked down at the cyclist or up at the sky (E2), both of which contradict the findings of Jin *et al.* [70], who state: 1. "users mainly watch the center of videos" and 2. "the top and bottom of videos are hardly ever watched". This discrepancy is likely the result of a difference in 360° video content (naturalistic vs. narrative), the amount of control viewers had over playback (full control vs. no control), and the goal or task of the viewer (generating design requirements vs. simply viewing content). Crucially, the lack of discussion of these factors in HCI studies of 360° points to the need to explore and discuss who, why, and how someone watches 360° videos in order to better support them.

Different Viewing Devices for Different Moments

Our participants chose different tools to view the 360° video (C3) in order to gain different types of insights into the 360° video (E4). This means that the reasons for choosing a particular tool go beyond the pragmatic ones (e.g., motion sickness, cost, ease of interaction). Therefore, we encourage the development of tools and interactions with 360° videos that support multiple devices (F2).

Designerly Empathy and 360° Video

There is a tension between the potential of 360° video to foster empathy and the criticism of using empathy as a proxy for the lived experience of the actual user group [55, 59]. We acknowledge that the 360° video methods we discuss in this paper could be used as a (rather poor) proxy for lived experience, however, the designers' reflection as they experienced being "with" the cyclist, rather than feeling "as" the cyclist (E5), suggests that 360° video could make designers more aware of the differences between the lived experiences of others and their own. Future work could help refine the understanding of the "type" of empathy that designers develop when using 360° video – how they develop their understanding of the internal state of their users, and how this understanding develops over multiple iterations of a user research process.

2.5.3. Transferability of Our Findings

In this study, we focused on understanding the use of 360° video to study one activity – cycling. Since the findings of this paper are based on the participants' behavior and experiences while using 360° video, and not on the specific outcome of the design task, we believe that the findings are transferable to designers using video to study other use-cases. This includes other forms of mobility (scooters, mopeds, etc.) as well as other activities where the camera can be mounted between the user and the "action". For example, the context of operators of heavy logging equipment by Sitompul and Wallmyr [49] could benefit from a 360° camera to enable designers to better understand how the operator interacts with the equipment as well as how they react to the changing context around them. The added value of 360° video

(capturing the different "sides" of an interaction) and the need to analyze both action and reaction is consistent with the behavior of our participants (E3, E2).

An example of a "design ethnography" use case where our findings are not transferable is the use of 360° video to document workshops in this study. The 360° footage was flattened into conventional video during analysis for three reasons: 1. the use of conventional video analysis tools, 2. the researchers' familiarity with the specific context of the workshops, and 3. that the actions of the workshop were on one side of the camera. To fully understand when 360° video is beneficial to a video ethnography process, future research could create a taxonomy of the wide variety of different activities, users, and contexts that designers could engage with. Unfortunately, this is beyond the scope of this paper, but it is one of many research directions that could support designers' use of 360° video throughout the design process.

2.5.4. Limitations

Our findings have three primary limitations that should be addressed in future research: 1. Participants were not previously familiar with 360° video. 2. Participants did not compare 360° video with conventional video. 3. The scope of our study was limited to a single iteration of VDE.

Although our participants did not have previous experience with 360° video, we believe that our work uncovers important findings - which can be refined through longitudinal study of designers' real-world experiences with 360° video. This call for increased documentation is echoed by Tojo, Oto, and Niida [6]. Future studies could begin with the opportunities described in Section 2.5.1 to help foster more experienced users of 360° video by addressing the broad challenges faced by inexperienced designers and eliciting the specific challenges of conducting 360° video design ethnography.

Additionally, the participants only engaged with 360° video during our study, limiting direct comparison of the quality of insights and specific viewing behaviors between conventional and 360° videos. Future work should closely analyze these differences for the same set of videos with the same design task to create a more detailed and empirical understanding of how 360° video affects a specific design case. Many of the viewing behaviors (E1, E3, E2) and challenges (C1, C2, C3) noted in our study are consequences of the spherical nature of 360° video. Thus, even without a direct comparison to conventional video, our work highlights important challenges for designers using 360° video.

Finally, our study only covered a single iteration of VDE, limiting insights into how designers re-watch 360° videos, forget the meaning of annotations, explore a larger set of 360° videos, and, most importantly, the differences between how the role of 360° video changes over the course of design processes. Exploring how 360° video enables (or challenges) how designers present their insights to other stakeholders in a design process as well as how 360° video alters methods such as video diaries and video prototyping [2], is crucial to the wider understanding and use of 360° video design ethnography and should be the subject of future work.

2.6. Conclusion

We conducted 16 workshops in order to how designers use, struggle with, and envision future tools for 360° video in the Video Design Ethnography process. Our findings show that participants appreciate 360° video, taking advantage of the additional visual context to gain rich insights into users' experiences. Specifically, they controlled both the time and perspective of the 360° video (E1) to understand the context of users (E2) as well as their (re)actions (E3). During the collaborative workshops, participants could share their annotations of events and impressions of the different contexts to create a list of features. However, participants struggled to share insights from 360° video – as insights often relied on multiple screenshots of the same moment – but compensated by using multiple screenshots as a single pseudo "360° screenshot" (C1).

These findings suggest two ways to support the use of 360° video in VDE workshops **Op1** Creating 360° video viewing software to support designers' iterative annotation of 360° video, and **Op2** Creating 360° video "screenshots" to support the way designers share and collaborate on insights during VDE workshops. We believe that these findings and opportunities open a new window into the use of 360° video in the design process, which can be further explored and documented based on these initial findings. We hope to inspire designers to experiment more with 360° video to develop their own techniques that will serve to refine the challenges and opportunities presented here.

3

Tangi: Collaborating With Tangible 360° Video Artifacts

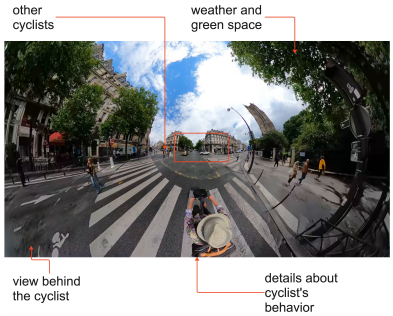
As discussed in Chapter 2, one of the fundamental challenges designers face when using 360° video is its incompatibility with the tangible representations used to share insights from conventional video in collaborative analysis. The spherical nature of 360° video forces designers to either use highly distorted projections or to use multiple individual screenshots – both of which complicate and distract from collaboration. Therefore, one of the opportunities identified in Chapter 2 was the creation of "360° screenshots" – new ways to create tangible embodiments of 360° material to support its use in Design Ethnography.

In response to this need, this chapter introduces **Tangi**, a web-based tool that converts 360° images into two types of tangible 360° video artifacts – "flat" that closely mirror conventional artifacts and "sphere-ish" artifacts that provide a 3D shape that approximates a sphere. The evaluation with nine experienced designers shows that Tangi's artifacts not only support tangible interactions commonly found in collaborative workshops but also introduce two new capabilities: maintaining spatial orientation within 360° environments and linking specific details to the broader 360° context. Additionally, participants reflected that providing tangible representations of 360° video opens up complex embodied interactions with a previously intangible media, allowing them to modify and create new artifacts with familiar tools and interactions.

This chapter is based on W. Meijer *et al.* "Tangi: a Tool to Create Tangible Artifacts for Sharing Insights from 360° Video." In: *Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction.* TEI '25. New York, NY, USA: Association for Computing Machinery, Mar. 2025, pp. 1–14. DOI: 10.1145/3689050.3704928.

3.1. Introduction

(a) A subsection of a 360° video cropped to match the FoV (Field of View) of conventional video.



(b) The same frame of video using a modified Little Planet projection [71].

Figure 3.1.: The difference in visual information of a frame when using conventional video and 360° video for an exemplar use case of studying cycling behavior, similar to Porcheron *et al.* [9]. Illustrating that 360° images, and videos, (B) contain significantly more contextual information, at the disadvantage of being significantly more distorted than conventional video. Video from Velo Mondial - CC-BY.

To better understand the needs and wants of potential users, designers[1] engage in Contextual Inquiry, gaining insights into the context around the user and the user themselves [72]. One method for gathering information about a context is the use of video, which enables prolonged and unobtrusive observation of a context [2, p. 19] or observation of contexts that are difficult or dangerous to observe in person – for example, logging equipment operators [49] or emergency medical services [73].

The process of designers engaging with video as user research material is referred to as Video Design Ethnography (VDE) [2], this iterative process centers around designers viewing and annotating videos individually and then engaging in sense-making to align their understanding of user needs and in turn design goals. A crucial component that supports this collaborative sense-making are "video artifacts"[2] Ylirisku and Buur [2] to describe similar boundary objects made from video. – tangible representations of designers' insights, such as storyboards or clusters of screenshots (Section 3.2.1). Designers use the artifacts to represent insights during discussions, documentation, VDE [2, 10, 17, 25] and as the output of the process [10].

The increasing ubiquity of 360° cameras has the potential to provide designers with richer and more immersive insights [36]. With a Field of View (FoV) of 360°, these cameras capture their entire visual context, solving issues with framing [4, 6]

[1] Someone engaged in the processes of (re)designing a product or service, regardless of profession or title.

[2] Not to be confused with compression artifacts, this term has been used by

and enabling viewers to understand more complex interactions – such as how a cyclist reacts to events in front or behind them [9] or the interaction between the conductor and their orchestra [7]. Designers are able to use this additional visual context to gather richer insights [43] into the context of their users (See Figure 3.1).

Unfortunately, as seen in Figure 3.1b the spherical nature of 360° video makes it challenging to view and share [4] using tools designed around conventional video, such as monitors and video artifacts (Section 3.2.3). To work with 360° video designers need to either discard most of the visual information – converting it back to conventional video (Figure 3.1a) or suffer from a heavily distorted image (Figure 3.1b). Thus, in order to take advantage of the benefits of 360° video, it is necessary to create tangible artifacts that enable the kinds of interactions offered by conventional video artifacts [43].

In this paper we discuss Tangi, a web-based tool for creating tangible artifacts from 360° video frames, in order to support 360° Video Design Ethnography (Section 3.4). To understand the utility of Tangi and the artifacts it creates, we conducted reflection sessions with experienced designers (Section 3.5). These sessions demonstrated that the artifacts Tangi produces enable tangible interactions that Buur, Binder, and Brandt [23] describe as essential to collaborative video analysis. Additionally, participants were able to easily modify and create new artifacts using the base elements provided by Tangi, showing the flexibility of paper-based artifacts to evolve to meet the needs of diverse design tasks [74].

Finally, we discuss the implications of Tangible 360° Video Artifacts, limitations of this early work, and future steps to further understand how 360° artifacts evolve over a longer design process (Section 3.7).

To summarize, this paper's key contributions are:

1. Tangi - an open source tool to quickly create Tangible 360° Video Artifacts.
2. Demonstrating the utility of these artifacts to support collaborative sense-making.
3. Examples of more complex artifacts that show the ability of paper-based 360° video artifacts to adapt to the needs of specific design teams.

3.2. Background

To expand on the general process of Video Design Ethnography described in 1.1.1 and the Video Card Game method described in 2.2.2, it is important to understand "video artifacts" – the boundary objects designers use to share insights from video.

3.2.1. What are Video Artifacts?

Video artifacts[3] Ylirisku and Buur [2] to describe similar boundary objects made from video. are tangible boundary objects [18] created from videos that –as with most boundary objects– have many forms which evolve over their use in a design

[3]Not to be confused with compression artifacts, this term has been used by

(a) The base element of video artifacts, the frame, in this case a frame from Big Buck Bunny.

(b) Meta-frame elements; arrows, sticky notes, and speech bubble – that provide information that does not exist in the frame itself.

(c) Multi-frame artifacts combine multiple frames, in this case a cluster of images that feature "animals" from Big Buck Bunny.

Figure 3.2.: Examples of the elements of Video Artifacts that designers use or combine to document and share their insights during Video Design Ethnography. Images from Big Buck Bunny - (c) copyright 2008, Blender Foundation

process [74]. Goldman *et al.* [75] generalize three types of video artifact – illustrated in Figure 3.2 – the individual frame of a video, meta-frame elements such as arrows and notes, and the arrangement of multiple frames into a single artifact. These elements can be further combined in complex ways, for example, the multi-frame artifacts can be arranged chronologically (e.g., a timeline [75]) or categorically (e.g., a mood-board [10], show in Figure 3.2c) or even form more complex artifacts where timelines are elements on a mood-board. These categories illustrate the importance of the "frame" – a single moment of a video, embodied as a photo – as a base element for most video artifacts. Shifting to 360° video, or 360° photos for that matter, complicates this base element of the frame, creating one of the major barriers for adopting 360° video in design ethnography (as discussed in Chapter 2).

3.2.2. Importance of Tangibility

While many interactions with video are digital (editing, viewing, etc.), Buur and Soendergaard [24] specifically point to the critical use of tangible video artifacts in collaborative sense-making to prevent the interruption of digital tools"[...] into the social sphere of design discussions without restraining the dynamics". Additionally, Brandt [76] describe how tangible artifacts provide designers with "things to think with", framing and aligning discussions and analysis by presenting themselves as a tangible token of abstract ideas. Lucero *et al.* [25] point to the importance of using tangible cards in the video card game method defined by Buur and Soendergaard [24], because these cards: 1. afford important manipulations such as pointing, rotating, or arranging, 2. can be marked on and annotated to record the discussion and create meta-frame elements in real time, 3. and trigger combinatorial creativity. It is precisely due to the tangible nature of these artifacts that they

support the highly collaborative sense-making processes that designers engage in. When being used to communicate the results of such a process (i.e., the output stage of VDE), the tangibility of video artifacts has an additional benefit: it makes them persistent [25]. This persistence is an important factor of the video artifact acting as a boundary object and providing different stakeholders with a common frame of reference [76] and avoiding the ambiguity of a video clip [25] by selecting a single, persistent frame. Finally, this persistence is indicative of the "artifact" nature of a video artifact, making it easier to preserve and allowing designers to re-engage with the knowledge embodied by video artifacts from previous projects or design teams [2].

3.2.3. How 360° Video Complicates Video Artifacts

The core challenge of creating tangible 360° video artifacts is the complex nature of a frame of 360° video. When presented as a flat artifact[4], a full frame of 360° video, or a 360° photo for that matter, is distorted (Figure 3.1b, making understanding the visual information in the scene – especially spatial relations within that frame [30] – cognitively challenging [4, 77]. To avoid this issue, one can use a perspective frame – a subset of the full 360° frame with a conventional FoV – resulting in a conventional screenshot without distortion but entirely removing the "360°" nature of a 360° video. Conversely, designers could create artifacts with larger than normal FoVs but not the entire 360° frame – resulting in trade-offs between distortion and context. This is further complicated by the fact that 360° video has the potential to generate insights based on connections between disparate areas of a 360° frame [43] (visualized in Figure 3.1b), adding another challenge to creating a 360° video artifact. While these distortions could be addressed using technology such as VR headsets or spherical displays, both of these have the potential to reintroduce the challenges that make *tangible* artifacts so important (see 3.2.2). VR headsets can isolate the viewer [34], again breaking the discussion discussed by Buur and Soendergaard [24]. For example, while spherical displays enable an undistorted view of 360° video that could enable collaborative interaction they require complex setups with external projectors [78], which limits when and where they can be used. Crucially, these digital interventions lack the persistence, arrangability, and ease of modification offered by paper artifacts that are important to VDE [25].

There are a number of papers that attempt to tackle the challenge of showing a frame of 360° video (Figure 3.3), here we will describe several and why they do not fit the needs of VDE. Li *et al.* [79] describe the concept of Route Tapestries (Figure 3.3), which simplifies the 360° video into two conventional videos of the sides of the street in order to provide a logical overview of a 360° video for editing. While this does reduce the distortion and provide important context, it is designed to provide an overview of the entire video and does not support connecting multiple elements of a single frame. Other papers recommend specific projections, such as the Little Planet projection defined by Nguyen *et al.* [71] (Figure 3.3), which does provide an overview of the 360° frame on a 2D plane (and thus could be

[4]Necessitated by many of the ways we document and share information, such as this paper.

(a) (b) (c)

Figure 3.3.: Three examples of ways to present 360° video from Li *et al.* [79]. A: the standard equirectangular projection. B: the Little Planet projection suggested by Nguyen *et al.* [71]. C: the Route Tapestries suggested by Li *et al.* [79], which show the "sides" of a 360° video to give an overview of the timeline of a video.

made into a tangible print out), however the view is highly distorted. [80] explore different methods of projecting equirectangular images onto flat or 3D shapes in Virtual Reality and found spherical thumbnails resulted in a better user experiences, however, these thumbnails and the interactions with them are contained in a VR headset. Another approach [81, 82] is to use an algorithm to "flatten" the 360° video into a conventional video or story-board. However these techniques are based the idea that there is a single, objectively defined, area of interest – which conflicts with the manor Meijer *et al.* [43] describe designers using multiple perspectives of a 360° video in the same moment to get insights which "...depends on one's interests as a designer" [2, p.91].

Largely, these methods focus on providing a simplification of 360° video aimed at digital interactions with the video (e.g., selecting a video, 360° video editing, giving an overview of the timeline of the video), and thus do not lend themselves well to the tangible, iterative nature of using frame level video artifacts during VDE workshops.

3.3. Design Space of 360° Video Artifacts

To further motivate and illustrate the challenge faced by designers wishing to engage with 360° VDE, we introduce two main axis for the design of frame level video artifacts:

1. **Spherical – Flat:** how much the artifact matches the spherical nature of 360° video, where the artifacts at the bottom only encapsulate a cropped subsection of the full sphere of 360° video, and the top end a complete, non-distorted, sphere.

2. **Digital – Tangible:** the embodiment of the artifacts, where fully digital artifacts leverage interactivity (e.g., changing FoV or perspective of the video) to reduce

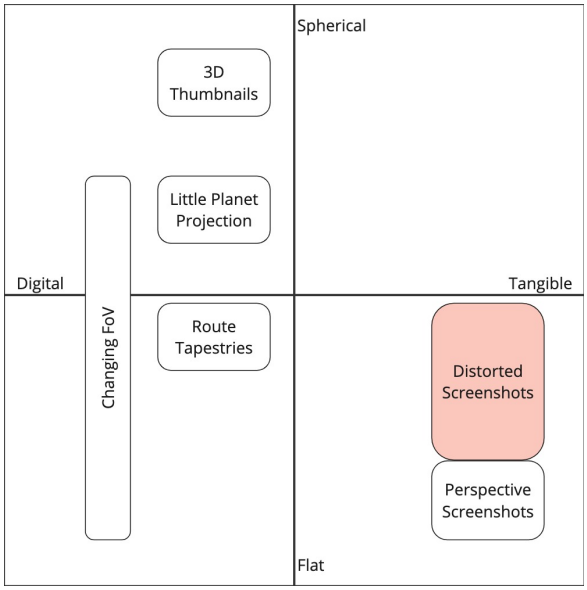


Figure 3.4.: The design space of 360° video artifacts with examples of different approaches of interacting with 360° content indicating the gap for Tangi: the lack of tangible artifacts that contain the full 360° context.

distortion and/or show additional visual context – and fully tangible artifacts support the interactions described in Section 3.2.2 and are thus physical and persistent.

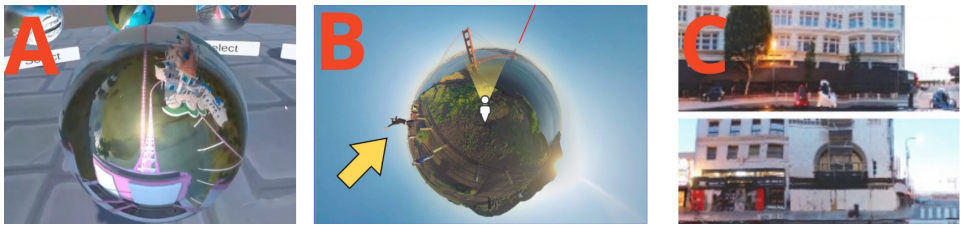


Figure 3.5.: Examples of (A) 3D Thumbnails [80], (B) Little Planet [71], and (C) Route Tapestries [79].

