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Crime scenes in Virtual Reality

A user centered study

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Brottsplatser i Virtuell Verklighet – En användarcentrerad studie

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ABSTRACT

A crime scene is a vital part of an investigation. There are however, depending on the situation and crime, issues connected to physically being at the scene; risk of contamination, destruction of evidence or other issues can hinder the criminal investigators to stay, visit or revisit the scene. It is therefore important to visually capture the crime scene and any possible evidence in order to aid the investigation. This thesis aims to, with an initial research question, map out the main visual documentation needs, wishes and challenges that criminal investigators face during an investigation. In addition, with a second research question, it aims to address these in a Virtual Reality (VR) design and, with a third research question, explore however other professions in the investigation process could benefit from it. This was conducted through a literature review, interviews, workshops and iterations with the approach of the Double Diamond Model of Design. The results from the interviews were thematically analyzed and ultimately summarized into five key themes. These, together with various design criteria and principals, acted as design guidelines when creating a high fidelity VR design. The first two research questions were presented through the key themes and the VR design. The results of the third research question indicated that, besides criminal investigators, both prosecutors and criminal scene investigators may benefit from a VR design, although in different ways. A VR design can, in conclusion, address the needs, wishes and challenges of criminal investigators by being developed as a compiled visualization and collaboration tool.

ABSTRAKT

En brottsplats är en vital del av en brottsundersökning. Det finns emellertid, beroende på situation och brott, problem som är kopplade till att fysiskt befinna sig på brottsplatsen. Risk för kontamination, förstörelse av bevis eller andra problem kan hindra brottsutredarna att stanna, besöka eller återvända till brottsplatsen. Det är därför viktigt att visuellt dokumentara brottsplatsen och eventuella bevis för att bistå utredningen. Detta masterarbete ämnar att, med en första forskningsfråga, kartlägga de viktigaste behoven, önskemålen och utmaningarna gällande visuell dokumentation, som brottsutredare möter under en utredning. Vidare ämnar projektet att, med en andra forskningsfråga, möta dessa i en Virtuell Verklighet (VR) -design och, med en tredje forskningsfråga, undersöka hur andra yrkesgrupper i en utredningsprocess skulle kunna dra nytta av den. Detta genomfördes genom en litteraturstudie, intervjuer, workshops och iterationer grundat i tillvägagångssättet Double Diamond Model of Design. Resultaten från intervjuerna analyserades tematiskt och sammanfattades i fem huvudteman. Dessa teman, tillsammans med olika designkriterier och principer, agerade designriktlinjer vid skapandet av en high-fidelity VR-design. De två första frågorna presenterades genom nyckeltemana och VR-designen. Resultaten gällande den tredje forskningsfrågan visar att, utöver brottsutredare, både åklagare och kriminaltekniker kan dra nytta av en VR-design, även om på olika vis. Sammanfattningsvis kan en VR-design möta utredarnas behov, önskemål och utmaningar gällande visuell dokumentation genom att utvecklas som ett kompilerat visualiserings- och samarbetsverktyg.

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ABSTRACT
A crime scene is a vital part of an investigation. There are however, depending on the situation and crime, issues connected to physically being at the scene; risk of contamination, destruction of evidence or other issues can hinder the criminal investigators to stay, visit or revisit the scene. It is therefore important to visually capture the crime scene and any possible evidence in order to aid the investigation. This thesis aims to, with an initial research question, map out the main visual documentation needs, wishes and challenges that criminal investigators face during an investigation. In addition, with a second research question, it aims to address these in a Virtual Reality (VR) design and, with a third research question, explore however other professions in the investigation process could benefit from it. This was conducted through a literature review, interviews, workshops and iterations with the approach of the Double Diamond Model of Design. The results from the interviews were thematically analysed and ultimately summarized into five key themes. These, together with various design criteria and principals, acted as design guidelines when creating a high fidelity VR design. The first two research questions were presented through the key themes and the VR design. The results of the third research question indicated that, besides criminal investigators, both prosecutors and criminal scene investigators may benefit from a VR design, although in different ways. A VR design can, in conclusion, address the needs, wishes and challenges of criminal investigators by being developed as a compiled visualization and collaboration tool.

Keywords
Interaction design; Virtual Reality; crime, prototype; Virtual Environments; point cloud; laser scanning; forensics; investigation; crime scene; DDMD; criminal investigator;

INTRODUCTION
Violent crimes have attracted the attention of people throughout history, from Jack the Ripper who terrorized the streets of London in the autumn of 1888 [24], to more recent crimes such as the double murder involving O.J. Simpson in the United States 1994 [9] and the terrorist attacks of Anders Behring Breivik 2011 in Norway [5]. From the 1800's to modern time the investigation methods and documentation techniques have changed drastically. Back then, murders were often solved due to a known relationship between the victim and the perpetrator with a straightforward motive [24]. However, nowadays there are technologies and techniques used during crime scene investigations that enabled the Crime Scene Investigators (CSIs) and forensic scientists to visually document the scene and secure evidence to facilitate and aid police investigations.

There is a problem with physically being at a crime scene. The risk of contamination and destruction of evidence increases with the passing time after finding a body [3] or a crime scene and the amount of people present at the scene [16]. Sometimes the opportunity to stay, visit or revisit the initial scene is also hindered [26] for different reasons. Currently the majority of the larger forensic laboratories around the globe are using, besides photography and video recording, laser scanners to document crime scene information in a three dimensional (3D) environment [6]. Laser scanning is seen as overall the most reliable and precise technology, when it comes to documentation and visualization in 3D [ibid]. The documentation of the scene with laser scanners allows for the chance to analyse and measure the crime scene with high precision, even years after obtaining the scan [3]. This method opens up new possibilities for forensic analysis and documentation, as well as visualization since it *is* possible to analyse (trajectories, line of sight, length measurements etc.), visualize and reconstruct a crime scene and the events virtually after the scene has been scanned [6]. The user also has control of the navigation throughout the environment and can interact with it in real time [28]. The 3D models of a crime scene are usually visualized on a two dimensional display or paper. When visualized on paper the perspective of the point cloud and 3D model need to be preselected to show a certain event or point of view. This can however lead to preconceptions and loss of information due to the lack of 3D perception of the preselected perspective [10].