To illustrate these axis, we discuss three examples of artifacts from literature in order of decreasing sphericality. The first example is 3D Thumbnails [80] (Figure 3.5-A) which enable users in VR to get an overview of 360° content by creating a spherical screenshot that the viewer can move around – thereby including the full context, but only when the interaction is digital. The second is the Little Planet projection (Figure 3.5-B) discussed by Nguyen *et al.* [71], which provides a view with a lot of the visual context but with high distortion – counteracted by a second view

in a VR headset. Finally, Li *et al.* [79] discuss Route Tapestries (Figure 3.5-C) which provide a view of the sides of a 360° video to provide an overview of 360° videos – again this is tied to a 360° video player with a conventional FoV. These approaches all rely on a digital interaction (controlling the perspective of a video player with a conventional FoV), making them not ideal for design workshops.

On the physical side of the design space, there are screenshots of 360° content – either by cropping the 360° video or using a heavily distorted projection of the 360° video onto a flat surface.

3.3.1. Design Considerations

Given the importance of tangibility and the purpose of conventional artifacts(Section 3.2.1), we define three design considerations for 360° video artifacts for VDE:

1. **Tangibility:** As discussed in Section 3.2.2, the tangibility of video artifacts supports collaborative engagement with insights from the video. This tangibility also supports provides the practical benefits of creating easy-to-modify artifacts [25] that are essential in enabling the collaborative negotiation process of VDE [17]. Therefore, 360° video artifacts for VDE should be tangible.

2. **Retain 360° Context:** One approach to address the challenge of 360° video artifacts is to simply crop the video, turning it into a conventional video that can be analyzed and documented using conventional video artifacts. However, this also throws away most of the visual context – which is the benefit of 360° video. Therefore, a 360° video artifact should retain the full visual context of 360° videos.

3. **Minimize Distortion:** fundamental to the challenge of just using full 360° frames as the basis of an artifact is the complexity of understanding the distorted image [4, 30, 77]. Therefore, to support their use when sharing insights, 360° video artifacts should minimize distortion of the 360° image.

3.4. Tangi

Given the need specific design requirements discussed in Section 3.3, we developed Tangi, a tool that enables designers to rapidly create tangible artifacts from 360° video. Based on the design space shown discussed in Section 3.3, we developed two distinct approaches to making frame level artifacts, both of which can can be quickly created with Tangi's online interface.

3.4.1. Two Approaches to Tangible Frames

We started the exploration of possible artifacts by focusing on paper-based approaches [83] to create artifacts tangibility and ease of modification pointed to in Section 3.3. We then turned to works of cartography[5] [84–86] which pointed to two

[5] a field that often deals with presenting spherical information using paper-based artifacts.

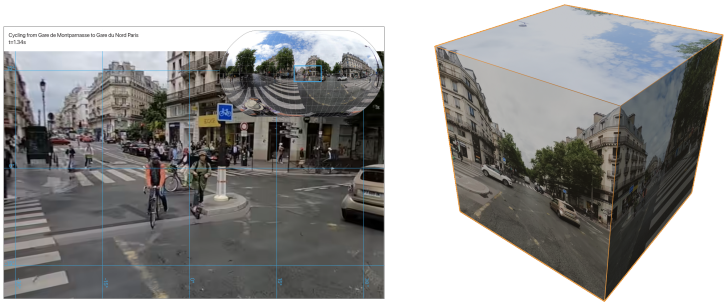
approaches that bridge the design space set up in Section 3.3. In the design space discussed in Section 3.3, **flat artifacts** enhance perspective screenshots by adding contextual information (i.e., moving up), and sphere-ish artifacts move spherical visuals to the tangible domain (i.e., moving right).

Flat 360° Video Artifacts enable designers to create 360° video artifacts on the same flat paper as conventional video artifacts, minimizing the complexity of adopting 360° video in VDE. As shown in Figure 3.6a, this was done by using a combination of non-distorted perspective screenshot and a mini-map that includes the full visual context and provides orientation of the perspective. This approach of providing a more distorted overview was inspired by atlases, which also provide the concept of graticules [6] to help orient the screenshot in 360° space.

Sphere-ish 360° Video Artifacts provide the entire 360° frame in an approximation of the actual spherical nature of the video. While this class is inspired by globes, making perfectly spherical globes is a time-consuming process [7]. Thus, we experimented with a variety of polyhedra to quickly make "sphere-ish" 3D representations of 360° video frames preliminary evaluation within the research team resulted in two shapes being selected:

1. the cube (Figure 3.6b). Simple to cut and fold, and also simple to understand (given the familiarity of a box).

2. the cuboctahedron [8] (shown in Figure 3.7). It has more facets than the cube, but importantly retains 6 large, orthogonal faces.



(a) Flat 360° video artifact.

(b) A "cube" Sphere-ish artifact.

Figure 3.6.: Examples of the two types of the Tangible 360° Frame artifacts generated by Tangi. Video from Velo Mondial - CC-BY.

[6] A grid of dotted lines to provide coordinate information in maps. See: https://en.wikipedia.org/wiki/Graticule_(cartography).

[7] See: CBS How Are Globes Made : The Art of Making Globes https://youtu.be/d0Lyw42Klew?t=48.

[8] See: https://en.m.wikipedia.org/wiki/Cuboctahedron. It also shares similarities with the work of Hurbain [87], a wonderful example of tangible 360° photo artifacts from at least 2003 – unfortunately not explored as a tool for design ethnography.

3.4.2. Tangi: the Online Tool

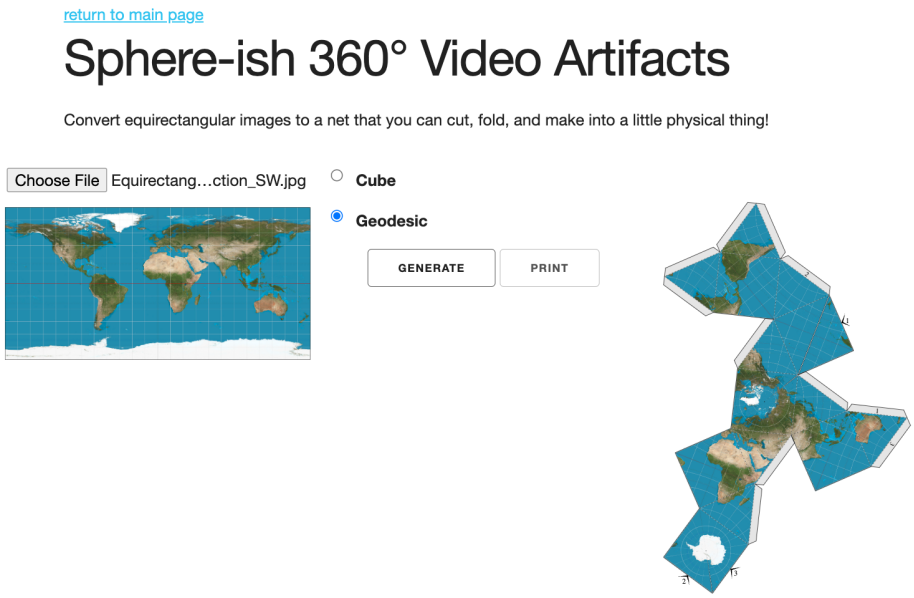


Figure 3.7.: The generator for sphere-ish artifacts, showing an example of generating a globe using an equirectangular map.

The online component of Tangi converts equirectangular 360° screenshots[9] into either flat or sphere-ish artifacts. The landing page

briefly describes the two types of artifact and provides links to generate them. The sphere-ish artifact generator (Figure 3.7) allows the user to simply open a 360° image file, select between a cube or cuboctahedron. It then projects the image onto the flat cut-and-fold template which can then be printed. Similarly, the flat artifact generator allows the user to upload an image, select an area of interest, and generate a flat artifact as shown in Figure 3.6a. The tool is available at `https://360artifact.com/`.

While Tangi is not the first tool that creates paper models of 360° images [87–89], the focus of Tangi is to specifically support designers by creating both flat and sphere-ish artifacts. Regardless of the tool used to generate them, this paper focuses on the utility of tangible 360° video artifacts for design work, and we encourage the community to expand on Tangi by modifying the source code (`https://github.com/WoMeijerPhD/360-tangible-artifacts`) or creating their own tools.

[9] which can be taken by 360° video players such as VLC `https://www.videolan.org/`

3.5. Evalutation

In order to understand the utility of Tangi and the artifacts it generates, we conducted sessions with nine designers who had experience with both 360° video and video design ethnography. We used snowball sampling to recruit participants (shown in Table 3.1) that to conduct a 2-3 hour in-person sessions with the lead researcher. The sessions addressed the following questions:

1. How do the example artifacts enable the tangible interactions designers use during VDE?
2. What are functions of tangible artifacts that are unique to 360° video?
3. How can the artifacts generated by Tangi support the creation of more complex and bespoke artifacts?

Participant	Design Experience	360° Video
P1	8 years	1 year
P2	15 years	10 years
P3	15 years	5 years
P4	6 years	2 years
P5	10 years	3 years
P6	8 years	1 year
P7	2 years	2 years
P8	3 years	2 years
P9	6 years	1 years

Table 3.1.: The relevant experience of the participants who engaged in the expert evaluations.

3.5.1. Session Setup

To simplify the challenges of coordinating working designers, the 2 to 3 hour sessions were conducted one-on-one with a participant and the lead researcher. The lead researcher acted as a fellow designer and shared a number of insights from a 360° video using artifacts generated by Tangi, scaled to fit on ubiquitous A4 paper. (example artifacts included in Appendix B). In addition to these initial artifacts, the lead researcher had a collection of 360° videos (listed in Appendix A.2.1) which participants could use to create additional artifacts. Participants were provided with workshop materials (sticky notes, pens, paper, dots, etc.) and paper-craft tools (cutting mat, box cutter, scissors, rotary perforation, etc.).

3.5.2. Session Flow

1. The lead researcher explained the purpose and elements of tangible video artifacts for conventional video using Figure 3.2, as well as the text from Section 3.2.1 for reference.

2. Participants were introduced to the specific challenge that 360° video introduces to creating these kinds of video artifacts using the text of Section 3.2.3.

3. Participants were asked to reflect on their own work and challenges with 360° video in general, and with creating artifacts specifically.

4. The lead researcher shared a number of example 360° videos and pre-assembled artifacts to demonstrate the capabilities of Tangi. (Appendix A.2.1) and pre-assembled artifacts (Appendix B) to demonstrate the artifacts created by Tangi.

5. Using these artifacts, participants were guided in a reflection on the concept of utility of the artifacts, contrast how the different classes of artifact provide different functions for collaboration, and when and how they might use these artifacts in their own work with 360° video.

6. During this reflection, participants were encouraged to create new artifacts and to modify artifacts to explore their ideas of how to adapt them to their needs.

3.5.3. Data and Analysis

Each session was recorded using a voice recorder, documented in a research notebook, and photos were taken of participants' notes, sketches, and artifacts they modified or created. We analyzed this data using reflexive thematic analysis [64, 65] with an inductive process. 1. The lead researcher spent two weeks familiarizing themselves with the data, reviewing sketches, notes, recording transcripts, and the artifacts created by participants. 2. An initial set of codes were generated from the data, focused on understanding the *utility* [39] of the artifacts for participants, as well as comparing the capabilities of 360° artifacts to conventional video artifacts [2, 23, 25]. 3. After checking these codes for consistency, clarity, and completeness, the research team iteratively created categories and re-engaged with the data to identify emergent themes – a process akin to Design Ethnography itself (see 1.1.1). 4. In a final meeting, the research team discussed the resulting themes, finally selecting and defining the themes defined and described below.

3.6. Results

Overall, participants echoed the need for tangible 360° video artifacts to support collaborative analysis expressing that the tool was *"...very cool - mhmm- really cool"* (P4) and that the artifacts created by Tangi would *"let me share my thoughts"* (P9). Specifically, Tangi's simple interface and paper-based artifacts impressed participants with its *"...super low threshold to produce and create"* (P6) which enabled the lead researcher and participants to create 34 artifacts over 9 sessions. After the initial sessions, participants 1, 5, 6, and 9 experimented with Tangi after the sessions for personal and professional design work. The sessions demonstrated that artifacts created by Tangi supported alignment and discussions in

a similar way to tangible artifacts for conventional video [17, 24, 25] without the difficulties of using conventional artifacts for 360° content [43].

As none of the participants mentioned significant issues with the utility of the online component of Tangi, our analysis focuses on the artifacts it generates. Our analysis revealed four themes specific to the utility of the artifacts generated by Tangi for the kinds of collaborative sense-making processes found in VDE:

1. **D**ifferences between the different classes of artifacts,
2. **F**unctions specific to tangible *360°* video artifacts,
3. **M**oving beyond the "frame" element,
4. **T**angibility and time.

Below we describe these themes and include quotes as well as images of the artifacts created during the sessions and visualizations of participants' actions.

[D]ifferences between the different classes of artifacts

D1 **Difference between flat and sphere-ish artifacts:** one primary distinction was the impression they gave to the observer, from the flat artifacts giving *"a more clinical, analytical perspective compared with the immersive nature of the cube"* (P5). In more extreme terms, the sphere-ish artifacts made P6 reflect that they *"...were God or something, I could see this complex interaction between all of these things"*. Other labels used to compare the classes of artifacts included *"conscious and unconscious"* (P1), *"human and more than human"* (P3), and *"atmospheric and analytical"* (P2).

This distinction also influenced how and when participants would use the different artifacts. For example P6 had a clear preference for the sphere-ish artifacts to *"provide an overview of the space, so if I am an architect looking at how to redevelop a space I would love that"*, strongly connecting the complete context with an overview of a space. P5 reflected on how these needs change through the design and analysis process and that by transitioning between flat and sphere-ish artifacts could enable a process *"...of inhabiting and then what's the word like observing? ... switching between the first person and analytical perspectives"*.

D2 **Difference between cube and cuboctahedron:** Participants noted that the cube allowed one to only see one face at a time, which gave more of a sense of *"...simply 6 flat images, which is more useful for analysis"* (P5). In contrast, the cuboctahedron was perceived more like a sphere because *"I cannot just look at 1 [face]. I will immediately already see multiple, so I am reminded that this is not just a weird picture in 2D"* (P9).

P1, P6, P8, and P9 all described how the smooth transition between the facets of the cuboctahedron also *"...encourages you to keep rotating around the sphere, you don't know when to stop"* (P1), which was seen as an advantage. However, P8 argued that this *"...makes it more difficult to understand since you have so*

many faces and you move from one to the next without stopping". P3, P4, and P7 similarly preferred the simplicity of the cube over the cuboctahedron, P2 and P5 not expressing a clear preference.

[F]unctions Enabled by Tangible 360° Video Artifacts Based on their interactions with the artifacts, participants described – and created their own artifacts – that touch on two functions that are unique to tangible video artifacts based on 360° content: the need to orient their understanding of the frame, and creating connections between the details of an insight and the overall 360° visual context.

F1 **Orientation:** Participants noted that one of the important challenges when working with 360° video was "orientation", both how *"the spatial relations between people in a single 360° image is impossible to understand"* (P3) and understanding the orientation of the video over a long time. Here, the facets [10] of the sphere-ish artifacts provided a clear set of sides to help multiple participants in a workshop agree on a specific orientation (P1, P5, P6, P7) and frame discussions during analysis (P1, P4, P6, P8). Specifically, P2 noted that the choice[11] to orient the major facets of the sphere-ish artifacts with the road in the example artifact was a smart choice that would simplify how multiple participants would understand the context as well as simplify the alignment of multiple artifacts of different road use.

F2 **Context-Detail Link:** One of the main functions discussed by participants was how 360° video creates a need to link the overall visual context to specific details In away this emerged from the creation of the flat artifacts which include the overall context in the form of the mini-map. Crucially this was missing in the sphere-ish artifacts which provided the entire context, however P5 noted: *"I'm not sure how to point out one specific thing. I feel like I want to, almost, desaturate the whole thing except the important part"*. Many participants opted to address this shortcoming by creating sphere-ish meta-frame elements (M1) discussed below.

[M]oving beyond the "frame" element While the artifacts presented to participants were initially limited to frame elements, which is commonly used for analysis of conventional video [17, 24, 25], participants' reflections expanded to include examples of meta-frame[12] annotations for sphere-ish artifacts, multi-frame artifacts that combine both types of artifacts, and several ideas that were important to mention.

M1 **Sphere-ish meta-frame elements:** one implicit difference between the flat and sphere-ish artifacts is the sphere-ish artifacts do not have any white-space for meta-frame elements. P5, P6, P8, and P9 experimented with solutions

[10] The large, flat faces.
[11] In reality this was a fortunate coincidence of the orientation of the video, which was helpful in eliciting this aspect of 360° video artifacts.
[12] Elements such as text and drawings that do not exist within the body of the frame. See Section 3.2.1.
[13] Video from European Space Agency - CC-BY. https://youtu.be/ZfFssKBiOn8

(a) P6's booklet of meta-frame annotations.

(b) An example of combining the motion over several frames in one 360° image suggested by P2, P3, P4, and P9. [13]

(c) A recreation of the multi-cube artifact suggested by P8 that maps part of a bicycle journey where the cyclist turns right.

Figure 3.8.: Additional examples of artifacts created by participants that go beyond the "frame" artifacts used as the basis of the sessions.

to this issue, with both P6 and P9 suggesting an external *"booklet"* (P6) or *"dog tags"* (P9) joined to the artifact with string, which contain the detailed meta-annotation text or drawings connected to color-coded dots on the main artifact (see Figure 3.8a). P5 suggested the use of cut up sticky-notes used tangentially to the artifact, while P8 suggested using flags (e.g., small pieces of paper on sticks), magnetically attached notes, and QR code markers printed on stickers that would connect to an app.

M2 **Multi-class artifacts:** One suggestion by P5 and P8 was the creation of multi-frame artifacts that combined the flat and sphere-ish artifacts to leverage the details of the flat artifact with the overview of the sphere-ish ones (see D1). Notably, P5 suggested using the sphere-ish artifact as the main artifact, with the flat artifacts either attached with strings where necessary or attached to the main artifact and unfolding like origami or a pop-up book. P9 on the other hand suggested the using all the artifacts like a time-line, where the choice of using a flat or sphere-ish artifact depending on the amount of detail or context deemed important at that moment.

M3 **Video specific** ideas: the artifacts that Tangi produces can support the use of both 360° photos and videos, participants came up with suggestions for novel artifacts that are specifically video based.

M3.1: **Motion analysis:** P2, P3, P4, and P9 all suggested that, when the background of the video remains static, it is possible to show the motion of certain actors within a video by overlapping multiple frames on one single sphere-ish artifact (an example is shown in Figure 3.8b).

M3.2: **Timeline artifacts:** P8 suggested creating artifacts that join multiple frames of 360° video together in order to show not only a single moment in a 360° video, but to act as a multi-frame artifact (i.e., a timeline). This was roughly mocked-up by taping cube artifacts together, as shown in Figure 3.8c.

Tangibility and Time Two observations made during the sessions by the researcher was how the intrinsic properties of the tangible artifacts impacted the sessions, specifically when creating or modifying the example artifacts and frustrations that surfaced during the sessions.

T1 **Ease of modifying paper:** because of the paper-based nature of the tangible artifacts used in this study, participants were able to easily cut, fold, and draw on the example artifacts to create their intended changes. P5, P6, P7, and P8 all used multiple print-outs of the same artifact to experiment with creating the artifacts described above. P6 was particularly enthusiastic when the lead researcher gave them permission to cut open one of the example artifacts, since they were simple to replace. Similarly, P8 used a pen to indicate how their eyes moved around the sphere-ish artifacts after the researcher reminded them the artifacts were simply paper.

T2 **Fragility and folding time:** while the paper nature of the artifacts made them easy to modify, they also made them fragile. P1, P3, P6, and P9 all broke one of the pre-assembled artifacts during their respective sessions. While this was not a costly mistake; cutting, gluing, and folding a sphere-ish artifact was time-consuming process, especially during the time constrained sessions. For this reason, P2, P3, and P4 only worked with pre-assembled artifacts. Besides the restrictions brought upon by time, the artifacts were also fragile, consisting of printed paper and simple glue. For example, P9 attempted to hastily cut and fold an octahedron, but ended up gluing it incorrectly which lead to frustration and P9 abandoning the attempt at creating the example artifact.