By introducing Virtual Reality (VR) to crime scenes, the dilemma of not being able to visit the crime scene in its initial state could be addressed. This could be done by letting criminal investigators visit the crime scene virtually, and letting them decide where and how to view the scene in its initial state. In the forensic community VR is gaining attention and it is seen as a possible tool for visualizing crime scenes for different purposes e.g. to reconstruct/animate the crime at the scene for investigators, actors within the court system, witnesses etc. [10]. It is clear that VR application for crime investigations is an area in need of more research. Furthermore, the questions of how to apply the technology and in what way are still questions that remain unanswered in full. With this in mind the purpose of this study is to map out the visual documentation needs, habits and challenges for criminal investigators and see how VR can be introduced to fulfil them. This is done by answering the following research questions.

- What are the greatest needs, wishes and challenges of criminal investigators regarding the visualization of a crime scene and its documentation?
- How can these needs, wishes and challenges be addressed in a VR design?
- What other stakeholders in the investigation process could benefit from the design and how?

BACKGROUND
Forensics
Forensic science is the collective term regarding the scientific areas which can be used to assist judicial actors. Biology, chemistry, physics, information technology and legal medicine are some of the areas included in this term. Forensics is the practical application of these to, among other things, assists litigations, reconnaissance- and intelligence activity [20].

Forensic investigation

When there is a reason to believe that a crime has been committed, a forensic crime scene investigation is done at the location in question, and depending on the situation its surroundings. The first ones at the scene are usually the uniformed police who seals of the scene and contact the Criminal Scene Investigators (CSIs). They also start talking to surrounding people so that the CSIs get an idea of where the forensic investigation should be performed [20]. During the first phase of the CSIs' investigation, prior to any other investigatory actions of the CSIs, the scene is visually documented. The purpose of the forensic investigation is to clarify as to whether a crime has been committed and if so, how? [20] According to Jamieson the definition of a crime scene is "*...any space or item that contains, or potentially contains, physical evidence that a crime has been committed or connecting something to someone to that crime*". The types of evidence that must be included, if possible, in a crime scene examination includes physical and circumstantial evidence as well as eyewitness testimony [16]. Before the crime scene is altered in any way, the crime scene investigator needs to make sure the scene is correctly documented. It is important during the securing of possible evidence to document its appearance, location and orientation [20].

Visual documentation and visualization

The visual documentation of the crime scene and the visual securing of possible evidence are done with photography and video recordings. Photography is, such as traditional and if necessary panorama, an important method regarding visual documentation and visual evidence gathering. When photographing crime scenes it is of the utmost importance to meet the possible need for overview-, close up- and detailed imagery. It is important to end up with a high quantity of informative pictures, since pictures can seem relatively insignificant during the initial state but become valuable later on [20]. In Sweden these photos are inserted into a report, see section *Forensic protocol* and *DurTvå*, along with other digital generated material [ibid]. According to a forensic scientist at the Swedish National Forensic Centre (NFC) photographing in a non-specific order can become troublesome when trying to get a good perception of how all documented evidence relates to the scene. Having a crime scene thoroughly visually documented could potentially minimize the amount of people needed at the scene. This could be done by having documented scene details available for staff at, or distant from, the scene and thereby reducing the risk of contamination [16]. Video recording is used as a complementary visual documentation method to photography in order to get a description of the surroundings. It is often used as an initial visual documentation method of a crime scene. This because having a representation of how the crime scene looked initially is of great value even though the level detail is often less in video recordings than in photographs. It is also used when recording walkthroughs with witnesses etc. at the scene [20].

Forensic protocol

In Sweden the result of a forensic investigation is reported in a forensic protocol. This so that the criminal investigators (CIs), the preliminary inquiry investigator, prosecutor and if necessary other stakeholders can take part of the knowledge connected to the crime and the crime scene. The content of the protocol includes all the information CSIs believe is of importance to the investigation [19]. This could be location descriptions, observations, secured evidence, analysis results etc. with complementary information and visual documentations and visualizations etc. All of the digital generated material is also included in the forensic protocol [4]. According to [10] the visualization and presentation of point clouds, see section *Laser scanning*, and 3D models intended for the CIs will most likely be Two Dimensional (2D) visualizations on screens or paper.

DurTvå

DurTvå is, stated and confirmed by a Crime Scene Investigators (CSIs) in training at NFC, a software where Criminal Investigators (CIs) can write, attach and take part of different kind of documents, scanned receipts, notes, PM's, suspicions etc., everything connected to and of interest to an investigation. Forensic protocols, analysis, images and other external documents not created by the CIs personally are also included. Based on the content in DurTvå a preliminary inquiry protocol is created for the prosecutor when the investigation is done. Each case has a specific case number (K-number) and possible evidence collected at the crime scene are categorized into "goods and traces". Evidence of this nature receive a goods number (G-number) and/ or a trace number (S-number) when added into a software program for CSIs called TekPro. Traces can be swabs, shoe prints, fingerprints etc. while goods and other coercive measures are confiscated/ seized and therefore also given a confiscation/ seizure number (B-number) when added in DurTvå. A confiscated/ seized goods could then first be added to DurTvå where it receives a B-number and then given a G-number when added in TekPro by the CSIs which will be visible for the investigators through the forensic protocols added as an external document in DurTvå.

Laser scanning

For medium and long range laser scanners the actual scanning is done by emitting a laser beam towards the surroundings, while quickly rotating it up to 360° horizontally and vertically, minus the area of the ground where the scanner is placed. Depending on the scanned surface, millions of 3D coordinates of surface points are computed into a point cloud [8][1]. A laser is usually combined with a camera, so the resulting laser measurements and photographs can be combined into e.g. coloured point clouds [6]. For shorter distances up to 2m, close-range laser scanners are more suitable. The scanning technology is different than of the long range, however a more dense 3D reconstruction is created. This method is used when documenting weapons, victims, bones etc. in detail that can be of value to an investigation [3].

The value of crime scenes in 3D

It is possible to measure etc. distance within a point cloud and thereby get answers to questions maybe not asked when at the crime scene, or view the scene from new perspectives. According to [8] the accurate scaled and coloured data obtained from laser scanning can be seen as " virtual conservation of evidence". It can be used to visualize the scene to different stakeholders e.g. investigators and the court. The visualizations can be shown from different perspectives such as from the victim's or perpetrator's point of view or narratives [3][21]. Other than this, the values of laser scanning and virtual environment/ 3D crime scenes are; visual documentation of locations hard to keep closed from the public for a longer period of time or that are not available at a later stage, securing of evidence that are sensitive to the touch, witness statements verifications, office briefings, training, lightning evaluation as well as virtual reconstructions regarding course of events and much more [26] [14]. According to Ebert et.al the reason why 3D documentation techniques were adopted by forensic professionals is because of the problem regarding the loss of information when a 3D environment is stored as a 2D projection on

a photograph or screen [10].