3.7. Discussion

Our analysis demonstrates how participants were able to use the example tangible 360° video artifacts shared during the sessions as artifacts to both analyze 360° video and share the resulting insights – a crucial step in enabling 360° VDE. The contextually rich nature of the sphere-ish artifacts lend themselves well to immersion and familiarization, while the flat artifacts gave a more focused view for sharing specific insights (D1). The study also elicited two uses of tangible artifacts specific to 360° video: supporting viewer orientation in the 360° space and linking the overall context to specific details. Additionally, the tangible nature of the artifacts enabled participants to prototype a series of more complex artifacts, demonstrating the ability of paper-based 360° artifacts to support the evolving needs of a design team [74]. In this section we will discuss how these insights can support a wider use of 360° video in design and beyond design, how Tangi will be expanded to support this, and finally the limitations of this study.

3.7.1. Paper Based Artifacts Support Bricolage

Participants expressed a wide range of preferences for which of the artifacts Tangi creates in different stages of the design process (see D1 and D2). The combination of personal preferences and purpose of the tangible artifacts reflects the concept

of emergent boundary objects [74]. During the sessions, the ease of modifying the paper-based artifacts (T1) let participants to quickly prototype changes or even novel artifacts. This enabled them to explore different ways to experience and document the 360° video without needing to switch from engaging in the physical workshop to a digital tool. By giving participants this ability to tangibly interact with an manipulate 360° material (both photos and frames of video), the artifacts enabled them to engage in "bricolage" [90], using the material at hand and its implicit restrictions to generate new artifacts and new insights while using them. For example, designers could cut out important actors from a series of artifacts and overlay them to quickly create an artifact that demonstrates the motion in a scene (similar to the concept shown in Figure 3.8b). Giving designers the ability to tangibly interact with and modify modify 360° video opens up new avenues for creativity and collaborative analysis through making without breaking up workshops with digital tools [17]. Finally, designers are "forced" to reengage with the moments of 360° video when creating and modifying Tangi's artifacts which evolves the artifacts beyond a simple boundary object and become part of the analysis and reflection process.

3.7.2. Tangi Beyond VDE

This paper focuses specifically on the use of (360°) video by designers for user research – however, there are other ways designers use video and other users of video. Buur and Soendergaard [24] describes two ways in which video is used in design processes: in early stages, teams work on sense-making (i.e., the focus of this paper), but in later stages of design processes, design teams shift to using video as an evaluation material for prototypes and initial ideas. Ylirisku and Buur [2] goes further and discusses how designers use videos to make provocations in order to frame discussions with clients and the public about implications of future design ideas. These uses of video in design could also benefit from 360° video – for example, by creating more immersive and complex *360°* video provocations. These uses of 360° video as the output of a design process faces the same challenge of needing 360° video artifacts to share insights and frame discussions that are discussed in this paper. Based on the utility of the tangible frame artifacts Tangi generates to support the creation of more complex artifacts (M2), designers can leverage Tangi to quickly and iteratively create bespoke types of tangible artifacts for provocations. Therefore, Tangi enables the exploration and study of how designers can use 360° video for prototypes and provocations with clients or the public as a whole.

Additionally, there are many uses of 360° video outside of design; such as education [91], understanding urban environments [92], or immersive journalism [93]. A specific example is the research of Sarkar *et al.* [29] on how 360° video supports firefighter training –enabling instructors to illustrate important actions in an environment that is difficult to recreate (i.e., burning buildings). In this context, the firefighter instructor needs to share insights (objects and events that require an alert) that happen in a wide visual context (necessitating 360° video) with a group with different experiences (students). This process of sharing and discussing insights mirrors the activity of designers in VDE [17], and thus the artifacts created by Tangi could help support these kinds of 360° video-based instruction sessions for

firefighters [29] or medical personnel [94, 95].

3.7.3. Future Work for Tangi

Both the participants and the authors of this paper found several opportunities to improve the current tool and the artifacts it produces (see T2). Based on this feedback, we have open-sourced the tool (https://github.com/WoMeijerPhD/360-tangible-artifacts) and are working on:

Improvements to the software, by providing the possibility to view a 360° video and take screenshots within Tangi itself. Currently, designers are required to have their own 360° video viewing software, adding to the complexity of adopting 360° VDE. By creating a full web based interface, this new version of Tangi would lower the threshold for designers working with 360° video even more.

Improve durability of artifacts by creating a 3D printed "core" to which the cut and fold patterns get attached by double-sided tape or using glue – also removing the need to cut out the flaps for glue. This was suggested by P7 when they witnessed the researcher struggling to glue a cuboctahedron. These strengthened artifacts would not only improve their persistence but also allow for more freedom in interaction (e.g., rolling or throwing artifacts) during discussions. These improvements would also make installations where the public engages with 360° video artifacts more resilient.

From Tangible Interaction to Tangible User Interface

P7's suggestion to use QR code stickers for meta-annotations (see M1) opened up the concept of using the tangible artifacts as tokens not just for the concept of a video at a specific moment [25], but also as a token for a tangible user interface for video [96]. This bridge to digital technologies could connect static artifacts with an important element of videos – time. For example, artifacts could act as bookmark for specific 360° videos at specific orientations, allowing designers to quickly re-engage with the 360° video that lead to the insight. Tracking artifacts could enable designers to use augmented reality to view these videos or to overlay dynamic meta-annotations, leading to more complex interactions without breaking the tangible interactions, reducing the burden of digital interactions breaking collaboration [23]. While adding a QR code to the artifacts would obscure some visual information, this could be avoided with techniques such as steganography [97] or infrared QR codes [98] to embed a marker into the facets of the artifact without impacting the visual information.

Enabling a Community Approach

Our evaluation of Tangi and the artifacts it creates demonstrates the value and more importantly the flexibilty of paper-based artifacts for 360° video (and photos for that matter). However, there are many types of (360°) video artifacts – with value that depends on the goals of the designers and the stage of the design process [74]. Investigating how Tangi (and the themes described in this paper) support diverse (and highly contextual) design work, requires giving as many designers as possible

access to Tangi. Therefor, we are expanding the Tangi website to support a community of practitioners to share how the artifacts they created as case studies. This will support both the development of a taxonomy of different artifacts and wide-spread experimentation with tangible 360° video artifacts – leading to new avenues for both design practice and research. By engaging with both the academic community (through this paper) and with practicing designers (using the Tangi tool and online community), the impact of tangible 360° video artifacts can evolve beyond this initial work.

3.7.4. Limitations

We were only able to engage with a limited number of designers experienced with 360° video (largely due to its novelty [6]) for a single session.

While this session did show the *utility* of Tangi to support collaborative design ethnography sessions, it is difficult to demonstrate how *effective* Tangi is for all designers – especially if viewed with the paradigm that all design problems are essentially unique [99]. Future work should evaluate Tangi in a number of different design contexts with a focus on how tangible 360° video artifacts evolve [74] over time.

We aim to support this by open-sourcing Tangi, thereby enabling other designers and researchers to create artifacts, explore how and when they are useful, and even generate new types of artifacts, and thus knowledge, based on this work.

Finally, Tangi is an initial approach to creating tangible artifacts for 360° video, as such we limited the scope of our tool to a few artifacts, while there are limitless approaches for different flat and sphere-ish artifacts. Additionally, we only explored a single scale of sphere-ish artifact based on the maximum sized artifact created using standard A4 paper. While this helped keep workshops focused on the overall utility of the tangible 360° video artifacts, there are countless possible variations. By providing Tangi as an open-source tool, we aim to enable a diverse community that can explore and evaluate a variety of shapes, projections, materials, and types of artifact. He *et al.* [83], for example, discuss how the scale and material choice of tangible cubes impact the interaction. Since there are no technical limitations to the size of Tangi's artifacts[14], future studies can use Tangi to explore how the impact of scale and material choice influence the utility and experience of interacting with 360° video.

3.8. Conclusion

In this paper we discuss the importance of creating tangible 360° video artifacts to support 360° Video Design Ethnography. To provide designers with such tangible artifacts, we developed Tangi, an online tool designed to swiftly create two distinct types of tangible 360° frame artifacts: flat and sphere-like. Using Tangi and example artifacts generated by it, we conducted nine sessions with designers experienced in 360° video which demonstrated the utility of these artifacts to support the

[14] Outside of artifacts (not the ones discussed in this study) from scaling images.

interactions found in conventional VDE. Participants were enthusiastic about the utility of tangible 360° video artifacts to support collaborative design work, and our analysis elicited two new functions of video artifacts: orientation and linking context with details. Additionally, participants created several novel artifacts using Tangi, demonstrating the value of paper-based artifacts to enable the creation of emergent boundary objects [74].

By offering a straightforward, accessible, and open-source tool, our goal is to enable a broad range of designers and researchers to engage with 360° video to develop deeper insights and consequently, better solutions tailored to a diverse array of users and contexts. Additionally, Tangi can support sharing 360° video insights beyond the initial design process (e.g., evaluation and provocation) and beyond design (e.g., education and training).

4

D360: Iteratively Annotation 360° Video

In Chapter 2 I discuss the hesitancy of participants to return to the 360° video during discussions due to the effort required to locate the correct file, timestamp, and crucially perspective. However, iteratively engaging with materials – viewing it to gather insights, using those insights to change the design, and then returning to the material to understand the change – is a core activity of Design Ethnography. Simplifying this iterative process for 360° video would make significantly lower a threshold for its adoption by designers.

In this chapter I discuss D360, a digital tool to support iterative re-engagement with 360° video by designers. Because it is web-based, it is easy for designers to access 360° video on multiple devices and annotate it. These annotations are then integrated into Miro, an online white-boarding tool used by designers for collaborative analysis. Crucially, D360 uses the annotations as links to the viewing software, giving designers access to the correct 360° video, timestamp, and orientation. Walkthrough evaluations with six professional designers demonstrated the utility of D360 as a way to trivialize annotating and returning to 360° videos – and highlighting the importance of iteratively engaging with material in Design Ethnography.

This chapter is based on W. Meijer, T. Dingler, and G. Kortuem. "D360: a Tool for Immersive, Iterative, and Collaborative Design Ethnography using 360° Video". In: *Proceedings of the 2025 ACM Designing Interactive Systems Conference*. 2025. DOI: 10.1145/3715336.3735793.

4.1. Introduction

Designers probe into the world of their users to inform the development of better products [10, 11, 14]. While designers use many different sources of information in their research, video specifically offers visually and temporally rich data, capturing complex interactions and behaviors over time [2, p.26]. However, video provides a limited window into the world of users - cameras have a limited Field of View (FoV) which can omit critical contextual information [49].

A technological solution for this shortcoming is 360° video [6, 36, 43]. 360° video provides a complete view of the visual context around users [4] and enables more thorough analysis of how users act and interact in their environment [7]. For example, Neubauer *et al.* [34] explore how designers can use 360° video to understand the context of astronauts on the International Space Station to develop an empathic understanding of a context that is literally a different world than that of the designers.

Despite its advantages, 360° video introduces new challenges. Conventional tools for video analysis lack support for spherical video, making it difficult to share and analyze 360° content [43]. Furthermore, existing 360° video tools are aimed at "flattening" 360° videos by selecting specific viewpoints, which does not support iterative exploration of 360° videos and encourages users to discard the 360° nature of the video for the convenience of conventional video.

To overcome these challenges, we developed the D360 system. First we used existing literature and first-hand experience to synthesize six design requirements that address challenges 360° video introduces during the stages of viewing, sharing, and re-inquiring that are crucial to Video Design Ethnography. D360 provides a web-based 360° video viewer where users can annotate 360° video. These annotations are then stored in a database along with information about the 360° video and users. Finally, to support collaborative analysis, D360 integrates with widely used online white-boarding tools such as Miro[1].

We evaluated the utility of the D360 system with an example scenario and walk-through sessions with 6 professional designers. The results demonstrate that the D360 system effectively facilitates the analysis of 360° video by giving designers a low-threshold interface for viewing and annotating 360° video, bringing those insights into a familiar interface (Miro), and providing a simple method to re-engage with the 360° video. Our analysis also indicates a number of additional design considerations for 360° video analysis tools for designers that will be integrated into a future version of D360. Furthermore, we discuss how tools like D360 can support the use of 360° video outside of design in use cases such as education which also focus on iterative engagement with material. However, our evaluations only explored artificial uses of D360 - in order to facilitate the study of D360 as used (or not) by designers in practice, as well as to support the extension or use of D360 for other purposes the source code for D360 can be found on Github.

By describing and evaluating the design considerations behind D360 as well as giving access of the tool to anyone, we aim to support the exploration and use of 360° video by designers, educators, laypeople, and researchers in order to better

[1] https://miro.com/

understand the actions, reactions, and contexts of users, professionals, and the subjects of ethnographic study.

4.2. Background

4.2.1. Design Ethnography

Nova [10, p.34] state that designers work with "the assumption [...] that documenting people's practices and products used in their natural habitat could be helpful for design". This assumption is the basis for approaches such as Contextual Design [72] – understanding the context of a user and use is an important factor in meaningful design decisions – or design probes [100] — inviting self-documentation of users and their context to understand what elements of a design are important to them. This process of documenting people's practices is generalized as "design ethnography" [10, 11, 14], and centers around the guidelines of developing **insights** into the user, their context, and their behavior [10, 13, 52], **inspiration** for design concepts [53, 54], and **empathy** for (or understanding the internal state of) the user [55–57].

Importantly, the process of design ethnography is "abductive, constructivist, and reflexive" [11, p.21] meaning that the purpose and outcomes of analysis co-evolve with the interpretation of designers and the guidelines of the design process. Thus designers re-engage with user research multiple times with different levels of detail and intention. Because designers (often) work in teams [2, 10], this process happens both individually and between team members, with designers engaging in "...negotiation, collaboration, debate, conflict, and other social action" [2, p.34]. Therefore designers engage in "shared sense-making" [2, p.106], using bits of the research material that represent specific insights and are used, known as boundary objects [18], as a way to "negotiation of opinions in the team" [25].

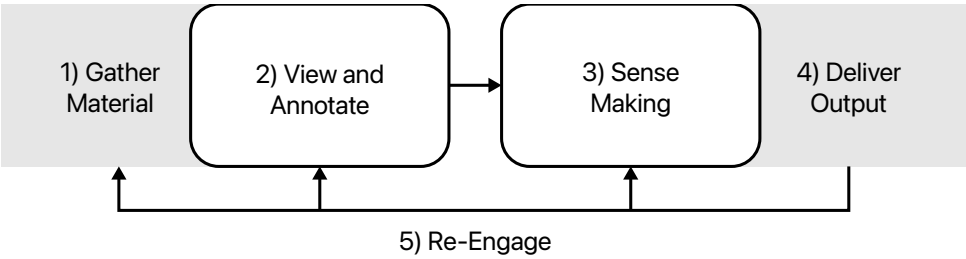


Figure 4.1.: A generalized model for Video Design Ethnography that shows the iterative nature of viewing and annotating videos, collaboratively analyzing these annotations, and re-engaging with the material to challenge assumptions in the design process.

4.2.2. Video Design Ethnography (VDE)

There are many types of data that can be collected for Design Ethnography - interviews, observations, generative sessions, photos, videos, audio recordings,

sketches, probes, etc. In this paper, we focus on the use of video as material for design ethnography, known as Video Design Enthnography (VDE). Video enables prolonged and unobtrusive observation of complex interactions [2, p.19], thereby enabling designers to develop insights into situations that would otherwise be too difficult, dangerous, or time consuming to observe. Beyond convenience, video also captures the temporal dynamics of interactions and contexts [2, p.26] which gives designers a window to understand not only a specific moment of a user's experience but how that moment came about and how those moments change over time. Video enables designers to continually re-engage with this rich and dynamic data, supporting an iterative process of discovering insights, negotiating the meaning of these insights, and then re-inquiring in the video to see if the new understanding of the insights matches the context [17]. Finally, designers use the visual richness of individual frames of video to embody and share their insights [25]. These frames are then used to represent a shared understanding, often using online white-boarding tools that support remote and asynchronous collaboration [101]. This combination of visual richness, share-ability, and unobtrusiveness means video is well suited for design ethnography.

4.2.3. 360° Video for Design Ethnography

While video provides rich and temporal information, it only provides a limited field of view into the world of users. This crucial limitation means that interactions and events happen "off camera", preventing designers from understanding all the actions and interactions in a context, for example not being able to understand where the users is looking during complex actions [49].

Fortunately, 360° action cameras[2] enable casual users of cameras to easily capture the full visual context around the camera [4]. Beyond simply capturing the context, the immersive nature of 360° video allows viewers to take the perspective of different actors in a scene, for example the view of a conductor or of an orchestra [7], and actively explore the video by moving their viewpoint, leading to greater immersion and empathy [47, 58, 102]. This additional context and immersion has been used to study a diverse set of contexts such as the International Space Station [34], firefighter training [29], and dyeing practices [5].

Thus, 360° video not only eliminates the issue of framing the camera correctly, but it also gives designers the ability to engage and immerse themselves in contexts that they are totally unfamiliar with.

4.2.4. Challenges Introduced by 360° Video

The fact that 360° video captures an entire spherical field of view around the camera presents a number of challenges compared to the "flat" video of traditional cameras. This makes 360° content more difficult to view and share using the same techniques as conventional (flat) video [4]. One approach to this challenge is to *flatten* 360° video using any number of map projections [3]. However, this results in distorted

[2] Such as the GoPro Max or Insta360 X4.
[3] For additional examples see: https://en.wikipedia.org/wiki/Map_projection

images that are difficult for to understand [77] - especially the spatial relations between different actors in the video [30]. Therefore, many 360° video players show a conventional subset of the 360° video and let the viewer change that perspective, eliminating the impact of distortion.

However, this approach means that the viewer is responsible for controlling the view, which adds a new challenge of sharing or combining control when two or more people view collaboratively [4, 103] as well as introducing a fear of missing out on certain moments or areas of the video [31, 104]. Additionally, the different devices used to view 360° content (laptop, mobile phone, or VR headset [105]) have different affordances. For example, headsets are more immersive but make detailed operations more challenging, while laptops give more control but are less immersive [43, 67, 68]. The addition of a specific subset of the 360° video also adds an extra element to keep track of when viewers want to re-visit a specific moment – requiring the user to not only find the correct video and timestamp, but also the correct perspective [43, 66].

Finally, in order to share insights from 360° video, designers either need to present the full frame (introducing distortion), crop the frame (removing the visual context), or use a digital tool that lets the viewer change the perspective (which requires designers to disengage from discussions during collaborative workshops, which is undesirable [24]).

4.3. Design Guidelines

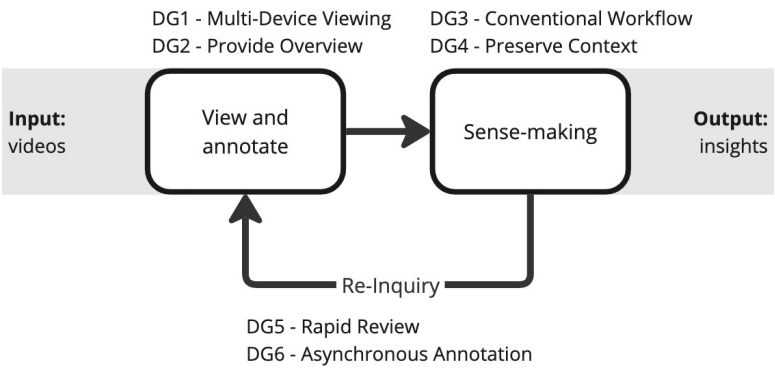


Figure 4.2.: The six Design Guidelines used in the creation of D360 mapped onto a simplified version of video design ethnography described in Section 1.1.1.

Based on the challenges that 360° video introduces to the process of VDE (See Chapter 2), examples of 360° video tools from literature, as well as first hand experience using 360° video for design ethnography we synthesized six primary Design Guidelines (DGs) for tools that aim to support the use of 360° video by designers. Figure 4.2 shows how these design guidelines link to the different stages of VDE described in 1.1.1.

DG1 **Multi-Device Viewing**: Different methods of viewing 360° video offer different annotation experiences, such as the more immersive but cumbersome VR headset or the more analytical view of a laptop [43, 71]. Tools should support viewing 360° content using multiple devices to give users the freedom to select the appropriate tool.

DG2 **Provide Overview**: Since users often only see a small area of a 360° video, which lead to stress about missing specific moments [43, 104]. Tools should enable users to maintain an overview of the full visual context to reduce this stress and increase contextual understanding.

DG3 **Conventional Workflow**: Designers have a workflow that they use in VDE to aid in engaging with collaborative analysis. Tools for 360° video analysis should integrate with workflows designers are familiar with [106] to simplify the process of adopting 360° video [43].

DG4 **Preserve Context**: One of the challenges with sharing insights from 360° video is the loss of the entire visual context when converting to flat screenshots [43]. Tools should represent annotations in a way that preserves both the visual context and orientation within the 360° view [71, 103].

DG5 **Rapid Review**: Finding the moment of a 360° video captured by a screenshot requires users to identify the correct video, time, and orientation, which is cumbersome [43, 71]. Tools should create "backlinks" that allow users to automatically return to the video, time, and orientation of annotations.

DG6 **Asynchronous Annotation**: Tools should support asynchronous collaboration (i.e., annotation by multiple designers) by attributing annotations to their creator, along with other meta-data [67, 68] (e.g., who used the tool, when, and what they created with the tool).

4.3.1. Existing 360° Video Tools

In the preceding sections we reference a few 360° video tools that help articulate and demonstrate the importance of some of the Design Guidelines, however these tools were made for other purposes than to support the unique process of 360° video design ethnography [43], and therefor it is logical that none of them fulfill all of the design guidelines. In this section we will discuss five 360° video tools that achieve *some* of the Design Guidelines – Vremiere [71], CollaVR [66], Tourgether360 [103], AVA360VR [107], and CACA360VR [108] – and discuss how none meet all the design guidelines set out for a tool to support 360° Video Design Ethnography.

The first two – Vremiere [71] and CollaVR [66] – are both aimed at collaborative editing of 360° video. Therefor they both implement the ability to view, annotate, and re-view 360° video. Specifically, Vremiere enables multi-device viewing (DG1, VR headset and computer), provides an overview and preserves context using the little planet projection (DG2 & DG4), and enables rapid review with markers (DG5) – however, its focus on editing means it does not fit into the conventional workflow, with their evaluation finding a preference towards the participants own workflows

over that of the tool. CollaVR is aimed at asynchronous annotation and viewing of 360° video (DG6), it enables collaborative viewing of 360° video *only* in VR headsets (thus not meeting DG1), but does support thumbnails that preserve some of the context of an annotation (DG4). More importantly, both tools are not publicly available, which reduces their utility for designers more-so than the fact they not meet all the Design Guidelines described above.

Tourgether360 [103] is a tool that lets two participants collaboratively explore 360° videos, which indicates that it could be used to collaboratively analyze 360° video by designers. It allows the two viewers to see each other in the 360° video, as well as to indicate an interesting area of the 360° video. Additionally, it provides a "mini-map" that shows an overhead view of the path of the 360° video (DG2). However, while these features are great for a rich, real-time collaborative viewing experience, it fails to support the iterative process of annotating 360° videos, using those annotations elsewhere, and then returning to the 360° video if necessary. It also only supports VR headsets (not meeting DG1), does not preserve context in annotations (not meeting DG4), and does not integrate into the workflow of designers (not that it was designed to, but not meeting DG3).

Finally, AVA360VR [107], and CACA360VR [108] are tools made by the BigSoftVideo group[4] for the purpose of analyzing 360° video in conventional ethnography (as demonstrated by Vatanen *et al.* [7]). Both tools are capable, they enable viewers to merge multiple materials (360° video, conventional video, multiple audio sources, transcripts) into a project, enable annotation by drawing on the 360° video, offer different 2D representations (DG4), and even enable viewers to record a presentation using the 360° video. However, this wide range of features comes at a cost – running the software requires a powerful computer, and more importantly, much of the work that designers would normally do in-person, can now be done only in a VR headset (not meeting DG1 and DG3). Thus, while AVA360VR and CAVA360VR are powerful tools for the more rigorous and solitary [6] methods of ethnography, they do not support the workflow and specifically in-person collaboration [22, 24] that is found in design ethnography.

Therefore, while there are a lot of tools that support some of the Design Guidelines that we synthesized, we have demonstrated that none of the tools we discussed fulfill all of them – as well as why these tools are not easily adaptable to the workflow of designers.

4.4. The D360 System

Based on the opportunities for a 360° video analysis tool for video design ethnography, we created D360, which consists of three pieces of software: 1. the D360 viewer, 2. a database for storing annotation sessions, and 3. Miro [5] integration. Figure 4.3 shows how annotations taken using the D360 viewer are saved on the database and then placed in a timeline on a Miro board. These annotations provide

[4] See https://github.com/BigSoftVideo.

[5] While there are other online white-boarding tools available Miro was used at the companies participants 1,2, 4, and 6 work for.

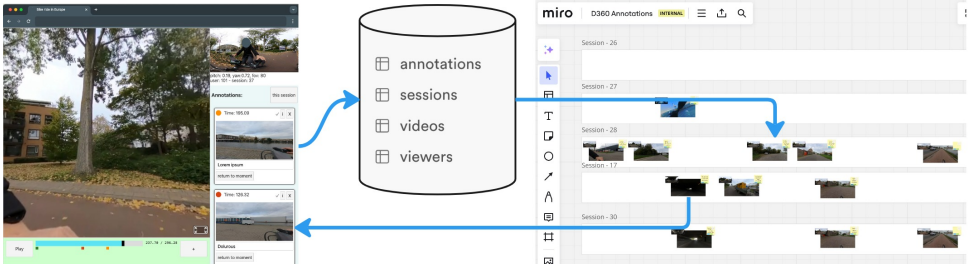


Figure 4.3.: An overview of the D360 system consisting of the D360 viewer (left), the database (middle), and the integration into Miro (right).

"back links" to the D360 viewer at the moment they were taken- enabling designers to quickly re-view the full 360° video.

4.4.1. The D360 Viewer

The D360 Viewer features a landing page which provides the user with an ID and allows them to to join a team; giving them access to an overview of a set of the 360° videos. When the user selects a 360° video to annotate, they are presented with the main D360 Viewer interface (Figure 4.4). This interface provides a large window to view and navigate the 360° video with a conventional FoV (4.4-A). The entire 360° frame of the video is included in a mini-map (4.4-B) in order to give an overview of the full 360° context (DG2 Provide Overview). The bottom bar (4.4-C) allows the user to pause the video, create new annotations (using the "+" button) and features a timeline that shows the progress in the video and gives an overview of annotations. These annotations are also shown on a scrolling sidebar (4.4-D) which shows the annotation image and time and allows the user to add text to the annotation and return to that moment (time and perspective) of the 360° video. Finally, the D360 Viewer is built using A-Frame [6] which enables users to view and navigate 360° video on multiple devices (DG1 Multi-Device Viewing): computers (with mouse controls), phones (using touch and tilt controls), and VR headsets (using head tracking).

4.4.2. The Database

D360 uses a relational database to store information about the videos, users, annotations, and annotation sessions. Specifically, we used Supabase[7] which provides Javascript APIs, authentication, and file storage. The database stores the video ID, timestamp, orientation, and user ID of each annotation (DG5 Rapid Review). Additionally, the database creates an "annotation session" when a user starts annotating a video. This enables other viewers to view not just a singular annotations but contextualize how annotations from one user connect together (DG6 Asynchronous Annotation). Finally, the database enables annotations to act

[6] https://aframe.io/
[7] https://supabase.com/

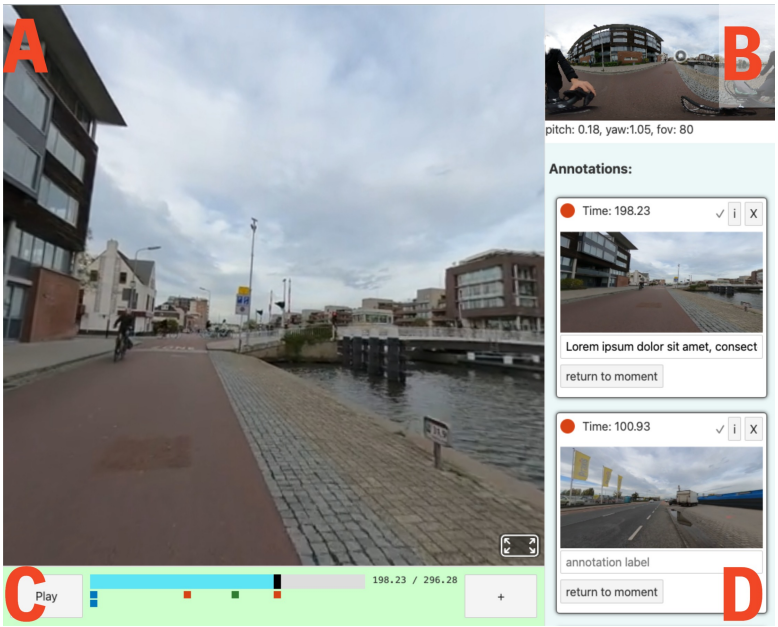


Figure 4.4.: The D360 Viewer web interface, showing (A) the 360° video view, (B) the mini-map, (C) the timeline and "+" button to create a new annotation, and (D) the scrollable list of annotations.

as back-links to the annotation session they were created in. This means that the annotation objects in Miro act as links to the full 360° video at the time and orientation of that annotation (DG5 Rapid Review).

4.4.3. Miro Integration

The data sent to the database can be integrated into a variety of tools (both for use by designers and for potential analysis of the annotating behavior of designers). Based on early input from the practitioners we engaged with, we opted to integrate the output of the D360 Viewer with Miro [8] - a popular online white-boarding tool that supports asynchronous and remote collaborative analysis. We created a small Miro plug-in that allows designers to quickly insert annotation objects (that include the full 360° visual context DG4 Preserving Context) into Miro boards (DG3 Conventional Workflow). These annotation objects also contain the "back links" that connect the annotation back to the D360 viewer (to enable DG5 Rapid Review).

The representation of annotations in Miro (Figure 4.5) consists of three items grouped together as one object:

A The screenshot of the view when the annotation was created. With a link[9]

[8] https://miro.com/

[9] Additionally, the image URL acts as a redirect, ensuring that the image - annotation link remains in

that redirects the user to the D360 Viewer with the same video, timestamp, perspective, and annotation session as the associated annotation (enabling DG5 Rapid Review).

B An overview of the full 360° frame to preserve the entire visual context of the annotation (enabling DG4 Preserving Context).

C A sticky note with the text of the annotation that enables two way editing with the annotation object in the database. It is also tagged with the user that created the annotation and the name of the session the annotation was created in (to support DG6 Asynchronous Annotation).

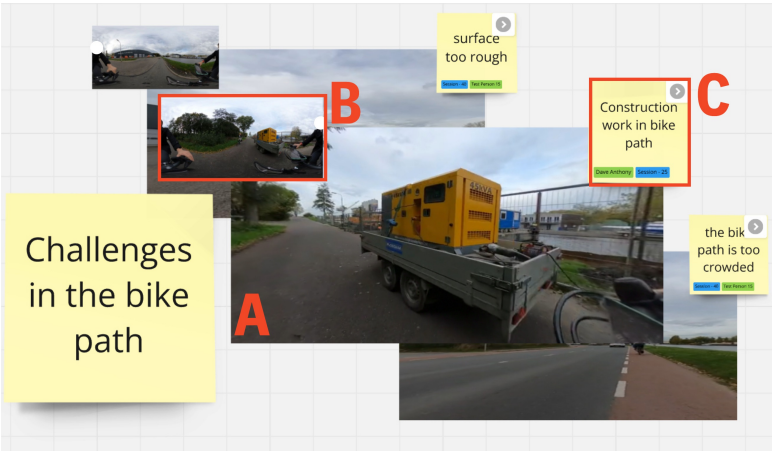


Figure 4.5.: An example of how D360 presents an annotation in Miro, composed of (A) the screenshot of the annotation, (B) an overview of the 360° frame, and (C) the text of the annotation.

4.5. Evaluation

The goal of our evaluation is to understand the conceptual clarity, ease of use, and value to the intended audience of D360 (experienced designers using 360° video) [39]. Since VDE is a complex process with methods that vary with design team, context, and stage of the design process [2, p. 91], attempting to create standardized tasks in order to evaluate the real world usage of the D360 system would fall into the "usability trap" discussed by Olsen [109]. Therefore, we studied the usage of the D360 tool by designers with 360° video experience in a walk-through setting approaches, as recommended by Ledo *et al.* [39] to evaluate D360 for "utility, not usability". Additionally, we provide an example usage scenario (Appendix A.3.1) to help further illustrate the utility of D360 for design practitioners. We demonstrate

the event of someone deleting the Miro link.

both "...what the tool can do" [39] and the utility of D360 for its intended users. In other words, we address the following research questions:

RQ1 How do the Design Guidelines defined in Section 4.3 align with the experiences of designers?

RQ2 How well are designers able to utilize the D360 tool to conduct VDE activities?

4.5.1. Participants

We conducted a walk-through evaluation [39, 110] with 6 designers who have experience working with 360° video for professional projects (Table 4.1). Participants were recruited through a combination of open calls on social media and snowball sampling. Participants were screened for experience with 360° video and engaged with 360° content[10] in their professional work - rejecting 2 potential candidates. The

	360° Experience	Design Context
P1	1 year	Robotics and Automation
P2	3 years	Urban Design
P3	3 years	Water Sports
P4	2 years	Urban Design
P5	4 years	ICU and Hospitals
P6	3 years	Robotics and Automation

Table 4.1.: An overview of the participants, their experience with 360° photos and/or video, and the context of their professional work.

number of candidates was limited, mainly due to the novel nature of 360° video in ethnographic practice [6, 43]. We elected to use a smaller number of participants who represent the actual target audience of the tool, rather than a larger group of "stand-ins" to avoid the issues of transferability discussed by Ledo *et al.* [39].

4.5.2. Sessions

The sessions were conducted one-on-one and lasted approximately one hour[11], and participants were remunerated with coffee, tea, and snacks.

To demonstrate the abilities of D360 for asynchronous and iterative collaboration we selected an example design task of the lead researcher created a number of 360° videos of "identifying challenges and opportunities to integrate AI technology onto e-bikes". This design task was chosen as it aligned with participants experience with automation and urban environments. To avoid issues with privacy the lead researcher recorded a number of 360° videos of themselves cycling using a GoPro Max 360° action camera. These 360° videos were then annotated in order to pre-populate a Miro board that was used during the sessions.

[10] Either 360° photos or 360° video.

[11] An unfortunately brief period since, limited by the availability of the participants. In many cases the discussion could have gone longer or the tool could have been used in multiple sessions.

1. **Introduction:** the lead researcher introduces themselves to the participant, who then reads and signs an informed consent form.

2. **Understanding the Participant's use of 360° Video:** The participant is asked to describe their workflow when using 360° video and discuss the benefits of 360° video as well as the challenges it presents.

3. **Demonstrating the D360 viewer:** The D360 viewer interface is demonstrated for the participant, showing the features described in Figure 4.4. The participant is asked to use the D360 viewer to annotate a brief segment of an example 360° video while being encouraged to think out loud.

4. **Demonstrating the D360 Miro integration:** The participant is shown how the D360 tool integrates into Miro (Figure 4.5), and is able to explore the Miro board with example annotations. The participant is encouraged to use the back link feature to see example annotations in the D360 viewer.

5. **Critiquing the Utility of D360:** The participant is asked to reflect on the utility of D360, specifically elements of their process that are not addressed by the system or elements the system addresses that are extraneous.

Data and Analysis

All sessions were documented by screen recordings, an audio recorder, notes taken by the researcher, and notes or sketches made by the participant. This data was used first analyzed to address the research questions by comparing the participants' descriptions of their process when using 360° video and summarizing their feedback related to how well D360 addresses the six design guidelines defined in Section 4.3. Later the data was used in an open, inductive process based on reflexive thematic analysis [111] in order to elicit novel design guidelines and unaddressed uses of 360° video in design. First the lead author familiarized themselves with the data and conducted initial coding of participant feedback and ideas. These initial codes then formed the basis of themes that aimed to combine key elements of the codes. These themes were then shared with the other authors who iteratively discussed and refined them.

4.6. Results

In this section we present the results of the walk-through sessions with professional designers. First, we describe how well the design guidelines formulated in Section 4.3 align with the experiences of designers (RQ1). Second, we describe three additional design guidelines elicited from the input of participants that were not described by previous work. Third, we describe participants' impression of the utility of the D360 system (RQ2). Finally, we define a number of additional features participants described for future versions of D360.

4.6.1. RQ1: alignment of design guidelines

All participants conducted analysis in a process similar to the reflexive VDE process described in 1.1.1, confirming the theoretical grounding of D360. Figure 4.6 shows an amalgamation of the process and how and when participants integrated 360° video.

For the specific design guidelines, participants described the importance and challenge of being able to find exact moments of 360° video DG5 (P1, P3, P4, P5, P6), annotating asynchronously DG6 (P1, P2, P3, P5), and frustration with integrating 360° content into their existing workflows DG3 (P1, P2, P3, P4, P5, P6) without discarding the full visual context DG4 (P1, P3, P4). Most participants limit their interaction with 360° video to laptops or phones due to limited availability of VR headsets (P1, P2, P4), but most (P1, P4, P5, P6) appreciated that different tools DG1. Some participants expressed that they experienced feeling overwhelmed by the amount of visual information in 360° video DG2 (P1, P3, P4), while the other participants did not mention it as a specific challenge with 360° video.

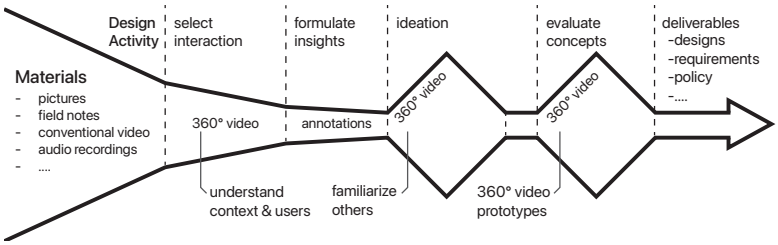


Figure 4.6.: An amalgamation of sketches from P1, P5, and P6 describing how and when 360° video is used in their design process.

4.6.2. Additional Design Guidelines

Based on our analysis of participants' description of their workflow with 360° video in Phase 1 of the sessions as well as reflections during the critique of D360 in Phase 5, we extract three *additional* design guidelines (AGs) for tools that seek to aid designers' use of 360° video:

AG1 **Interaction Threshold:** One of the main challenges identified by participants is that the increased file size (P1, P3, P4, P6) of 360° videos and the need to use specific viewing software (P1, P2, P5, P6) presented significant friction when engaging with 360° video. P1 indicated that *"[they] can only watch 360° videos on [their] coworker's computer because he has the software"*. Similar logistical challenges include footage lost because SD cards were being used to transfer files from 360° cameras (P3, P6), incorrect camera settings resulting in 360° videos not being recorded (P4, P6), and file format issues (P1, P2). Largely this means that a lot of time is spent on the logistics of 360° videos both in analysis and when sharing the video with others during workshops (P6), and that remote collaboration with 360° videos is *"...limited by the software and devices that [team members] have access to"* (P4).

AG2 **Mixed Sources of Information:** contrary to the video-lead process described by literature [2, 17], participants expressed a preference to use their own recollection (P1, P3, P6), field notes (P2, P3, P6), voice recordings (P1, P4), conventional video (P3, P6), or photos (P1, P2, P3, P4, P6) as an initial resource in order to narrow down the *"...things we're interested in"* (P1) before engaging with 360° video, since there is *"... never enough time"* (P6) for analysis. This presented an additional friction for participants, since they had to find the relevant moments in 360° videos that were potentially stored on different devices (P1, P3) or properly documented (P2).