Previous and related work

Virtual Reality (VR) and Virtual Environments (VE) have been utilized in many different fields. They have been used in a study as a treatment tool for phobias and other exposure therapies [34], as an affective medium [27], for burn pain treatment [23], to view body scans at different scales and by using a data glove surgeons and patients are able to interact with them [18].

The use of 3D technologies and techniques for crime investigations have been researched extensively. In 2012 a novel mediated reality system was designed and analysed in order to enable the collaboration between crime scene investigators and their remote expert colleagues. This by virtually enable the experts to, in an augmented space, join and interact with the investigators who were wearing a head-mounted display[1] (HMD) at the scene [25]. VR and VE have also been utilized in a case study evaluation where users with an HMD were fully immersed and then by using a 3D interactive hand-held mouse interacted with the environment. The user had the possibility to explore a crime scene while looking for information connected to the crime. It was made clear that VE of crime scenes can be greatly beneficially for analysis, training and briefing presentations, but it has to be highly accurate and with a high fidelity. The needed fidelity level does vary from application to application [32]. Ebert et.al proposed an application area for immersive VR technique by presenting a system that will enable crime scene investigators to visit the scene virtually as if they were standing there themselves. The investigators were "present" at the scene of a crime while viewing a reconstructed animation of said crime. According to Ebert et.al, using VR could be a solution to the current visualization problem, where 3D reconstructions are projected onto a 2D display and thereby reduce spatial information [10]. VR can raise both physiological as well as social responses from users similar to the responses they would have in the physical world [13].

Design guidelines for VRGUI

When it comes to interfaces and standard interaction devices for 3D virtual environments there was, in 2005, no standardization nor any specific guidelines for its practice [12]. This has as far to the authors' knowledge not changed. However, in 2016 a Bachelor Degree Thesis summarized research regarding design principles for VR Graphical User Interfaces (VRGUI) into ten discovered guidelines [12]. The following is a summary of the guidelines applied in this thesis;

- Allow users to be lazy and do not require them to turn their heads and bodies unnecessarily.
- It is also recommended to create 2D alternatives in 3D UIs since 2D tasks are easier in a cognitive manner than 3D tasks and will therefore increase usability. 2D input devices are also recommended to be used instead of 3D input devices.
- Objects in VR need indications as to whether they are intractable and active as well as using the human instincts when designing GUIs in VR.
- Interactive objects should also, when in VR, not be placed less than 75cm and no more than 3 meters away from the user.
- Finally, if using head-gaze[2] or other gaze input modalities, a cursor or crosshair to indicate where the user's gazing is recommended [12].

Usability criteria for VE

Breaux et.al. presents in their paper [30] an approach to create usability in VE system design and evaluation. This is done in a structured manner called "Multi-criteria Assessment of Usability for Virtual Environments (MAUVE) system". This was created due to the lack of design principles when designing VE User Interfaces (UI) since these UIs are different regarding e.g. perspectives and physiological interactions from traditional Graphical User Interfaces (GUIs). The purpose of the developed principles was for them to act as design and evaluation heuristics. Depending on the goals of the VE system the importance of the principles categories will differ. The following sections will address the criteria relevant in [30] and addressed in this thesis.

Interaction

Interaction has been defined as "...the general look, feel and behaviour as the user interact with an application" [30]. The hierarchically sub-classed principles of interaction are, *Navigation*, *Object Manipulation* and *Wayfinding.*

Navigation: The users should be able to move and travel in a controlled and free manner so the ability to perform tasks in different positions is enabled. This should not be cognitively difficult but a natural and stream-like behaviour.

Object Manipulation: This has been defined as "...the process of indicating virtual objects within an environment to reposition, reorient or query them." The user-interaction-experience within VEs is fundamentally dependent on the selection and manipulation of objects. The ability to realize which objects are selected or active as well as providing other interaction options such as rotating objects, manipulate levels of detail when required and change attributes are important depending on the tasks.

Wayfinding: If users find it challenging to realize where in the VE they are, or wishes to be located the result may be a poor task performance in effectiveness and efficiency. Therefore it is important to add visual and navigational assistances.

Presence

This principle has to do with the stimulation of psychological factors such as the feeling of "being there" in a VE and not at one's physical location [32] as well as the tendency to react/ respond to the VE and its objects as if they were real [13]. The usability of a VE system may be influenced by the level of experienced presence by the users since it is believed that a higher feeling of presence may increase the user's' involvement. Some general guidelines, regarding how the VE could look like, to increase the sense of presence, is to have the environment simple but keeping the natural and realistic look and to be able to have direct contact with virtual objects [30].

Immersion

This principle has to do with the stimulation of physiological factors, it is somewhat of a system driven involvement [32] and refers more to the interface configuration and e.g. setup of the VR [13]. There are different factors to be considered when striving to increase the sense of immersion. Some of these are needs to feel isolated from the physical world, control and interaction, to feel included in a situation and the perception of that one can move by oneself. The sense of immersion is also important when dealing with VR applications [32][30]. It is more likely to experience a

[1] A HMD is a head-worn headset or helmet containing displays located in front of the user's eyes which provides a stereoscopic wide view of the VE [11] or augmented reality.

[2] Head gaze is an interaction input simulating the gaze with and as a cursor placed mid-air, centred in the user's field of view [12].

higher sense of presence, and thus gain a more real and valid behaviour, the more immersed one feels. This is especially true when speaking of stressful, unethical, unconventional or socially undesirable behaviour [13].

RESEARCH AND DESIGN PROCESS

The research approach and design process of the high fidelity VR design is based in the Double Diamond Model of Design (DDMD). In this model the idea of diverging and converging the design process in four stages is applied. The first stage purpose is to "expand the thinking to explore the fundamental issues" so that the problem can be defined in the second convergent stage. In the third divergent stage the solution is explored widely before it is delivered in the fourth convergent stage [22]. The first stage consisted of a literature review and interviews to map out the visual needs, wishes and challenge of visual documentation of crime scenes and their documentations CIs face during an investigation, as well as the technology behind it. The second stage consisted of the analysis of the results from the interviews that were used to define the main needs, wishes and challenges mentioned above. The third stage, based on the defined areas from the second stage, consisted of two workshops to kick-start the design process of the VR design and open up for several design suggestions and ideas. The fourth and final stage consisted of the creation of the high fidelity VR design.