AG3 **Using 360° Video Beyond VDE:** the D360 tool is designed to support collaborative analysis between designers - however participants identified several ways they use 360° video outside of analysis. These included using D360 to familiarize new team members with a context during on-boarding (P1, P3, P5, P6) and using 360° imagery in reports generated for clients (P1, P4, P6). Additionally, participants discussed using the D360 system to aid in using evaluating design ideas or prototypes. Examples given by participants include seeking to understand the impression of urban spaces that people had (P2, P3), asking others for feedback on sports performance (P4), or analyzing a recorded interaction with a prototype (P5).

4.6.3. RQ2: Utility of D360

Both when exploring the functionality in phases 3 and 4 as well as during the critique in phase 5, participants expressed that the D360 system provides additional utility for their use of 360° video. Participants were enthusiastic about the speed and simplicity of making annotations (P1, P2, P4, P6), especially compared with other 360° video software that *"...just doesn't let me note things down quickly"* (P1). The choice to integrate annotations with Miro was also seen as a way to streamline analysis (P1, P2, P3, P6) and aid with sharing insights from 360° video to other designers (P1, P2, P4, P6) and even as a way to present results to clients (P1, P6). Finally, participants pointed to the importance of quickly re-engaging with the 360° video (P1, P3, P4, P5, P6) in order to *"...really see the insight in the context"* (P5).

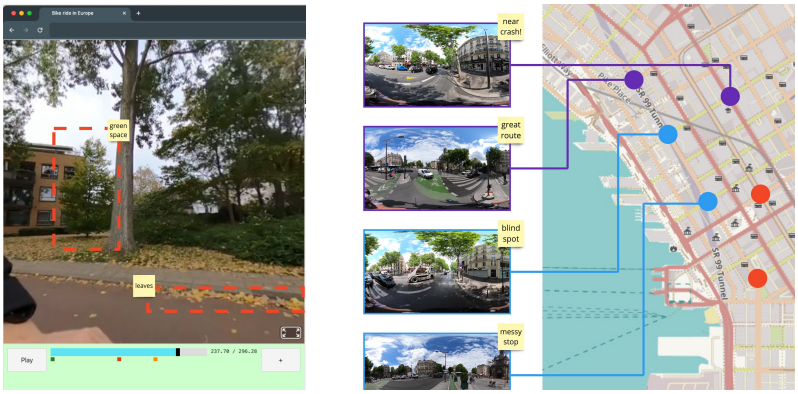
4.6.4. Additional Annotation Functionality

Throughout the sessions, participants provided a number of suggestions for improvements or additional functions (AF) for D360. Here we describe three such suggestions that focus on utility improvements[12]:

AF1 **Refined Annotation Input:** annotations created by D360 simply capture the viewpoint of the user in time, which provided enabled participants to quickly *"...add and annotations and just keep playing the video"* (P5). Participants did suggest more additional annotation functions such as drawing on the screenshots (P1, P2, P4, P6), using voice input (P3, P4), or providing quick

[12] We thank the participants for their input on improving the UI of D360, however these are less transferable to other tools.

numeric ratings (P2, P4). P3 expressed frustration that the button to create an annotation was outside the 360° video, and would prefer to directly add annotations to the 360° frame rather than the sidebar (Figure 4.7a).



(a) A mock-up of the "in-frame" annotation method described by P3.

(b) A mock-up of the map based overview for displaying annotations described by P2, P3, and P4.

Figure 4.7.: Examples of two suggestions for improving D360 provided by participants, in this case used to represent an analysis of bicycle-traffic interactions.

AF2 **Meta-Frame Context:** while participants appreciated the addition of the mini-map in the annotation object (Figure 4.5-B, P1, P2, P4, P6), there were several suggestions for context beyond single frame artifacts.

Some suggestions focused on improving the context around time. For example by providing an overview of the entire 360° video along with specific annotations (P1, P3), adding timestamps to annotations (P4), or providing a short animated sequence of frames before and after the annotation (P2, P6).

Another direction was to use a different dimension to provide context by overlaying annotations onto an interactive map of a city (P2, P3, P4 - Figure 4.7b) or a floor plan of the location the 360° video (P1, P5, P6). Another suggestion was to group annotations based on contextual elements (e.g., parks, supermarkets, factories) close to the camera in the moment of the annotation (P3, P4, P6).

AF3 **Greater Focus on Time:** Participants (P1, P3, P6) expressed frustration about not having enough control over the time of a 360° video video (e.g., frame by frame, playback speed, rewinding) in order to quickly navigate the whole video and then analyze specific moments in detail. When discussing how D360 places annotations in Miro on a timeline, P3 expressed how *"time is linear but not linear, you know?"* – some periods of 360° video have few annotations while other moments have many (P1, P3). Another element of non-linearity is

the fact that some processes that are being redesigned are not recorded in the correct sequence (P6) or in multiple smaller 360° videos (P1, P3) – requiring the rearranging or merging of different 360° videos, potentially from multiple cameras (P1).

4.7. Discussion

In short, our results show that 1. the design guidelines used in the development of D360 reflect the experiences of designers (RQ1), and 2. designers are able to utilize D360 to conduct collaborative 360° video analysis (RQ2).

This means that D360 provides the utility necessary to help designers actually leverage the benefits of 360° video in VDE [43] opening the door to providing richer and more impactful insights [7] in the messy, iterative, and collaborative workflows of designers [2, 17].

Here we will discuss future directions for D360 or similar tools to further support the use of 360° video in design, expand on the concept of "linking" between different types of user research material, and how these kinds of tools could be useful beyond design. Then we discuss the limitations of this study and how future work can overcome them. Finally, we discuss how designers can actively engage with the important issue of privacy and 360° video.

4.7.1. Towards 360° Video as Designer Clay

Ylirisku and Buur [2] discuss the concept of video as "design clay", providing designers with material they can mold into another video by editing, composing, or adding new footage in order to demonstrate the importance of certain current interactions or envision future ones that are enabled by their design. While the design guidelines behind D360 focus on the analysis of 360° video for user research, participants highlighted the value of using D360 to share insights as an output. In this way D360 can provide a rudimentary ability for designers to engage with 360° video as clay - molding by creating a chain of annotations that together provide a new sequence. To enable designers to truly use 360° video as "clay", future tools should provide designers with a simple way to edit 360° videos - quickly creating a series of clips which can be assembled together to illustrate a specific concept and then "baked" into a 360° video provocation that can be shared and serve as a new object of analysis. Moving beyond editing existing videos, tools such as D360 could expand to help designers further leverage 360° video for envisioning, prototyping, and sharing future interactions. For example, by enabling them to quickly sketch 360° storyboards, such as those explored by Henrikson *et al.* [68], which could be overlaid on the real context using 360° videos. Another direction would be to dynamically link clips together in 360° viewing software, giving designers the ability to create "choose your own adventure" 360° experiences that can be used to highlight or explore possible futures. By providing flexible creative tools that integrate into the workflows used by designers, 360° video can truly become a clay that designers use throughout the design process, from analysis, to prototyping, to deliverables.

4.7.2. Linking More Than Video

One of the main mechanisms of the D360 system is the "back-links" created between annotations and the 360° video itself. This helps reduce the complexity of returning to a moment of 360° video described by both our participants and literature [66], which in turn supports the iterative process of sense-making engaged in by designers [11]. Moreover, these links ensure that the rich visual context of 360° video is at hand even when the insights are represented in a simplified, static form – the annotation object – which also enables insights from 360° video to be integrated with user data from other sources. This blending of multiple sources of information in analysis is a core part of design ethnography [10] and is used by participants to reduce the amount of time required to analyze 360° video (AG2).

Here we propose two new kinds of linking to support designers when engaged with multi-modal user research (with or without 360° video) by improving switching between modalities (AG2) and discover similar moments [10, p.54] respectively.

1. **Cross link:** connecting moments (actions, descriptions, results) from different sources of user research material using cross-modal information retrieval [112]. For example, linking a moment described in field notes with the 360° video at that moment as well as a reflection of the subject of the video in a post-hoc interview.

2. **Automatic link:** connecting *similar* moments together to provide multi-modal recommendations [113] for user research material that helps expand the understanding of the analysis or suggesting connections between annotations that would lead to new dimensions of analysis.

To implement these two types of linking in an easy to use and scalable way requires tremendous technological effort. Fortunately, previous research has already explored how to search videos using text [114, 115] or even images of objects [116], which can form the technological basis of both cross and automatic linking.

Crucially, we apply the lens of "linking" to frame the technological development of these AI tools as ways to enable and enhance the messy, iterative, and constructivist process designers [10, 11] rather than automate the entire process. Future tool-kits can provide these links to designers, enabling them to engage with vast amounts of different types of user research material easily and switch between different media to discover insights at the level of detail that fits their analysis at the moment.

4.7.3. Uses of D360 Beyond Design

Based on input from participants and related literature, we propose several use cases for D360 outside of a design context. One use case is education, where 360° video is leveraged to help students engage with environments they would otherwise not be able to access such as construction sites [117] or operating rooms [118]. One example discussed by [29] is how expert analysis of 360° video can support firefighter training. By having an expert annotate a 360° video with "events of interest" and using the video with the annotations to explain the event and the reasoning behind the importance to students. Here, D360 would provide a number of advantages,

by being able to create an annotation session, an expert instructor would be able to share all the events of interest in-situ with the 360° video, enabling students to review these sessions asynchronously. Students could also use D360 to self-annotate a 360° video, the results of which are collected in Miro, providing the teacher with an overview of the students work. The teacher could then analyze their students annotations and quickly bring up the 360° video and associated annotations when discussing with students. Another example of supporting education would be by providing authoring tools (Section 4.7.1), an easy to access viewer, and the ability to ask questions or make remarks via annotations, D360 could support the use of 360° video as a way to for students to engage with cultural heritage [119].

4.7.4. Limitations of the Study

As recommended by Ledo *et al.* [39], our study focused on understanding the *utility* of the D360 tool for the specific target group, rather than the *usability*. However, our study is limited by the number and diversity of designers we engaged with. The emergent nature of 360° video technology [6, 43] restricted the pool of experienced designers we could recruit. Engaging with a larger and more diverse group of designers in future studies could provide more nuanced insights into the utility of the various functions of D360, as well as uncover additional design considerations specific to individual contexts. Nonetheless, our participants' reflections on the utility of D360 align with the activities of VDE described by Ylirisku and Buur [2], suggesting that the utility of D360 is generalizable to the overall practice of 360° VDE.

Additionally, due to the novelty of D360, we evaluated it using a usage scenario and walk-through evaluation. While these evaluation methods do give insights into the utility of D360, to provide a deep understanding designers' use of D360 – what annotations they make, how they differ from those made with conventional video, and how D360 specifically supports their workflow – requires designers to be able to adopt D360 in the wild. By providing the tool to designers everywhere and seeing the behavior of users, future studies can truly understand the utility of D360 without participant bias [120] and in real world scenarios [39]. This would provide rich insights into the longitudinal evolution of the use of D360 (i.e., how its utility changes over the life of the design process, as hinted at in Figure 4.6) as well as how transferable the utility of D360 is to designers from other backgrounds, working in other domains, and with different experiences.

By providing D360 as an open and accessible tool, we aim to enable future studies to understand and expand on how designers engage with 360° video and what utilities of D360 they do not use or are missing.

4.7.5. Privacy and 360° video

When it comes to user research, 360° video sits at a crossroads of flexibility and privacy. While the ability to capture the full visual context enables designers to reframe their analysis to fit "their interests as a designer" [2] even as those interests shift and evolve over course of a design project, it also strips the subjects (active subject *and* passive ones such as bystanders) of 360° video of agency in analysis

as well as giving them no ability to hide from the camera [6] and forces them to share everything. This presents a major ethical concern for the use of 360° video by designers - how can they respect the privacy of users when the advantage of 360° video is contrary to principles like Data Minimization[13]. Based on this friction, we call on designers who use 360° video to consider five principles when working with 360° video from users:

1. **Restrain:** only use 360° video when the additional context is beneficial.
2. **Inform:** ensure subjects understand that 360° video truly captures both the full visual context and audio around the camera.
3. **Empower:** give subjects the ability to censor specific moments or areas of the 360° video.
4. **Restrict:** limit what is available outside the design team by only sharing relevant videos, limit access to relevant stakeholders, and anonymize as much as possible.
5. **Forget:** limit the retention time for 360° videos of individuals to prevent it being used for purposes the subject did not consent to originally.

While these principles are pragmatic guidelines, the larger discussion of the ethics of 360° video remains an open question [6] that intersects with ethics in user research in general. As the ones engaged with understanding the user and their context, designers and researchers should actively engage with this question, both individually and collectively, both within and next to projects.

4.8. Conclusion

The D360 system was developed to support rapid, iterative, and collaborative analysis of 360° video so that designers can leverage the additional visual context it provides. The system consists of a 360° video viewing and annotation tool that exports the annotations to Miro - enabling designers to engage with 360° video and integrate it into their existing workflows.

Our evaluation of the D360 system through demonstration and walk-through with experienced designers demonstrated its utility. Designers are able to use the viewer to quickly explore and annotate 360° video on multiple devices. The Miro integration enables designers to use familiar tools for collaborative analysis and the annotations generated by D360 maintain the full 360° context. Finally, the meta-data collected by the D360 system helps keep track of attributing annotations to team members and provides “back-links” that connect the annotations back to the complete 360° video. Our analysis also elicited addition functions important to designers engaged with 360° video: 1. lowering the threshold of interacting with 360° content, 2. mixing multiple sources of information into user context, and 3. using 360° video for on-boarding new team members or to evaluate design ideas.

[13] Only collecting directly relevant personal information. https://www.edps.europa.eu/data-protection/data-protection/glossary/d_en#:~:text=Data%20minimization

Participants indicated limitations in relation to how D360 creates annotations as well as how to better represent the context and time of annotations. Furthermore, there are limits in the scale and scope of our study, in large part due to the novelty of 360° video in practice. In order to enable future work in addressing these limitations, we have open sourced D360 at [URL removed for review]. By providing D360 as an open and accessible tool, we enable designers to immediately start using 360° video – laying the groundwork for naturalistic case studies that can understand the utility of D360 across different design teams. This also opens up D360 for contexts beyond design such as education or crowd sourcing, and as a research tool for understanding the use of 360° video in those contexts.

In summary, the D360 system represents a significant advancement in the tools available for video design ethnography. It provides a simple, web-based interface for viewing and annotating 360° video that feeds into existing workflows. As open source tool, D360 enables designers to immediately adopt 360° video.

5

Conclusion

The proof of the pudding is in the eating.

Hans de Winter[1]

[1] Instructor for the voorjaarscursus vogels kijken 2024, who provided insightful and friendly guidance on my birdwatching journey.

This dissertation addresses a significant gap in design research: how 360° video can enhance the process of Video Design Ethnography. While conventional video has long been used by designers to capture user contexts and provide temporally rich insights [2, 3], 360° video offers a unique affordance – by capturing the complete visual context around the camera it gives the *viewers* the affordance to navigate the viewpoint of the video, rather than the person recording to control the perspective [4]. Existing studies demonstrated the value of 360° video as material for conventional ethnographic methods [5–9] – however Design Ethnography is a distinctly less structured, more iterative, and more collaborative practice [3, 10, 11], pointing to a gap in knowledge. In other words, prior to this dissertation it was unclear how 360° video might benefit Video Design Ethnography, what challenges it might introduce, and how to enable designers to integrate the medium into their workflows. This work provides the knowledge necessary to understand these gaps as well as tools and practical guidelines that can enable design practitioners to effectively engage in the novel practice of 360° Video Design Ethnography.

In this chapter, I summarize the contributions of my work – first I answer the four research questions defined in Chapter 1. Then, I connect my work with the discourse on design ethnography more broadly. Next, I present the meta-contribution of this work, the Framework for Designerly 360° Video, that provides a theoretical framework for understanding the actions of designers as well as practical guidelines that help support researchers and practitioners. Finally, I reflect on implications and future work that this dissertation implies and proposes as a starting point for future research about 360° VDE.

5.1. Resolving the Research Questions

Chapter 1 laid out three central research questions to guide this investigation, focusing on the benefits, challenges, and techniques to support 360° video in Design Ethnography. These questions are:

RQ1: How can 360° video benefit Design Ethnography?

RQ2: What challenges do designers face when engaging in 360° Video Design Ethnography?

RQ3: How can tangible representations of 360° video support collaborative sense-making?

RQ4: How can digital tools enable iterative engagement with 360° video?

These questions build upon each other: RQ1 examines the motivations for designers to engage in 360° VDE, RQ2 investigates the barriers and challenges that make 360° VDE a practice that needs to be supported, and RQ3 & RQ4 address how specific approaches to design tools can support designers when facing these challenges. In other words these questions lay the ground work and provide knowledge and tools to support 360° VDE as an activity understood by researchers and approachable for practitioners.

5.1.1. RQ1: How can 360° video benefit Design Ethnography?

To re-iterate from Chapter 1, the key advantage of 360° video is that it gives the viewer the affordance to navigate the viewpoint of the video after it is captured, rather than relying on the recording. In Chapter 2 I demonstrate how this affordance gives designers key advantages when engaged in Video Design Ethnography: the increased immersion when viewing, and the ability to develop novel, multi-perspective insights.

The participants in Chapter 2 were able to use the affordance of navigating the viewpoint of 360° video to freely exploring the context as if physically present in the scene. Allowing them to form a deep understanding of the context and how it might *feel* to be in contexts that were different from their own. This immersive understanding of a context is a key element to foster greater empathy, a crucial factor for the outcomes of design projects [56]. More specifically, in Chapter 2 I describe how participants expressed that 360° video enabled them to develop a specific type of empathy – instead of "feeling as" the subject of the 360° video , they instead experienced "feeling with" the subject, in the same space – this type of empathy might enable designers to avoid the (false) promise of empathy discussed by Bennett and Rosner [59]. The importance of this immersive quality of 360° video is also echoed in Chapter 4, where participants pointed to the importance of using 360° video to familiarize colleagues who join the team later, using 360° video to effectively bringing them "into the field".

Additionally, by shifting of selecting where to pay attention (what the subject of the video is and knowing where they are) to *after* capture gives this agency to the viewer [4] – this is the key to rich multi-perspective insights that are simply not possible with conventional video. Unlike a traditional video that locks the viewer to one camera angle, in Chapter 2 I demonstrate how 360° videos enable designers replay events from different vantage points. Specifically, designers can take advantage of this by "exploring both time and space" – they could scrub through the timeline of the 360° video while also panning around the scene at each moment. This freedom allowed them to discover connections within the environment that would have been missed with a single angle recording. I refer to the outcome of this exploration as intra-frame insights: insights that result directly from the ability to connect multiple perspectives with one frame of 360° video.

By looking around, the designer links cause and effect across the scene – a form of insight generation that Porcheron *et al.* [9] also observed (using 360° video to study cyclists, they connected environmental events with the cyclist's reactions). My work confirms this benefit in a design context: designers developed richer and more nuanced insights about user behavior and context than would have been possible with conventional video. They built a holistic understanding of interactions "around" the camera by connecting people, objects, and actions across the 360° field of view in both space and time. Such comprehensive insight, grounded in full context, ultimately leads to better-informed design outcomes.