Interviews and meetings

To better gain an understanding of the field of forensics before the first stage, a meeting was held with a forensic scientist at the NFC (National Forensic Centre). During the meeting the main topics were laser scanning, crime scenes in 3D and their value to forensic analysis and investigations. After the meeting and the literature review qualitative data was gathered through semi-structured telephone interviews with three Crime Investigators (CIs), two Criminal Scene Investigators (CSIs), one prosecutor and one professional who creates visualizations for the prosecutor, making the prosecutor's presentation of a case easier to understand for the district court and court of appeal. The main target group in this study consists of the CIs, however, the other professionals were interviewed in order to get a broader insight into the investigation process, and to determine if they have, along with the CIs, a common need for visualization of a crime scene and its documentation.

A pilot interview was initially held in order to prepare and make sure no important questions were forgotten. During the telephone interviews, when, where, how and why visual documentation was needed and utilized were discussed as well as the experience-based opinions regarding the potential inadequacy in this process. The first questions covered the interviewees' background and previous experience in order to later elaborate on their opinions and experience regarding visual documentation and the visualization of a crime scene and its documentation. The final stage of the interviews covered their opinions regarding more modern technologies such as laser scanning and 3D models as well as if, and in that case how, they could see value in introducing VR to investigations as a visualization tool for crime scenes and their documentations. All interviews were recorded and then transcribed to facilitate the analysis of the qualitative data.

Design

The Design process was carried out both at the Royal Institute of Technology KTH in Stockholm and then finalized at NFC headquarters in Linköping.

Workshops

After the interviews, answers were sorted by profession and then analysed through an approach inspired by thematic analysis. Two main interaction scenarios were identified; *Interaction with goods and traces in an environment* and *interactions that affects the environment in some way*. These two interaction scenarios cover the visualization needs of crime scenes and their documentation as well as confront the challenges found. After analysing the interviews, two video workshops were conducted with the layout and implementation inspired by [33].

The first workshop was held with five Master students within Human Computer Interaction (HCI) and Interaction Design at The Royal Institute of Technology (KTH) in Sweden. The second one was conducted with three forensic scientists and two forensic scientist trainees, one with a background in military research regarding 3D visualization and use of different kind of 3D sensors. During the workshops the participants got to focus on the two interaction scenarios mentioned previously. These two workshops contributed with different design angles and served together with design guidelines for VRGUI [12] and MAUVE [30] as the foundation of a low fidelity paper design suggestions and thus the iterated high fidelity VR design.

Software and Hardware

The high fidelity VR design was created by using the following soft- and hardware:

- 360° panorama photos taken by a laser scanner at a staged crime scene.
- HTC vive – An HMD immersing the user in a VE [15].
- Storyboard VR– A prototype visualization tool in VR by Artefact [31].
- Adobe Illustrator and Photoshop

Implementation of the design

The low fidelity paper design suggestions were iterated several times with forensic scientists and a forensic scientist trainee at NFC. The feedback was taken into consideration when moving forward with the designs. The final step was to transfer these designs into Storyboard VR where a staged crime scene was experienced and visualized through VR.

RESULTS

In this chapter the most important results and findings from the interviews along with the workshops and finally the high fidelity VR design is presented.

Interviews

The aim of the interviews was to map out the needs, wishes and challenges concerning the visualization of crime scenes and their documentation. The interviews results were thematically analysed so the qualitative answers from the semi-structured interviews were sorted into different categories in a hierarchical fashion. The top three categories became the different professions; *CIs*, *CSIs* and *prosecutor*. Each of these then have the subcategories; *physical crime scene* and *visualization of a crime scene and its documentation* where the following categories were identified; *Needs*, *Wishes* and *Challenges.*

Criminal Investigators (CIs)

CIs are the main target group in this thesis and are therefore most in focus in this section. Two out of three CIs said, when asked, that they deal with visual material either in their own office or meeting

rooms with colleges through computers, projectors etc. They also had no or close to no hands-on experience with VR.

Physical crime scene

What all CIs have in common is the need to, preferably as soon as possible, visit the physical crime scene. This is done in order to get a detailed- and overview of the location, a feel of the surrounding space, distance, and possible movements, where items are located at the scene and their relation to each other, bullet trajectories etc. By having been able to see the location for themselves beforehand, the investigators understanding may be greater than it would have been had they only had the location described to them by witnesses, a forensic protocol, suspect etc. This was the greatest need and wish identified for all CIs interviewed; being able to visit the crime scene.

When it comes to other needs regarding the crime scene, two out of three CIs mentioned that they would like to be able to discuss with colleagues what they have seen at the scene, different theories. Also mentioned were the needs to make complementary scene investigations and a way to present their knowledge of the scene, and what has been found there, to those who do not know the material as well they do. When it comes to visiting the crime scene (apart from the risk of contaminating the scene) only having a limited amount of time to spend there was deemed as an investigatory challenge. This can influence the investigator's perception in different ways.

"[...] if I could be able to walk around as much as I would like too, if the body is laying there bleeding, then I would have a good picture. But it's a limited amount of time I've got there at that moment and you forget things and you do not really know what to look at/ -or for at all times either [...] "

- Criminal Investigator #3

However, there was also one CI who was unsure whether he had a need to be closer to e.g. a dead victim. He thought it sufficient enough to be at a distance with protective contamination gear and still receive all the understanding of the crime scene and victim that he needed.

Visualization of a crime scene and its documentation

All CIs mentioned that whatever the visualization tool may be, the environment needs to be as similar to the real location as possible. One also mentioned that if there is some margin of error from the real scene, it needs to be apparent. Other identified needs were for a kind of "base material" of the visualization if the whole presentation of the scene and its documentation is not yet completed as well as easy access to the visualization tool.

"You can get a thought when you sit in your room and work, that you want check something out, so if you now have a 3D picture you can easily, I think, open it and look how it relates to your thought. So you don't have get in the car and go 4 (Swedish) miles to the scene. So, that's something, [...] if you can get to know the crime scene in a completely different way, you can take a look at it often."

- Criminal Investigator #2

The greatest and most relevant wishes identified were to be able to visualize the crime scene and to do so through different perspectives and angles in a "free moving matter". To be able to do this during the same environmental circumstances as when the crime was committed, and being able to visualize the field of view of witnesses. Two out of three CIs also mentioned the wish of being able to mark out findings and traces in the environment and the ability to interact with them.

"[...] when you can add different findings, click on them and get; here we have found a cigarette butt, DNA on it, which correlates to this and that person and so on. Stuff like that so you can make connections. In an easy way, you get clear perception of what's found and what's been seen"

- Criminal Investigator #2

Other wishes identified were the ability to have witnesses, suspects and plaintiffs etc. show where they were positioned, the ability to visualize blood spatter and analysis theory testing. Furthermore the wishes to manipulate the environment by opening drawers, measure and to be able to view the crime scene in both a detailed and overview perspective as well as what motions are possible and not in specific areas were also mentioned.

The lack of understanding of the environment, distance, depth, angles, volume, luminance, field of view and where the photographer stood when taking a specific photo were the greatest challenges identified regarding using video and images as visualization tools. It was also mentioned that there sometimes can be an excess of visual material during an investigation. Regarding the visualization of a crime scene with more modern technology the aspect of the visualization being created with not enough legal certainty was also mentioned. The risk of being able to manipulate the digital crime scene in a "digital contamination" manner, that is to move things around to the point that it gives an incorrect perception of how the crime scene looked initially, was also mentioned by one of the interviewed.

Prosecutor

A prosecutor was interviewed to gain further information regarding the investigation and presentation process in court as well as to see however a prosecutor could be a potential stakeholder in terms of the design.

Physical crime scene

Two specific needs regarding the physical crime scene were discovered. The first need identified for the prosecutor was to, with the court, visit and inspect the scene of the crime. During this visit, all members of the court along with attorneys etc. get a walkthrough of the scene with relevant information such as where the body and specific evidence were found. This need was also mentioned by one CI interviewed.

"It may be that the court also wants to inspect this apartment, how it looks to form a perception of distance and how it looks then, so we usually keep the crime scene for a long time. If it is outside at Normalmstorg for example it may be more difficult for understandable reasons. It is then important that you've documented and recreated the crime scene in a good way. "

- Criminal Investigator #3

The second need was for the prosecutor her-/himself to visit the crime scene one or several times during an investigation process. This in order to get an idea of how it looks, where evidence has been found etc. This need is similar to the investigators' needs regarding the physical crime scene mentioned in the previous section.

"But we always go there when it's a violent crime to see the location itself. I find it invaluable to get to visit the location and get an idea of what it looks like, where things were found"

- prosecutor

A challenge regarding the inspection of a crime scene is the time, effort and money it takes to get all the members of the court to a specific location or locations.

Visualization of a crime scene and its documentation

The greatest need identified regarding visualization was to present all relevant information from the preliminary investigation protocol during the statements of facts in a court in the best possible way. This in order to provide an insight and understanding of the alleged course of events and evidence connected to the prosecuted. This need was also pointed out by a CI.

" [...] it is extremely important for a prosecutor to visualize the alleged event of what has happened. And then to be able to move [within the visualization] a little more, what we should say a little more in the 3 dimensional worlds, correctly illustrated etc. Then the court will probably come very close to what has happened I think."

- Criminal Investigator #3

When it comes to a visualization tool the need to present timelines, people, maps, course of events, forensic evidence, film recordings, autopsy results, correlations between evidence and other relevant objects and people were identified. It was also emphasized that everything being visualized must be based on the preliminary investigation protocol. The tool needs to be easy to use with no set presentation structure since all cases are different and therefore require different structures.

The greatest and most relevant wishes identified were to show where evidence have been found, where witnesses, prosecuted, victim etc. were positioned at the crime scene. When dealing with the visualization of crime scenes, the greatest wishes identified were to be able to move freely, change perspective and to show hidden objects. An indication of the margin of error from the real crime scene, if there is any, was also mentioned.

"I have seen during training that there is some sort of 3D recording of crime scenes. So one could imagine something like a computer game in 3D that you can walk around in and show the real crime scene, but you show it on a screen"

"[...] during the preliminary investigation you would like, optimally, if you had some sort of photo documentation that was a 3D rendering so you could have the crime scene on your computer and check it out without being on site during the actual investigation. When you get ideas or you want to view things etc. And then during court proceedings where you can show the court that this is what it looked like when our CSIs came, they found these things here and there [...]"

- prosecutor

Crime Scene Investigator (CSIs)

CSIs were interviewed to gain further information regarding the investigation process as well as see whether they could be potential stakeholders in terms of the design.

Physical crime scene

A distinct difference between the needs of CIs, prosecutors and CSIs is the fact that CSIs absolutely need to physically be at the crime scene in order to do their work.

Visualization of a crime scene and its documentation

The most relevant need for CSIs regarding a tool for visualizing a crime scene and its documentation is the potential to show CSI colleagues the visualization. This becomes important when a second opinion or fresh pair of eyes is needed.

The most relevant wishes for a visualization tool is for it to have the possibility to add evidence, traces etc. with information, correlations to other relevant information and to gather all information regarding the scene and its documentation in one place/ platform. In order to be able to filter away details if needed and to be able to visualize details e.g. drags marks were also mentioned. The possibility to recreate the course of events, move objects, see animations, zoom, measure, and an indication of what part of a visualization is enabled for interacting and free movement were wishes identified.

Other insights

A CSI in training mentioned during a conversation at NFC that when visualizing traces and goods virtually it would be a good idea to have K-, S- and G-numbers for each presented. This would enable the connection in DurTvå and communication between co-workers. Conversations with forensic scientist at NFC also revealed that witnesses sometimes are reluctant or afraid of returning to crime scenes.

Key themes

The greatest needs, wishes and challenges can be gathered and summarized into five key themes, and are acting as design guidelines for the VR design;

1. Being able to virtually v*isit/ revisit* the crime scene in *new and freer perspectives and movements* by visualizing it in a *realistic manner*, during the same *environmental conditions* as when the crime was committed.
2. *Share, discuss and present* observations and theories with colleagues and other stakeholders to increase collaboration and communication.
3. *Limited amount of time* spent at the initial crime scene could influence one's perception of it in a negative way. The less time one spends at a crime scene, the greater the risk of being unable to visually identify e.g. important items or circumstances.
4. Visualizations of *findings* tied to specific locations, with detailed information about what those findings consist of and are connected to.
5. Being able to visualize the *relationship* between the crime scene and findings in a *holistic manner*, with the ability to perceive *distance and depth* as well as *orientation and navigation* within the VE.