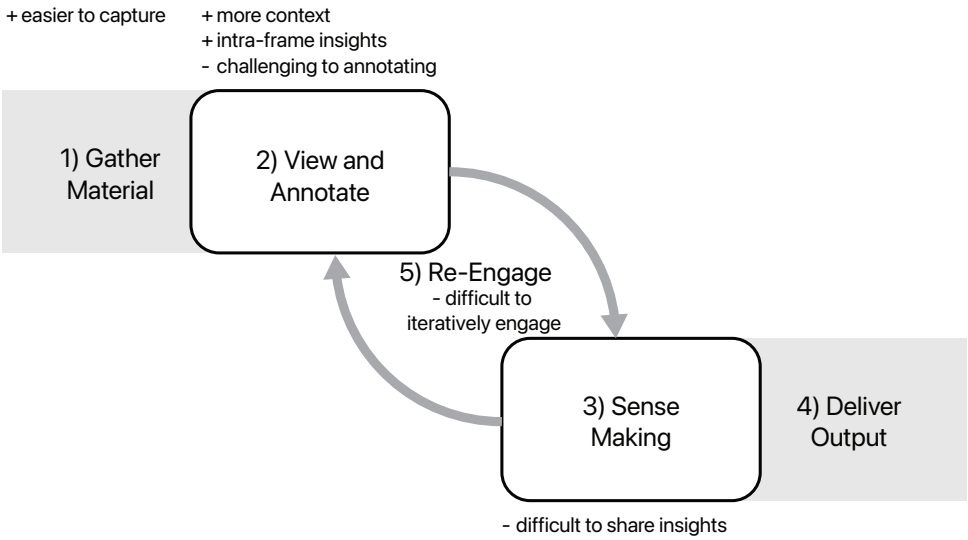


Figure 5.1.: The impact of 360° video (both benefits and challenges) mapped onto the generalized model of the Video Design Ethnography process defined in Chapter 2.

5.1.2. RQ2: What challenges do designers face when engaging in 360° Video Design Ethnography?

Despite its clear benefits, my research uncovered several practical challenges that currently hinder designers from fully embracing 360° video in ethnographic work. In Chapter 2, I identified three main challenges that participants faced: difficulty in annotating and analyzing 360° footage, difficulty in sharing 360° video insights, and difficulty in re-engaging with the material throughout the design process. These challenges help explain why designers have not widely adopted 360° video yet.

First, designers face challenges when annotating and analyzing 360° video. As discussed in Chapter 2, designers are able to view 360° video with a variety of tools, however they struggle creating rich annotations – a core part of Video Design Ethnographic [2, 24]. One challenge for analyzing 360° video discussed in Chapter 2 is the that, while the affordance of controlling the viewpoint gave participants the ability to immersively explore and connect elements of the context, it also resulted in a "Fear of Missing Out", where the amount of visual information made them feel like they were missing elements that could be interesting or even viewing completely different elements of the same 360° video as others. Additionally, designers struggled with creating detailed annotations, specifically, while the VR headset was seen by designers as immersive it limited designers' ability to create annotations (by preventing them from writing notes).

Second, sharing insights from 360° video with a team is not straightforward. In Chapter 2, I show how designers resorted to using multiple "perspective"

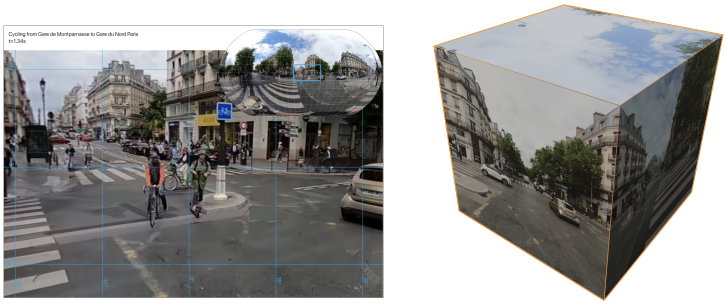
screenshots (flat screenshots of where they were looking) in order to share insights that connect multiple viewpoints within one frame. This means that participants had to arrange multiple individual elements (that got lost and put out of order) in order to demonstrate a single insight – a significantly higher amount of effort compared to sharing insights from conventional video. This difficulty sharing insights is especially meaningful for Design Ethnography, since the analysis process is specifically collaborative [3, p.196].

Finally, designers face challenges in iteratively re-engaging with 360° video. Participants in Chapter 2 did not attempt to re-engage with the 360° video they used to form insights because of the perceived complexity finding the originating 360° video, timestamp, and orientation. This "low searchability" [6] – in other words the complexity of returning to the same moment – of 360° video presents a very real barrier for re-engaging. Similarly, in Chapter 4 participants highlighted that once they had viewed the 360° videos and created initial annotations, they were unlikely to return to the 360° video later in the process – the time and effort required to return to a specific moment within a collection of 360° videos it was simply too high. Furthermore, Chapter 4 highlights how technical challenges such as ensuring that a designer can access all 360° videos from one device, and having access to the correct software or viewing device for 360° video also present pragmatic barriers to re-engagement. Overall, the difficulty to quickly re-engage with the 360° video that lead to an insight presents a barrier to the iterative engagement with material that lets designers develop deeper insights and use 360° video to validate or challenge design ideas.

5.1.3. RQ3: How can tangible representations of 360° video support collaborative sense-making?

Chapter 2 demonstrates that one of the primary challenges designers face when using 360° video is its incompatibility with printed screenshots – the tangible representation of insights that serve as the basis for collaborative sense-making [24]. Opening up the question of what novel representations can be, and how they can support collaborative sense-making. Therefore I created Tangi (Chapter 3), a tool that converts 360° images into two types of tangible 360° video artifacts shown in Figure 5.2 – "flat" that closely mirror conventional artifacts and "sphere-ish" artifacts that provide a 3D shape that approximates a sphere. As I demonstrate in Chapter 3, providing designers with these tangible representations of 360° frames enables crucial interactions for collaborative analysis such as pointing, rotating, arranging and acting as a surface for annotations [25, 28].

Additionally, Chapter 3 highlights two novel functions of tangible representations specific to 360° video: providing a reference frame to orient discussions and providing a link between the overall context and specific details for documenting insights. First, since 360° video provides a complete sphere of video, it is important during collaborative sense-making to establish a common frame of reference, in Chapter 3 I discuss how the design of tangible representations can provide this orientation, either through the use of visual indicators such as graticules or through an elicit alignment of facets for polygonal representations of 360° video. Second, as



(a) Flat 360° video artifact.

(b) A "cube" Sphere-ish artifact.

Figure 5.2.: Examples of the two types of the Tangible 360° Frame artifacts generated by Tangi. Video from Velo Mondial - CC-BY.

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discussed in Chapter 2, the benefit of 360° video for analysis is to be able to connect details from multiple perspectives together within one frame of 360° video, however this requires a way to connect multiple details with the overall context (one of the challenges participants faced in Chapter 2), by providing a tangible representation, this connection between details and the overall context can be maintained, allowing designers to communicate specific insights while keeping their relationships in the context.

Expanding beyond the advantage of tangibility for sharing insights, Chapter 3 also elicited how designers can use the malleability and ease of generating tangible artifacts to construct multi-element artifacts such as timeline or clusters, without needing to interact with complex digital tools – enabling the creation of these artifacts to be done collaboratively during the analysis process, rather than stopping it. Through engagement with designers an additional benefit to creating tangible representations of 360° video occurred, it gave them the ability to "edit" it. Designers were able to engage in a form of bricolage, taking multiple 360° artifacts and combining them together to insert people from one 360° video in the the context of another, or quickly creating a timeline of events with distinct frames.

5.1.4. RQ4: How can digital tools enable iterative engagement with 360° video?

Chapter 2 illustrates that 360° video is challenging to iteratively engage with – once a 360° video insight is made, returning to its origin requires finding the correct file, timestamp, and perspective, a process made challenging due to 360° video's "low searchability" [6]. This means that 360° video exacerbates the challenges with iteration in Video Design Ethnography discussed by Wasson [16] and Buur and Soendergaard [24] – friction in re-engaging with the original source material during the VDE process makes the process slower and discourages iteration.

Therefore I created and evaluated D360 (Chapter 4), a digital tool that provides

three functions to support iterative engagement with 360° video: 1. providing a lightweight, multi-device viewing interface, 2. creating annotation objects that link to their source 360° video, and 3. integrating into the existing workflow of designers.

Breaking this down, first, participants valued the ability of the D360 viewing software to allow them to access 360° video on multiple devices (an opportunity also identified in Chapter 2) while also eliminating the technical threshold of needing to have access to specific software and files (i.e., lightweight). Next, D360 creates annotation objects that are composed of the overall 360° image *and* the perspective of the annotation (supporting the connection between details and context discussed in Chapter 3) – crucially, these annotation objects serve as links to enable designers to quickly re-engage with the source 360° video, at the correct time and perspective. Finally, D360 represents the importance of aligning closely with existing workflows – in this case Miro[2] – participants in Chapter 4 noted the utility of engaging in collaborative analysis of insights from 360° video in with a familiar tool. Beyond reducing the learning curve of adopting 360° video into their workflow, Chapter 4 shows how tools like D360 designers can engage with 360° video insights as other material (field notes, photos, screenshots, etc.), enabling rich, multi-modal analysis. Overall, D360 demonstrates how these three elements enable digital tools to support designers in iteratively re-engaging with 360° video.

5.2. Expanding the Design Ethnography Discourse

Beyond the immediate realm of 360° video, this work contributes to the broader discourse on Video Design Ethnography [2, 17, 23, 24] (VDE) by reinforcing and extending its core principles. In particular, my findings reaffirm the importance of engaging with, and authoring using, materials to support the kinds of collaborative practices found in Design Ethnography. Additionally, this research offers a theoretical insight: making novel media like 360° video integrating into *existing* workflows (rather than new ones) and making it more *malleable* greatly increases its value for design. This aligns 360° video with long-standing design ethnography approaches rather than positioning it as an outlier.

While the benefits of 360° video for ethnography are often discussed at the level of an individual viewer (greater insights, more empathy), my work clearly demonstrates that, in order to benefit Design Ethnography, the material designers work with needs to support (not hinder) collaborative sense-making – both during in-person workshops (like the 360° version of the Video Card Game Method [24] discussed in Chapter 2) and asynchronously (supported by persistent, tangible artifacts in Chapter 3 or by digital tools as in Chapter 4). In order to enable this kind of collaborative sense-making, it is necessary to give designers the ability to share their insights (i.e., tangible artifacts), but also re-engage with the original 360° video (i.e., with an easy to access viewing tool) – principles that are not reflected in more conventional ethnographic uses of 360° video [6, 7]. This aligns with the work of Buur, Jensen, and Djajadiningrat [22] and Buur and Soendergaard [24], who explore how to enhance the process of conventional VDE by making the complete

[2] A widely used online-whiteboarding tool.

video *easier* to view collaboratively – there is a need to leverage the richness of materials during sense-making, but it should not impede collaboration, but enhance it. In Chapter 2 I describe how the spherical nature of 360° video prevented designers from engaging with the material in an easy way (i.e., designers had to use multiple screenshots that they manually held together), my work with Tangi shows that, by changing the embodiment of an artifact, it is possible for designers to engage in the same with with 360° video material. This is an important lesson for all *richer* materials for Design Ethnography, if the material representation does not lend itself to creating a boundary object [18] that designers can use to frame discussion, it will challenge the process. This means that for other sources of rich material, such as sensor enhanced video explored by Gorkovenko *et al.* [121], it is crucial to develop representations that designers can interact and align with. Collaboration is not simply a quirk of Design Ethnography, but a core attribute that must be supported [3, p.196].

A theoretical contribution of this research is the importance of the *malleability* of a medium in relation to its usefulness in Design Ethnography. More specifically, a material that is malleable (e.g., easy to modify, cut, combine, change, etc.) enables designers to more deeply engage with it [25]. By looking closely at 360° frames while modifying them, participants in Chapter 3 were able to find new insights and combine different views – an interaction that was only possible because the paper-based artifacts generated by Tangi are malleable, allowing designers to engage in bricolage [90, 122] and create new meaning, insights, and ideas by modifying the materials at hand.

Ylirisku and Buur [2] discuss how the editability (i.e. malleability) of video allows designers to use it as a "clay" – moving beyond using it for analysis but also using it to create compilation videos that embody specific insights insights or even using videos to present the impact or outcome of the design process. It is easy to create an assemblage of videos from users, along with videos created by designers that insert their solutions into the context. Unfortunately, 360° video is much less malleable – participants in Chapter 4 noted that they were unfamiliar with editing 360° video and envisioned a strength of D360 as a way to segment and "rearrange" different 360° videos.

In summary, an overarching contribution of this dissertation is contextual and theoretical: it situates 360° video within the established practices of Design Ethnography, reaffirming the importance of bringing material into the collaborative engagement and calling for a focus on enabling designers to use rich materials such as 360° video by ensuring they are malleable. Rather than treating 360° video as an entirely new paradigm, my work weaves it into the workflow of Design Ethnography – essential for not just isolating it as a nice practice, but weaving it into the process designers use and making it possible to integrate 360° video with other materials.

5.3. Framework for Designerly 360° Video

One of my aims with this work is to provide knowledge that helps support the practice of 360° Video Design Ethnography – knowledge both about the process

and about how to support that process. To this end, I synthesize the "Framework for Designerly 360° Video " that helps illustrate how 360° video gets adapted by designers. In this section I build this framework up by: 1. looking at the novelty of 360° video in terms of the affordances it presents to the viewer to construct an interaction space, then 2. showing how different design actions and tools navigate that space – specifically 3. reflecting on how Tangi and D360 support designers in navigating the space, and finally 4. using the framework to illustrate potential new tools to support 360° VDE in the future. By presenting both a space and a way to navigate it, my framework provides a comprehensive way to both describe design action and to frame and motivate future tools.

Affordances of 360° Video

It is possible to examine 360° video through a lens of affordances [20] – in other words, what it allows a viewer to control – Gaver [19] points out that "media spaces" offer several affordances for viewing information – affordances for vision (i.e., capturing an image), affordances for listening (i.e., capturing sound), and affordances for motion (i.e., capturing a sequence). This last affordance – motion – is what makes video such a useful medium for observation, it "...capture[s] activities as they unfold in time" [2, p.26], and most importantly, lets the *viewer* determine the important moments, rather than the person capturing the information (as would be the case with field notes or discrete photos). From the perspective of a team engaged in Video Design Ethnography, this is the key affordance of video – being able to navigate the temporal aspect of the material during analysis. Now we can use the

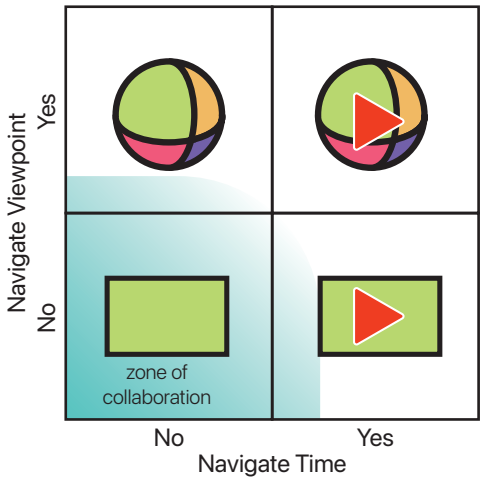

Figure 5.3.: The Framework for Designerly 360° Video , showing the affordance space based on two affordances of 360° video – navigating time and navigating viewpoint – as well as the "zone of collaboration" within it.

concept of affordances to clearly describe what 360° video adds onto conventional

video – the affordance of changing the viewpoint. As Jokela, Ojala, and Väänänen [4] states "...the viewer of the 360-degree picture[3], not the camera user, could then afterwards select the subject and the viewpoint that they wanted to focus on. Thus, we can say that 360° video presents two major affordances for viewers – navigating through the time of the material, and navigating the viewpoint of the material. It is this ability to control both aspects that makes 360° video such a rich material, and these affordances enable designers to develop richer, more holistic, and unique insights. These two affordances enable us to create a simple "interaction space" for 360° video compared to other material, with two binary "dimensions" – the affordance of navigating the time of the material and the affordance of navigating the viewpoint of the material. This space is shown in Figure 5.3, which also illustrates that this space connects 360° video (yes time, yes viewpoint), a 360° frame (no time, yes viewpoint), a conventional video (yes time, no viewpoint), and a conventional frame of video (no time, no viewpoint).

Figure 5.3 also shows the "zone of collaboration" – an illustrative gradient of the "ease" of engaging in collaborative analysis with the materials. The purpose of this illustrative zone is to connect the affordance of consuming the material with the "preferred" affordance of collaborating with the material. For example, the work of Buur and Soendergaard [24] on the Video Card Game Method highlights that of giving participants in a workshop access to the affordance of time (i.e., having full videos rather than the video cards) reduces the collaborative discussions and prevents designers from engaging equally with the material – whereas using the video cards (i.e., no time, no viewpoint) enables designers to engage with each-other *and* allows for important tangible interactions [25] that are not possible with videos. For the other dimension in the space we the affordance of viewpoint, here we also see a decrease in the "ease" of collaborative engagements – the affordance of viewpoint complicates engagement in two ways. Printed 360° video frames are inherently distorted – especially when it comes to understanding the spatial relations between different areas of the frame [30]. Using a digital viewing tool means there is no distortion, but falls into the same issue as giving designers access to a complete video; it breaks the discussion [24]. While some design teams might be more willing to deal with these challenges, there is still a clear advantage to collaborating with material that is static both in time and in viewpoint – thus designers need to move the material they engage through the space.

Navigating the Space

How do designers move their material through the space? There are two key actions: authoring and re-engaging. Here I refer to *authoring* as the explicit act of creating a lower affordance version of the material – when a designer selects frames of a video they author an artifact (a lower affordance representation to embody insights). The same goes for removing the affordance of navigating the viewpoint from 360° content, the designer is authoring a distinct way of looking at the material – an artifact that serves to embody *their* insights, a subjective interpretation [3, p.88]. The

[3] or in our case video.

reverse action is "re-engagement", that is, going from an authored artifact back to the original material – for example to share the importance of an insight [2, p.107] or to aid in negotiating between members of a team [17]. These actions are (or

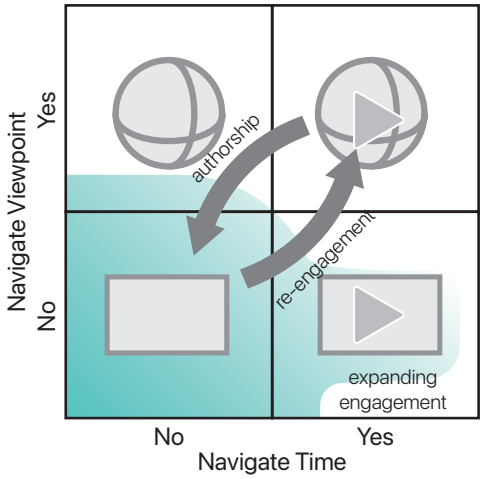

Figure 5.4.: Navigating the framework – designers can "author" artifacts that reduce the affordances of the material they work with and share, or they can "re-engage" and return to material with more affordances. Tools can both support designers in making these moves, and support expanding engagement by making it easier to collaboratively engage with material.

should be) enabled by tools – in order to author a frame artifact, designers need the ability to freeze a video, extract the frame, and (possibly) transform it into a tangible embodiment. While this is very easy with modern computers and printers, it still requires designers to use tools, and thus those tools need to be made. An example of a tool that supports re-engagement is the Video Mosaic [27], which lets designers author frame artifacts (screenshots) and re-engage with their source video. We can use the movement to map the challenges designers face when engaging with 360° video – a lack of annotation tools makes it difficult to author artifacts, and similarly a lack of tools that support re-engagement complicates collaboration. In other words, adding the affordance of navigating the viewpoint means that 360° video is further from the zone of collaboration.

However, this zone of collaboration is not static, it can be changed with tools. For example, by providing designers with a "Video Action Wall" that made viewing and interacting with videos more open and physically accessible to everyone in a workshop setting, [22] in a sense lowered the effort required to engage with the affordance of navigating time – in turn expanding the zone of collaboration. Similarly, Tang and Fakourfar [32] provided two people with the ability to view 360° videos together, showing a potential path to ease the engagement with 360° video (and 360° frames) during design workshops – although this remains to be explored.

Figure 5.4 illustrates how the space can be navigated, both in terms of designers

authoring and re-engaging (i.e., changing the affordances of the materials they interact with) and based on how tools enable designers to more easily collaborate with material with affordances.