Key theme number 1 and 3 are met in different degrees due to the crime scene VE and will be met further in the discussion section. How the others are addressed and met in the design is described both in the following sections and to some extent in the discussion section.

VR design

Based on the interviews the aim for the workshops was to design for the key themes. The two interaction scenarios *"Interaction with possible evidence/ goods/ traces in an environment"* and "*interactions that affects the environment in some way"* were therefore created, since all of the interactive key themes can be included in them. During the two workshops several design suggestions were developed. Due to the participants' different fields, the first workshop generated more suggestions focused on interaction design, while the second became more featured oriented. The majority of the suggestions were taken into

consideration when developing low fidelity paper design suggestions as well as the iterated high fidelity VR design.
The high fidelity VR design and interactive icons seen in Figure 1 and 2 are based on, besides the key themes, examples by the interviewees, workshops as well as conversations and iterations with forensic scientist at NFC. They are also inspired by the design and sorting of evidence and traces by the software SceneCenter Forensics[3] [29].
The high fidelity VR design is addressed in four interaction scenarios where different kinds of features are presented. The interactive icons located within the VE are meant to meet several of the needs, wishes and challenges summarized in the key themes. Three scenarios were video recorded and one was illustrated;

1. An interaction with a gun (goods) where the user can find information regarding what traces were found on it and to whom the fingerprint found belongs to as well as information connected to the person[4]. This meets key theme number 2, 4 and 5 since the findings' information is presented to the user in a holistic manner where the relationship between the fingerprint on the gun and an individual is displayed.
2. An interaction with a blood trace where two sets of blood traces were found. The user can take part of whose blood it is and then choose to only see blood traces connected to one of those individuals[5]. This meets key theme number 1, 2, 4 and 5 since the information of the traces is presented to the user as well as giving s/he a visualization of the relationship between the traces in a holistic manner. Therefore s/he sees the crime scene in a new perspective.
3. An interaction where the user can filter what traces and goods are visible at the crime scene. This is presented in combination with an illustration of the environment menu[6]. This meets key theme number 1, 2, 4 and 5 with the same motivation as for scenario number two.
4. An illustration of how blood spatter analysis could be visualized in a VR environment. This to indicate from where the act causing the splatter originated, shown in Figure 1. This meets key theme number 2, 4 and 5 since the visualization is presented to the user so s/he gains more understanding how and where the act resulting in the blood spatter trace occurred and therefore gains a holistic view of the crime.

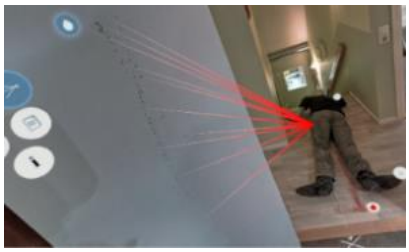

Figure 1. Blood spatter analysis indicating where the act causing the spatter originated.

[3]SceneCenter Forensics distributed by the SpheronVR allows users to visualize a crime scene and other possible evidence analysis information through pre-selected perspectives. This by displaying 360° photos on a 2D screen.
[4] Interaction scenario #1 https://vimeo.com/217703910
[5] Interaction scenario #2 https://vimeo.com/217704018

Design layout of the VE and GUI

The possible evidence located within the VE are divided into traces and goods since that is the classification existing within the software DurTvå and the software SceneCenter Forensics [29]. The division is therefore already familiar to the target group. Figure 2 shows interactive traces and goods where they were discovered at the crime scene in a virtual 360° photograph. This gives the user a holistic overview of what has been found where and information connected to them, thus meeting key themes number 2, 4 and 5. The interactive icons were designed to be intuitive regarding being selectable and active in agreement with MAUVE's object manipulation principle [30] and UX guideline of interaction indication. They were also designed to be intuitive regarding what kind of information they contain as well as not to overtake the focus from the crime scene.
Further information regarding the trace or goods and other interactive options are shown in "windows" seen in Figure 2.

Figure 2. Screenshots of interactive icons and windows in the VE. Upper; from scenario number 1. Lower; from scenario number 2.

This design decision was inspired by the desktop metaphor[7], making the interaction more intuitive and simple for the users when crossing over from computer screens to VR. This since they are already familiar with a desktop environment on a computer and the interactions and functionalities existing within those. Thus meeting the recommendation of keeping UIs simple [12]. The design is also based on 2D tasks being cognitively easier than 3D tasks [12] and so to increase usability only 2D selection options were designed. The information connected to a trace of goods appears in a window in front of the user at the distance of three meters [12] within their immediate field of view (FOV) and the comfortable degree recommendations[8]. Figure 3 shows how further selections will eventually form a cylinder surrounding the user, giving the illusion

[6] Interaction scenario #3 https://vimeo.com/217704148
[7] The GUI of a computer is designed through a conceptual metaphor of a desktop [2] relating to things user can understand.
[8] Users of HMD's can comfortably turn their heads 20° up and 12° down [12].

of several screens beside each other going "deeper" in the selected information for every interaction. The cylindrical window design is based on the surrounded tile menu [12] which is considered the best solution for displaying menus.

Figure 3. Illustration of windows located around the user in a cylindrical manner.

Interaction affecting the VE

To meet number 1, 2, 4 and 5 of the key themes the interactive icons for affecting the environment seen in Figure 4 were designed. They meet key theme number 2 by being able to record voice and video when in the VE to share, discuss, collaborate and communicate with co-workers etc. theories or other thoughts and ideas. Key theme number 1 and 5 is met by the adding of reference objects in the VE and the ability to measure, giving the users a new perspective of the surrounding space. Key theme number 4 is met by a Level of Detail (LOD) icon where the user can choose what traces and goods s/he wants to view in the VE. This without first having to interact with a trace or goods and thereby also gaining a holistic view of the crime scene. A holistic view of the crime scene is also facilitated by the "connecting circle" icon selectable for traces and goods. It connects e.g. a specific trace to an individual and thereby also meeting key theme number 5. This is illustrated in the second design scenario mentioned previously. Key theme number 1 is met by enabling the user to view the VE in different weather conditions as well as photographs of the crime scene. There is also a document icon containing all documentation regarding the crime, crime scene etc. that can be found in the software DurTvå.

Figure 4. Interactive icons for the VE

The blueprint map of the crime scene with the user's position indication and field of view can be seen in Figure 5. This was designed to fulfil the MAUVE design criteria of visual and navigational assistances [30] [30][30][30][30][28][28][28]and the orientation and navigation of the VE in key theme number 5.