Understanding Tangi and D360 within the Framework

Now it is possible to map my tools (Tangi and D360) in this framework – as is shown in Figure 5.5. First, Tangi is a tool that expands the zone of collaboration – it makes it easier for designers to collaborate with 360° frames because it creates tangible artifacts (thereby enabling tangible interactions important to collaborative analysis such as stacking, annotating, etc. [25]) that have less distortion than simply printing out the 360° frames. Therefore, the artifacts Tangi generates make it easier to collaboratively analyze material that provides the affordance of navigating the perspective. However, because it does not provide the ability to take screenshots of 360° videos, Tangi does not provide designers the complete ability to engage in authorship – instead it relies on designers using other 360° video viewing tools which have screenshot functionality. On the other hand, D360 is more directly aimed at

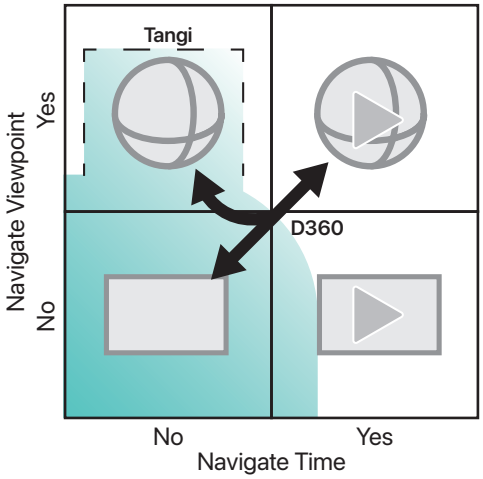

Figure 5.5.: The two tools covered in this work - Tangi and D360 - mapped onto the framework. Tangi expands the zone of collaboration by making 360° frames into tangible artifacts that designers can use in workshops, while D360 supports authorship and re-engagement by providing annotation and viewing tools for 360° video.

supporting designers with authoring and re-engagement. It provides a viewing and annotation interface that generates both 360° screenshots and perspective ones (thus providing two author moves with one action) *and* the artifacts it generates provide links to quickly re-engage with the full 360° video – supporting designers in easily moving the material they work with through the space.

Using the Framework as a Guide

Now that I have established the framework *and* mapped out my contributions to navigating it, it is possible to demonstrate how other designers and researchers can use the framework to inform new research or tool development. One obvious starting point is the connection between Tangi and D360, we can see that D360 enables authorship of 360° frames, which Tangi can then make easier to engage with. Outside of the tools I created there is a clear gap for a tool to author conventional video from 360° video – while this is partially covered by 360° video editing software provided by camera manufacturers, it is important to ensure that there is also support for re-engagement, *and* that the video is still embodied or augmented in such a way that it is easy to engage with. Another direction is to expand the zone

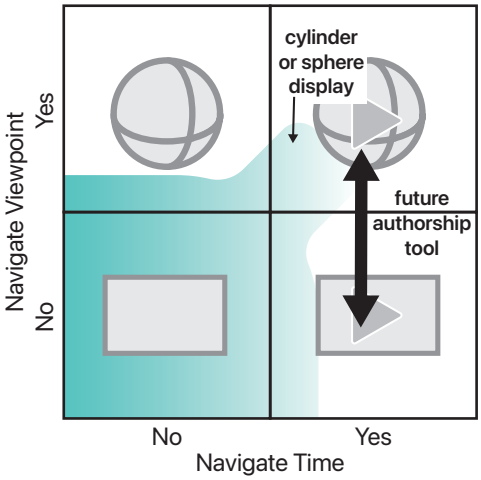

Figure 5.6.: Two potential future tools mapped onto the framework – future authorship tools can support the path between 360° video and conventional video, while novel displays could make it easier for designers to collaboratively engage with 360° video in workshops.

of collaboration for 360° video. Earlier I mentioned the collaborative 360° video viewer made by Tang and Fakourfar [32], this serves as a basis for exploring methods to ease this engagement, either by providing advanced software that bridges the gap between the individual act of view 360° video and the need to collaborate or potentially by changing the embodiment of 360° video using cylindrical [123] or spherical [124, 125] displays. These possible directions are mapped in Figure 5.6.

To summarize, this framework represents a major contribution of this work – it provides an interaction space that connects the affordances of materials with the actions of designers, it illustrates the impact of these affordances on collaborative analysis, it provides mechanisms for both navigating the space and expanding the zone of collaboration, and it helps illustrate how the two tools I developed support different design actions and work together. Finally, this framework provides directions for future development, and I encourage other designers and researchers

to engage with it to inspire novel ideas and help frame their work through this framework.

5.4. Reflections

Beyond the formal findings and contributions, there are broader reflections to acknowledge – nuances and considerations that arose from the process of this research as a whole (and through the creation of this dissertation specifically). These reflections address the context and scope of my work and are important for understanding how to apply the insights and tools responsibly. I discuss three such reflections here: 1. clarifying who the "designer" is in the context of this dissertation, 2. recognizing that 360° video is not a standalone solution for all design research needs, and 3. considering the ethical implications of using 360° video in ethnographic work.

The "designer" in this work

In this dissertation I address designer(s) as if they were a homogeneous and well defined group – it simplifies the narrative, but it does not do justice to the diversity of the people who call themselves designers. To clarify, when I say designer, I am specifically referring to:

> A member of a team[4] who actively engages in ethnographic research with the goal of informing a design process.

In other words, the designer discussed in this work is someone engaged with the techniques Müller [11] discusses as being synonymous with Design Ethnography: quick and dirty ethnography, short-term ethnography, rapid ethnography, and, design ethnography. Crucially, this does not necessarily align with job title – a user researcher, a design ethnographer, a product designer, or even an engineer could all fit this description, as long as they engage in understanding a context and the people within it to feed the design process. For example, participants who I engaged with had varying levels of experience with design and Design Ethnography, but none of them explicitly identified as "design ethnographers" – thus I refer to them (and the subjects of this research) as "designers" who are engaged in an ethnographic process.

This leads to an important point: I deliberately use the term "designer" instead of using the label of "ethnographer". For one, Design Ethnography is a small part of the larger design process, that loops back into DE (the iterative nature discussed by Crabtree, Rouncefield, and Tolmie [3]). But most importantly, I am aiming specifically at the distinct act of design ethnography (i.e., quick and focuses on areas for change rather than formal description [11, p.3]) and its indifference to formal, prescriptive methods [3, p.67]. To this end, by addressing "designers," I position the work squarely in the domain of design practice, highlighting that the tools and

[4] While individuals *can* engage in Design Ethnography, it is almost always a collaborative process [3, p.196], and thus those are the designers I focus on.

methods are for those who engage in the design – even if they do not use the term ethnography.

In reflection, using the umbrella term "designer" is useful to not only keep the dissertation cohesive, but also to ensure the correct audience for the outcomes of this work. By avoiding the term "ethnographer" and highlighting the "designer" as a target, it connects with both practitioners who identify as "design ethnographers" as well a those who simply identify as "designers".

360° Video Alone is Not Enough

In order to simplify the storyline, motivation, and discussion of this work, I present 360° video as an obvious and important advancement for Design Ethnography. While I have show that 360° video provides designers with unique insights and a richer understanding of context, it is important to frame it within the broad range of material that designers can engage with. Firstly, 360° video is a tool for *observational* user research – important for understanding what people do and the context, but as discussed by Sanders and Stappers [63] is only one mode of understanding people. Interviews, surveys, and especially generative co-design methods (like having users sketch or create artifacts) can reveal things that observation alone cannot. For example interviews can uncover motivations or internal thoughts that are not visible in a (360°) video, and generative methods can elicit the thoughts and creativity of the person who is *actually* being designed for [63]. That being said, for observational methods in Design Ethnography, I have demonstrated and believe that 360° video offers significant benefits for designers.

That being said, designers do not only gather one material when engaging in observational Design Ethnography. This is because there is additional information about the context – who was there, field notes and photos from a member of the team who captured the 360° video, data gathered from desk research [3]. All the data that is gathered, embodied in different materials, gets analyzed together [10, p.53] – which requires them to co-exist on the same level of interaction. This blending of different sources is one of the main reasons why the challenge of sharing insights identified in Chapter 2 is crucial – and why Chapter 3 used tangible representations of 360° video, in the same way that conventional video artifacts enable designers to engage with video insights on the same level as other material [24, 126]. This importance of enabling insights from 360° video to co-exist with other materials is one of the main insights from Chapter 4 – by integrating 360° video into an online white-boarding tool designers were using for other material (Miro), D360 allowed designers to connect insights from different materials and use field notes to inform where to look in 360° video and insights from 360° video as evidence for the findings in field notes.

Finally, it is important to discuss the fact that, while more immersive than other materials, 360° video is not a replacement for real experiences – both real engagement with the context [3, p.82] or as a replacement of the experiences and thoughts of the people in the context themselves [59]. 360° video provides a contextual richness that is extremely valuable, but it addresses only certain questions. It presents the complete visual context, enabling deep understanding of

the environment. It enables viewers to change their viewpoint within the 360° space, allowing them to explore complex interactions for multiple perspective, leading to a deeper understanding of what happen and why. However, it still only provides visual information and sound, and is not a replacement for other sources of information. Like any useful tool, it is up to designers to understand how, when, and where to use (or not use) 360° video and the accompanying tools covered in this work.

However, I take a more pragmatic approach – while conventional RtD projects focus on generating knowledge and meaning over multiple iterations, I have a tighter focus – enabling the novel practice of 360° Video Design Ethnography.

However, unlike more open RtD, I started both projects with a , however I focus more pragamtically on using these artifacts

Ethical Use of 360° Video

One of the assumptions in this dissertation is that designers can gather 360° video of their users – practically (as discussed by Jokela, Ojala, and Väänänen [4]) but also ethically (an open question put forward by Tojo, Oto, and Niida [6]). This is because the core advantage of 360° video – that it captures the full visual context – is inherently at odds with the concept of "data minimization" [5]. How can designers bridge wanting to collect as much info because they do not know what they will need with protecting the privacy of their subjects by only collecting the data they need.

One answer to this quandary is to anonymize the 360° video using techniques such as face-swapping [127], however this means designers can no longer trust insights from people's facial expressions or where they look, and more fundamentally that someone's face is not the their only identifying attribute. Instead I encourage designers to actively inform and engage with their subjects using the Sensitive Data Donation framework proposed by Gómez Ortega, Bourgeois, and Kortuem [128]. Most important for 360° video, the framework highlights the importance of working with participants to help them understand the sensitivity and use of their data (something people with little experience with 360° video might not understand), and to establish ongoing informed consent, where participants are made aware of how and why their data is being used (especially useful for the flowing process of design ethnography. Naturally, if someone is an unwilling participant (i.e., they appear somewhere in the 360° video, but are not involved in the process), then remove them from the visual record if at all possible. Finally, techniques such as those proposed by Gómez Ortega, Bourgeois, and Kortuem [128] help structure a good-faith engagement with participants, but designers are still ultimately responsible for their participants, and thus should use these as a *minimum* for engaging with sensitive data, rather than the most they should do.

5.5. Limitations and Future Work

Like all works, this dissertation and its findings and outcomes have limitations – some are the result of deliberate choices in scope, others from shortcomings in time,

[5] See: https://en.wikipedia.org/wiki/Data_minimization

structure, and access. Acknowledging these limitations is important because it not only contextualizes the findings but also points to fertile areas for future work. Here, I discuss two main limitations: (1) the separation of the two tools (Tangi and D360) and the need for an integrated workflow, and (2) the fact that the studies were conducted with artificial design questions rather than in long-term real-world design projects (i.e., "in the wild"). Here I outline how these limitations provide rich future work.

Bringing Tools Together

The two tools discussed in this dissertation – Tangi (Chapter 3) and D360 (Chapter 4) – were conceptualized, developed, evaluated, and documented as research papers in parallel. This is because the opportunities for these two tools discussed in Chapter 2, which is the origin for the two tools, are independent. Creating artifacts to share insights from 360° videos (Tangi) is important for sense-making and collaboration it is not necessary or relies on annotating and iteratively engaging with 360° video (D360). While this specialization allowed each tool to be honed for its specific purpose, it means that we did not formally study a scenario where both tools are employed by the same team on the same project.

On a pragmatic level, there is no reason the tools cannot be used in conjunction with each other. For example designers could use D360 to view and annotate 360° videos, then pass 360° images D360 generates to Tangi to create tangible 360° video artifacts. These artifacts can be used in collaborative sense-making workshops, however as discussed in the end of Chapter 3, the artifacts Tangi creates do not (currently) provide a mechanism to connect back to a digital representation. Initial tests with adding QR codes to the artifacts show that they can easily act as "tokens" that point back to their originating moment in a 360° video in the D360 viewer – a workflow that could be automated in a new version of Tangi.

Such a combined workflow raises interesting research questions: Where are the "seams" when transitioning from a digital tool like D360 to a physical tool like Tangi? Do designers naturally gravitate to one or the other first? Does starting with tangible artifacts change what annotations you make later, or vice versa? By engage with designers using both tools, we can identify any friction and develop design recommendations for a more seamless integration of tangible and digital ethnography tools.

Even more importantly, combining both tools can lead to new capabilities, and elicit insights, than the individual studies I conducted. For example, tangible artifacts could act as tokens for a tangible 360° videos editor [96] – enabling designers to quickly combine and rearrange clips of 360° video that get picked up by a digital tool for further refinement and viewing. This concept of "tangible editing" could also be used to mark areas of interest physically that get annotated digitally as well, or even add elements to 360° videos (via annotations).

In summary, while Tangi and D360 are individually validated solutions to specific challenge with 360° VDE, their separate development limits potential interactions that bridge their respective physical and digital approaches. Future work should start by simply integrating these tools to see how their combined use elicits knowledge

about the use of tools and needs for future tools for 360° VDE. Building from there, future work can explore how these two different domains – tangible and digital – can be combined to leverage the benefits of both for more intuitive and malleable use of 360° video by designers.

Understanding 360° VDE in the Wild

Another limitation is that all the studies in this dissertation were conducted in somewhat artificial settings – time-bounded workshops, rather than organic, months-long design projects owned by a design team. While I took care to recruit experienced practitioners and make the tasks realistic (e.g., using design briefs and scenarios that resemble real projects) – the short term use is not the same as evaluating the tools in the wild, on actual design problems that matter to the participants over an extended period. This was largely due to practical constraints: it was not possible to find a design team who were willing to use 360° video and allow me to embed myself in their work long term.

This means that, while I present clear advantages and challenges of 360° video, there are undoubtedly use-cases and design requirements for the tools I evaluated that will only emerge from real world use. For example, participants in Chapter 4 noted the importance of using 360° video to on-board new team members or convince clients – a process I was not able to recreate in order to understand how D360 did or did not support this need.

Future work should aim to deploy 360° video tools in real design projects ("in the wild") – by providing a team with a 360° camera, Tangi and D360, and some training, it is possible to observe and elicit how their use of 360° video evolves over the design process and how the tools are able or fail to support those interactions. The goal would be to see how designers incorporate 360° video not only in initial ideation and requirement setting, but also to help reflect on and evaluate design requirements [17].

This kind of longitudinal study would be able to understand the trade-offs between different materials and different tools throughout the design process, and more importantly, give insights into the direct impact of 360° video on the design process. In Chapter 2 I describe how designers are able to generate novel insights from 360° video, as well as form different modes of empathy, however it is difficult – I would argue impossible – to really understand how this impacts the eventual design result without a study that is able to connect how the insights gathered from 360° video impact the design decisions later on in the process. Finally, an in-the-wild study would solidify the external validity of the contributions. While I worked to ensure that the designers I engaged with had real world experience and were not all from the same team, there are a multitude of different approaches to VDE, and thus to 360° VDE. By engaging with multiple design teams, it will be possible to identify if the design guidelines I generated are transferable to different designers working in different contexts, or if there are limitations to the applicability and impact of these findings. This is all rich ground for future work, building off of the novel insights and early, exploratory evaluations of tools I conducted in this work.

In summary, moving from lab to field is an important next step for understanding

and supporting 360° VDE. It is important to understand how diverse design teams in real-world situations use 360° video and the tools I created in this work, and see how much of my findings are transferable – and what the boundaries of that transferability are. Finally, going in the wild will provide insights into the rich and complex interactions designers have with their tools throughout the design process – something that I was not able to do, but will help expand and strengthen 360° VDE.

5.6. Closing This Work

In conclusion, this dissertation has demonstrated how embracing a new medium – 360° video – can generate new knowledge *for* Design Ethnography and *about* Design Ethnography. Mainly, 360° video, when supported by thoughtful tools and methods, can deepen designers' understanding of users and contexts, enrich collaborative sense-making, and inspire creative new ways of engaging with research data. These realizations were possible by enabling designers to "design their own tools" in a research context – taking research insights and applying them to tools that support the practice of 360° VDE, and using them as a probe to again generate research insights. The foundational ideals of design from Schön [12] and others are reflected throughout this work: from reflecting-in-action with new materials, to iterative sketching and prototyping of processes, to recognizing the tacit knowledge embodied in artifacts.

This work enhances the practice of Design Ethnography by providing both tools and knowledge for practitioners – but also for other researchers. By highlighting the importance of not just documenting design action but engaging in active, generative research, I hope to encourage renewed interest in Design Ethnography and how other rich materials can benefit it. Ultimately, this work provides a monumental step to the goal of fostering the practice of 360° Video Design Ethnography, not just because it is interesting, but because the richer, more empathic, multi-perspective insights it generates can enable the development of products and systems that truly fit into their context and the needs of the people within it.

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A

Additional Materials

A

A.1. Additional Material for Chapter 2

A.1.1. Semi-Structured Interview for Chapter 2

1. Usability:
   - 1.1: Overall, how would you describe your experience today?
   - 1.2: What were your biggest frustrations? What went well?
2. Use of video:
   - 2.1: Can you describe a bit about how you used the video?
   - 2.2: Can you talk about how you used the 360° nature of the videos?
3. Impact (empathy)
   - 3.1: Could you describe the cycling experience in [your context]?
   - 3.2: What techniques did you use to identify important moments?
   - 3.3: How did you identify (with/as) the cyclist during the ride?
4. Applicability (future directions):
   - 4.1: What feature/functionality would you want to add?

A.1.2. List of 360° Videos for Chapter 2

Title	URL
360° VR Bike Commute - Ortigas Avenue to Robinsons Galleria Bike Parking	https://www.youtube.com/watch?v=Az7l412k9po
Ayala Malls Cloverleaf Bike Parking 360° VR Bike Commute	https://www.youtube.com/watch?v=p25FJjkWvo8
Recto Avenue to Legarda bike lane and Flyover 360° VR Bike Commute	https://www.youtube.com/watch?v=q1kawpEhv0o
Magsaysay Boulevard, Legarda, Recto 360° VR Bike Commute	https://www.youtube.com/watch?v=X-AFalkcWcU
360° VR Bike Commute - Mckinley Hill to Venice Grand Canal Mall Bike Parking - with GoPro Max	https://www.youtube.com/watch?v=ExqUiLyA0u8

Table A.1.: The videos used for the South East Asian (SEA) context of the study in Chapter 2.

Title	URL
Insta360 VR 360° Look at NYC | eBiking Cycling New York City Manhattan | Park Ave | Times Square	https://www.youtube.com/watch?v=ulwzg7mIKuA
VR 360° Virtual Cycling Harlem NYC | Biking New York City	https://www.youtube.com/watch?v=nTDQsukmyTY
360 Degree Bike Riding in Vancouver BC Canada	https://www.youtube.com/watch?v=iWwBIzMKQag
Cycling Downtown Toronto - 360° VR Video	https://www.youtube.com/watch?v=nssJpiRYDTw
Rideau Street Bike Ride in 360° Downtown Ottawa Cycling Tour to the Parliament of Canada Spring 2021	https://www.youtube.com/watch?v=kL7KTO7B4-U

Table A.2.: The videos used for the North America (NA) context of the study in Chapter 2.

Title	URL
Cycling to Gare du Nord Paris	https://www.youtube.com/watch?v=5OMXDKevBeY
Cycling from Gare de Montparnasse to Gare du Nord Paris	https://www.youtube.com/watch?v=L8OGy9NeqRU
Cycling from Gare de Montparnasse to Gare du Nord Paris	https://www.youtube.com/watch?v=_UaMffM_png
Paris Streets in 360 VR Video by Bike 1	https://www.youtube.com/watch?v=jiAUTSLJZpM
Paris Streets in 360 VR Video by Bike 2	https://www.youtube.com/watch?v=iSjh6zGhyvw
Paris BusBike lane	https://www.youtube.com/watch?v=0gcXcrkJU6k

Table A.3.: The videos used for the Western Europe (WE) context of the study in Chapter 2.