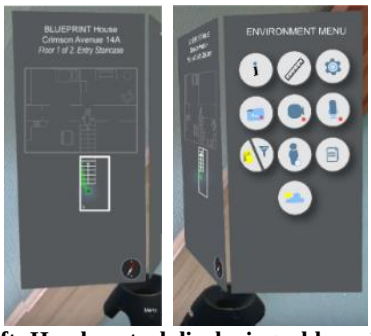

Figure 5. Left: Hand control displaying a blueprint with user position for navigation. Right: Interactive icons for environmental features.

The blueprint maps were, as well as the adjacent environment menu containing the icons in Figure 5, designed to be attached to a hand held control. Since no crime scene is ever the same, the merging of these two features in a VE could become problematic e.g. if they were designed so that when a user looked up a "drop down" menu would become visible. This would be problematic if there were blood spatter on the ceiling and each time the users wanted to inspect them a menu would appear. This dilemma could arise in other situations depending on the crime scene. To avoid this, the visual and navigational assistance along with the environment menu were designed to be attached to a control and not to be part of or merged with the VE.

Interaction with traces and goods

To indicate which objects the user can interact with and when the interaction takes place [12], the goods and traces that can be interacted with are presented as icons. These interactive icons seen in Figure 6 represents a specific trace or goods found in the VE, as well as different features. The top five icons represents different traces; blood, fingerprints, fibres, DNA and ignition particles. The G icon represents goods found at the crime scene. For each trace and goods the S-, K- and/ or B-number are presented. This was done to better communication between co-workers, since it can be important to know what specific evidence is in focus during a conversation. The other icons are features possible for traces and goods, depending on the situation. 3D enables a 3D view of a goods, the intersecting vectors enables a blood spatter analysis visualization, and the circle connects traces and goods to e.g. a specific individual. The voice and video recorder enables the user to record thoughts and observations when in the VE. This could then be share with co-workers or saved as a notation.

Figure 6. Interactive icons for goods and traces

To fulfil the MAUVE criteria of indicating which objects are selected or active, the interactive icons were designed with three different modes, visible in Figure 7.

Figure 7. Modes of interactive icons. From left; default, hovered and selected.

DISCUSSION

In this thesis the greatest visualization needs, wishes and challenges of CIs were explored and addressed. This by the creation of interaction scenarios presented through a high fidelity VR design. In this section the research questions are revisited. This is done by discussing the VE of the high fidelity VR design and the use of VR. Thereafter a possible interaction method will be discussed, thus addressing along with section *Key themes* and *VR design*, the two first research questions. The final research question will be addressed in section *Other stakeholders*.

The high fidelity VR design

The VR design met all of the key themes in one way or another. However it also had some limitations regarding the experience of realism, presence and spatial information. This will be discussed below.

The most frequently mentioned need and wish identified was for the user to be able to visit the crime scene, the key theme number 1. This is to some extent met with the HTC Vive and 360° photos. This is due to the sense of being immersed with the HMD. The experience of presence is likely to increase the more immersed the

user feels, leading to the user's behaviour being more real [30]. This increases the possibility of feeling present at the virtual crime scene. The user is therefore to some extent immersed with the HMD and feels present at the crime scene, meeting key theme number 1. Using 360° photos could result in an experience where the user is on a different height then they are accustomed to due to the camera tripods height. This could, as a result, induce motion sickness due to unexpected and perceived visual stimuli [30] and thereby risking reducing the user experience. The set height can also increase the risk of reducing the sense of realism.

The user is also locked to specific positions and orientations depending on where and how the 360° photos were taken. The user can look around however s/he wishes, meeting key theme number 1 of freer perspectives, since 360° photos contribute with more spatial and holistic information than traditional ones. However, the same theme is not met in full. This since the user cannot "move" around the whole crime scene, rather they can only "jump" between already taken photos, hence limiting the free movement and perspectives. Since the user can percieve him-/herself as being present at the crime scene for however long they wish and their surrounding being a 360° photo, key themes number 1 and 3 of limited amount of time spent at the realistic virtual crime scene with a holistic view are met. Although, being that the VE are 360°photos, the same challenges indentified for traditional photos e.g. understanding of depth and volume, are likely to be present for this kind of 360° photos as well. This could potentially be improved by either adding distance indicatiors in the photos or by replacing the photos with a laser scanned point cloud with the possibility of free movement and teleporting with the HTC Vive[9]. The point cloud also address the previosly mentioned issue of the camera's height since HTC vive can in a 3D space allow for the user to be on their own height when immersed. Point clouds in VR could also challenge the loss of e.g. spatial information when visualizing point clouds (or other 3D models) on a 2D surface in a preselected point of view [10]. Since point clouds are the most precise and reliable technology regarding documentation and visualization in 3D [6] and considering that they can be seen as "virtual conservations of evidence" [8], point clouds could possibly also meet the issue of legal certainty. However, what becomes problematic in a user experience manner when introducing a point cloud to VR is the impression that a point cloud can look solid from afar but when coming closer it becomes more sparse and "dissolved" [7].

To deal with this issue perhaps a different scanning approach where medium to long range scanners capture the larger spaces while the close-ranged focuses on the details of the crime scene. By doing this a point cloud could become more detailed and less "dissolved" when coming closer to close-ranged scanned sections. Point clouds can also through e.g. triangle meshing be approximated and become reconstructed surfaces. This could however result in a somewhat incorrect spacial representation [7]. According to conversations with forensic scientists at NFC it takes a lot of manual labor to create a meshed point cloud and there is also a risk of mis-representing the space. It is important not to experience too much mis-representation due to the risk of lowering the sense of realism. Another imaginable approach for creating the best suited VE could perhaps be a combination of laser scanning and photogrammetry[10]. Regardless of method chosen to visualize a crime scene it needs to meet key theme number 1 of realism (a similar requierment also observed in [10] as "realistic depth perception") and free movement. This to increase the sense of presence and thus influence the involvement in, and usability of, the VE [30] and in turn meet key theme number 1 of virtually visit the crime scene more extensively.