A

A.1.3. Ideation Template

Figure A.1.: The template used during the ideation phase of the second workshop discussed in Chapter 2. First participants were asked to individually fill out one template for each idea they had for improvements to the workflow of using 360° video. Once finished, participants were asked to share their ideas and fill in new templates for ideas that came up during the discussion.

A.2. Additional Material for Chapter 3

A.2.1. 360° Videos used in Chapter 3

Table A.4 contains a list of the example 360° videos provided to participants during the study discussed in Chapter 3. These videos were selected based on cases used in previous literature [34, 43]. Participants were free to search for or request additional videos, although only P5 briefly attempted to.

Video Name	Context	URL
Ayala Malls Cloverleaf Bike Parking 360° VR	Cycling	https://youtu.be/p25FJjkWvo8
Cycling to Gare du Nord Paris	Cycling	https://youtu.be/5OMXDKevBeY
Astrobee robots in 360° | Cosmic Kiss	Space	https://youtu.be/ZfFssKBiOn8
Space science in 360° | Cosmic Kiss	Space	https://youtu.be/Hrg4yxhHOOM
Firefighter Training - Overview	Firefighting	https://youtu.be/BLx6rLj2Ziw
360° cockpit view | SWISS Airbus A320 | Geneva – Zurich	Flying	https://youtu.be/HEEIzZ7UjRg
How To Land An Airplane | 360° Interactive Cockpit	Flying	https://youtu.be/4Vb22o1NsEw
BrightFarms Virtual Reality Greenhouse Tour	Gardening	https://youtu.be/bcKm3yxWOQI

Table A.4.: The example videos provided to participants during the evaluation of Tangi and the artifacts it produces.

A

A.3. Additional Material for Chapter 4

A.3.1. Usage Scenario D360

Based on our engagement with designers using 360° video before and after the expert evaluation (Section 4.5), we describe how an iterative Visual Design Exploration (VDE) process aimed at identifying automation opportunities in industrial kitchens could benefit from the capabilities of D360. This work is conducted by a team of three designers — Alex, Ben, and Chloe — with support from engineer David. This usage scenario demonstrates how D360 facilitates designers conducting VDE based on observations of designers using 360° video for a VDE process. The design task and clusters are illustrative and do not reflect the quality of insights generated in a real process.

Initial Annotation. Alex and Ben independently annotate 360° videos using the D360 viewer. Due to motion sickness, Alex prefers the desktop interface, while Ben opts for the immersive VR headset experience. To accelerate the process, they annotate different sets of videos from various kitchen types. Each creates initial action clusters for potential automation. Alex's clusters are based on perceived emotional responses to tasks, while Ben's are grounded in perceived automation difficulty.

Collaborative Sense-Making. Alex and Ben spend three hours in a meeting room aligning their annotations. Alex begins by sharing their overall video impressions, annotation method, and cluster formation. Ben follows suit. They then use Miro to merge overlapping clusters. However, Ben questions the relevance of the "creative complex cutting" cluster as their videos lacked such actions. Alex promptly demonstrates these moments using the D360 viewer. The session concludes with Alex and Ben agreeing to refine their annotation process by mapping tasks based on the "mundane-novel" and "easy-complex" axes.

Onboarding Chloe. New designer Chloe joins the team and uses the Miro board to understand the VDE process thus far. The D360 viewer clarifies ambiguous annotations. Chloe observes that the "difficult to automate" cluster primarily contains early annotations by Ben. They suggest Alex and Ben revisit relevant videos to reassess automation difficulty.

Sharing with David. To incorporate expert input on automation feasibility, David joins the design team for a generative session to create three functional concepts. Alex, Ben, and Chloe share their evolving understanding of kitchen dynamics throughout the VDE process. David proposes creating a task timeline, which Chloe promptly implements using the D360 viewer and Miro. The session results in three automation concepts outlined on the Miro board. Post-session, David leverages the Miro board and D360 links to inform other automation engineers about the specific needs and goals of the three concepts. Two concepts are subsequently prototyped and evaluated in a test kitchen. For convenience, the evaluation is recorded using 360° cameras but cropped to a conventional field of view due to the designers' familiarity with the context.

Importance of D360 This example highlights D360's role in supporting the iterative nature of VDE, particularly its ability to facilitate rapid video revisiting and collaboration – functions that are not possible with current 360° video tools. Additionally, the example illustrates how, by integrating annotations into

conventional tools (i.e., Miro), D360 enables design teams to use 360° video along with other sources of information in collaborative. Finally, the example underscores the value of screenshots and annotations for conceptualizing and sharing 360° video insights, while D360 enables seamless re-engagement with the full 360° view when needed.

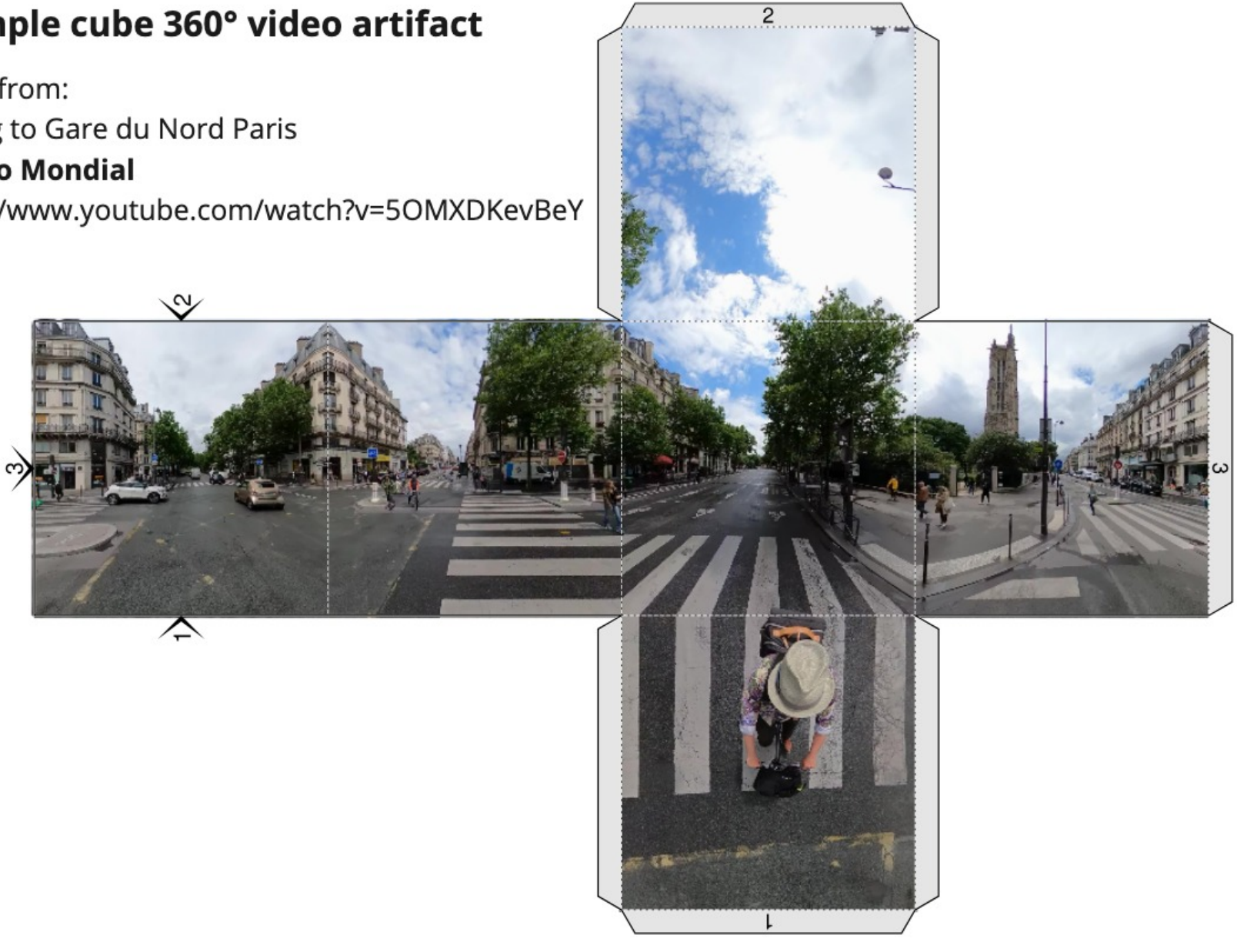
B

Example Tangible 360° Video Artifacts

Here are two example tangible 360° video artifacts generated by Tangi (as discussed in Chapter 3). Each artifact is credited to a video by Velo Mondial CC-BY – I want to thank them for providing so much 360° video footage with a Creative Commons license so that not all the photos are of me.

Example cube 360° video artifact

Taken from:
Cycling to Gare du Nord Paris
by Velo Mondial
https://www.youtube.com/watch?v=5OMXDKevBeY



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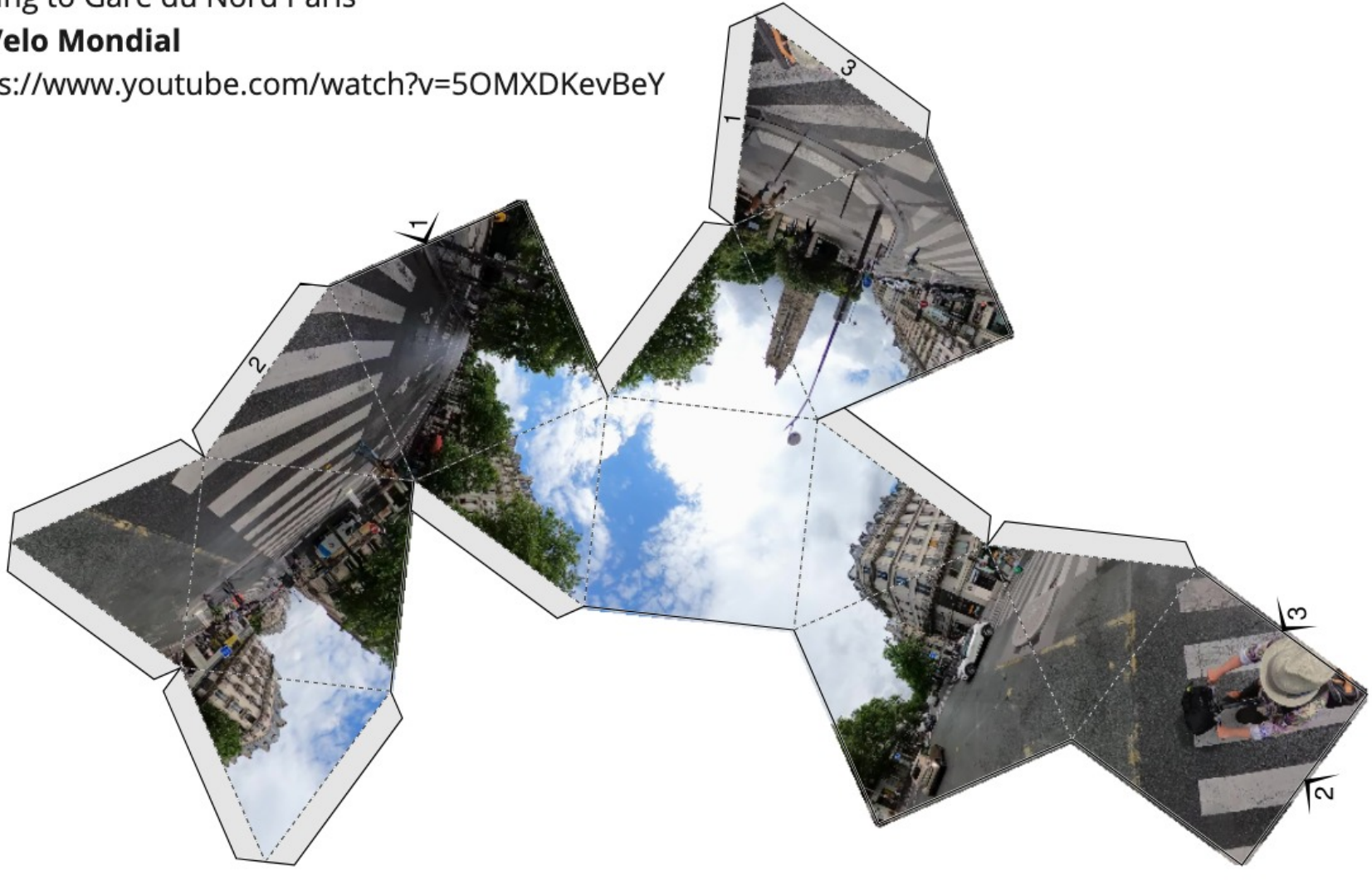
Example geodesic octahedron 360° video artifact

Taken from:
Cycling to Gare du Nord Paris
by Velo Mondial
https://www.youtube.com/watch?v=5OMXDKevBeY



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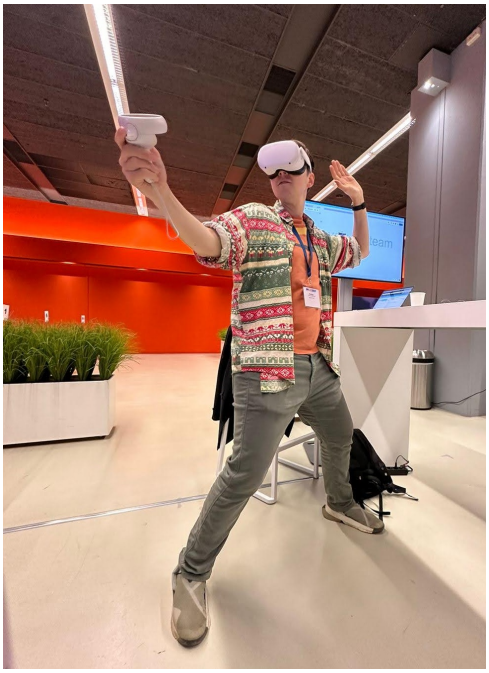
About the Author



The Author using a VR headset to annotate 360° video.

Wouter "Wo" Meijer was born on September 13th, 1993 in the Netherlands, but moved to Seattle when he was 7. There he started his main interests of improvisational theatre and building robots.

He returned to the Netherlands, specifically Delft, and did a bachelors in Mechanical Engineering (boring), a masters in Industrial Design (more fun), worked for a bit, and then did the research that makes up this dissertation during his PhD.

In the future, who knows what he will do. But he will try his best to make it interesting and make sure he and his family and friends thrive. Because he is a little witch, trying his best[1].

[1] Like Kiki [1].

List of Publications

1. W. Meijer, J. Bourgeois, T. Dingler, and G. Kortuem. "Tangi: a Tool to Create Tangible Artifacts for Sharing Insights from 360° Video." In: *Proceedings of the Nineteenth International Conference on Tangible, Embedded, and Embodied Interaction*. TEI '25. New York, NY, USA: Association for Computing Machinery, Mar. 2025, pp. 1–14. DOI: 10.1145/3689050.3704928

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3. K. P. Venkatraj, W. Meijer, M. Perusquia-Hernandez, G. Huisman, and A. El Ali. "ShareYourReality: Investigating Haptic Feedback and Agency in Virtual Avatar Co-embodiment". In: *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems*. CHI '24. New York, NY, USA: Association for Computing Machinery, May 2024, pp. 1–15. DOI: 10.1145/3613904.3642425. URL: https://dl.acm.org/doi/10.1145/3613904.3642425

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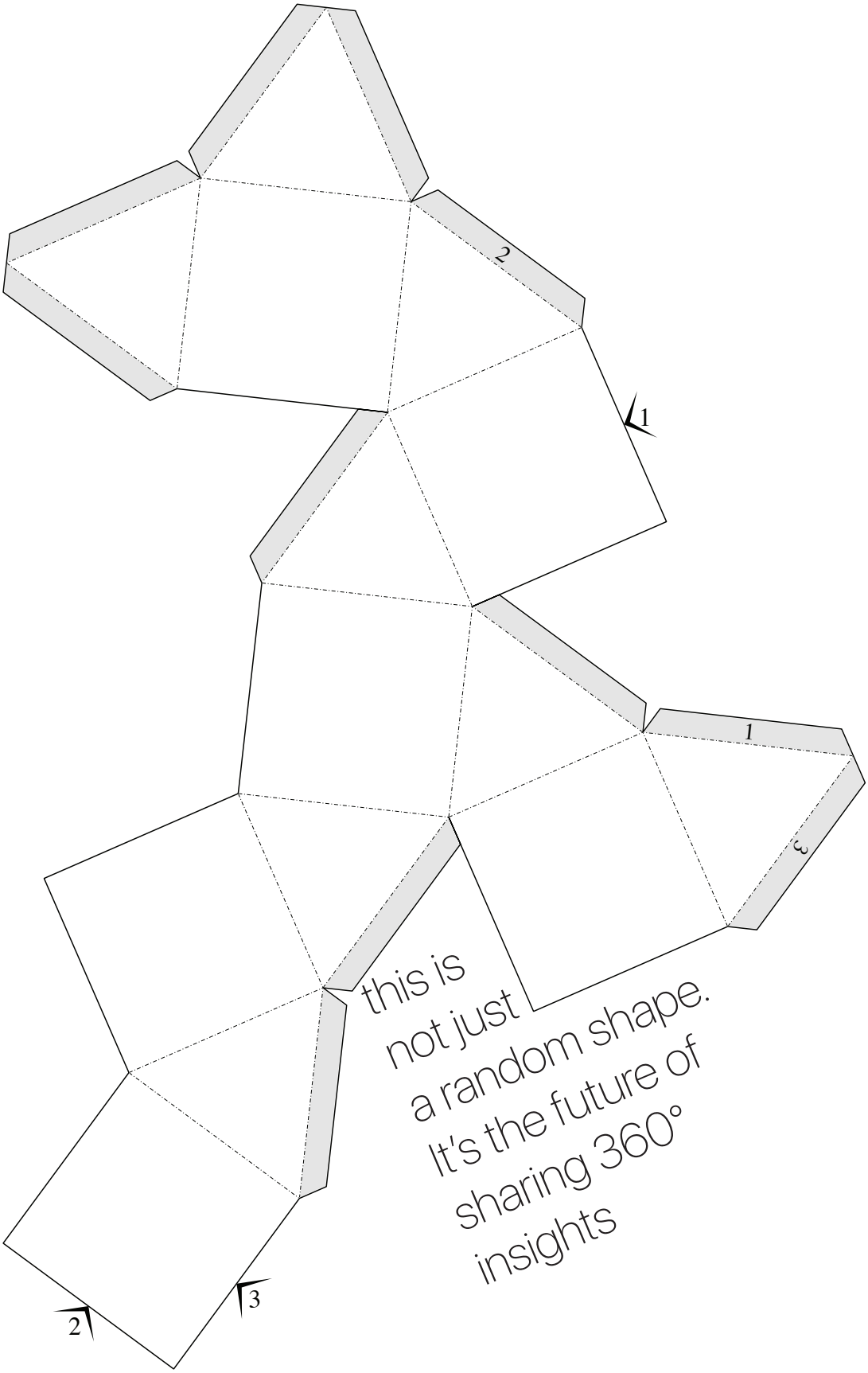
7. A. Gomez Ortega, J. van Kollenburg, Y. Shen, D. Murray-Rust, D. Nedić, J. C. Jimenez, W. Meijer, P. K. K. Chaudhary, and J. Bourgeois. "SIG on Data as Human-Centered Design Material". In: *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems*. CHI EA '22. New York, NY, USA: Association for Computing Machinery, Apr. 2022, pp. 1–4. ISBN: 978-1-4503-9156-6. DOI: 10.1145/3491101.3516403. URL: https://doi.org/10.1145/3491101.3516403

8. W. Meijer. "Destructive Feedback: a user created strategy for collecting user feedback in shared systems". In: *ETIS'22: Fifth European Tangible Interaction Studio*. 2022. URL: https://pure.tudelft.nl/ws/portalfiles/portal/147626431/paper1.pdf



this is
not just
a random shape.
It's the future of
sharing 360°
insights