The use of VR

A VR design could challenge the lack of understanding regarding distance, depth, angels, volume field of view etc. of photos and video recordings. However, as discussed in section The high fidelity VR design, 360° photos as a VE might not be the best suited VE for such a task. It could however become easier to connect crime scene photos and get a more coherent perspective of the crime scene by "jumping" between the 360° photos than only viewing traditional ones, thus meeting key theme 6 of holistic view. Traditional photos and video recordings might miss documenting e.g. objects or areas that were considered not important initially but later on turned out to be so. Also moving the video camera too quickly over areas with low resolution might result in poor visualization. This is addressed when 360° photos are taken so that they cover the whole crime scene, enabling the user to "return" to the initial scene. VR could thus act as a complement to images and video recordings, aiding the investigation with spatial and holistic information [10] that might be lacking otherwise. VR could also address the issue of excess of visual material existing during an investigation, mentioned by a CI. This could be done by compiling large amounts of visual material in one place. A VR design could thereby act as a complement and compiling tool, gathering all digitalized documentations and putting them in context and correlation to each other. Thereby meeting key theme number 6 even further.

The VR design developed in this thesis provides, apart from previously discussed, the possibility to "filter" what is visible in the VE, correlations to other findings and individuals as well as the recording of thoughts or observations when immersed. This could be used to e.g. facilitate the collaboration and communication between co-workers, thus meeting key theme 2. As far to the author's knowledge, this is not provided in the same context in other already existing software or research in this area. If a crime scene was virtually documented in a non-destructive, detailed, real and spatially correct manner (such as a e.g. point cloud would) and enabled free movement, VR could provide the opportunity to observe the scene outside of preselected perspectives. Thereby provide the user with information which might otherwise be lost [10] as mentioned in previous sections.
Visiting the crime scene is one of the greatest needs identified, which suggests that visually documented material is not sufficient when conducting an investigation. If a visualization tool existed enabling the CIs to gain the visuals needed in a quick manner, one could assume that energy, time and resources could be saved by virtually "being present" the crime scene. It could also possibly be used to update stakeholders involved in the investigation without having them visit the scene. Such a tool could also open up for visualizations of crime scenes no longer available, or those of unsolved cold cases. Conversations had at NFC revealed that witnesses sometimes are reluctant or afraid of returning to crime scenes. A VR visualization tool with free movement could allow them to "visit" the scene in a safe manner and thereby aid the investigation. This concept could also be applied to confirm

[9] Example video of a very sparse point cloud in Unity: https://vimeo.com/217988342

[10] By using a mathematical relationship between object and image points from digital images it is possible to gain 3D information [3].

narratives or statements regarding field of sight etc. without having to physically visit the crime scene.

The interaction

According to [12] users should be allowed to be lazy, e.g. not being forced to move in their seat or to stretch their necks, since this may degrade the user experience. The CIs interviewed often goes through investigation material in their offices or meeting rooms. When introducing a new visualization tool it is likely to assume that it would be used in the same space. This together with never having, or only a few times, experienced VR indicate that it would be preferable if the interaction was not overly complicated or space demanding.

It is recommend to use 2D input devices rather than 3D when dealing with a simple UI [12] and since the input interaction necessary for the icons in the VR design is a straight forward "hover and click" it can be argued that using a simple interaction input would be favourable. Considering what is mentioned above and that the users are accustomed to computers and interactions associated with computers, the idea of a similar interaction input evolves. One possible interaction input would be to use gaze tracking where the orientation of the user's head approximates where s/he gazes. This interaction input is claimed to be "one of the most intuitive ways of interacting with a VRGUI" [12]. To simulate the gaze a cursor is placed mid-air and centred in the user's field of view. The experience of the cursor provides the user with the feeling of being in control of the system by using their head/ gaze direction [12]. This together with the selection of e.g. interactive icons being a "click" on a hand controller could possibly be very intuitive. This since it is similar to interactions associated with the computer's mouse interaction and not dependent on large spatial demanding movements.

Other stakeholders

A visualization tool for crime scenes and their documentation could be relevant for both prosecutors as well as CSIs. Regarding prosecutors, their needs, wishes and challenges regarding the physical crime scene and the visualization of it are quite similar to that of the CIs; they need to visit the crime scene to get a feeling of what has happened, what possible evidence have been found and where. These needs are met with the VR design based on the same reasoning as with the CIs. However, there is also the need for court presentations and "walkthroughs" of the scene during the statement of facts. This could be seen as a "filtered" version of the VR design presented since only the relevant and important information is needed during this phase. When the CIs would use such a tool, it is important not to exclude findings, connections etc. that have not been thoroughly examined and ruled out. This since the CIs might not yet know what is important or not during the investigation phase. However, for prosecutors during the statement of facts what is important and how is already established. They are therefore in need of a "filtered" free structured presentation tool. It could be that the Level of Detail icon presented in section *Interaction affecting the VE* could be used by prosecutors in such manner.

While interviewing CSIs it became abundantly clear that their presence at the physical crime scene cannot be replaced with a virtual one. Therefore it would merely aid them in their work when in need of a second opinion, a pair of new eyes and as a discussion and communication tool with colleagues. This collaboration and communication need is in line with the purpose of [25] where a collaboration tool between CSIs and remote experts was designed.

Critical discussion of the method

Based on the Double Diamond Model of Design qualitative data was gathered through semi-structured telephone interviews, conversations and workshops. Since this thesis is a user centred study the voice of the users needed to be heard. To facilitate the chance of being able to go a little "deeper" interview sessions were conducted with a set of predefined questions which allowed the interviewees to reflect, share and explore [17] their needs, wishes and challenges. Since the interviews were conducted over the telephone, the risk of missing non-verbal cues arose [17]. It might not have been revealed if the interviewees were distracted, tired, confused etc. These factors could have influenced the results of the telephone interviews, but they could also have been taken into account had the interviews been conducted face-to-face. When analysing qualitative data, there is a risk of missing information if one is not thorough. To minimize the risk of creating a VR design lacking in vital areas it would have been desirable to user test it with the CIs. Although the design was iterated with forensic scientists, whom are knowledgeable in the area of 3D crime scenes and forensic analysis, it would have been preferable having CIs present during the iterations. Another important aspect to consider is the fact that there were only three CIs interviewed and so the results can therefore not account for the target group as a whole.

Further research

The next step with this VR design would be to user test it. Even though it has been iterated, it is not validated. This needs to be done in order to assure that there are e.g. no misunderstandings of the representation of the crime scene that risk misleading investigations. As mentioned in previous sections, the VE could perhaps consist of visualizations other than 360° photos. It needs to be researched which kind of visualization that is best suited to meet the user requirements. The interaction method should also be in focus and explored more closely.

CONCLUSIONS

The greatest needs, wishes and challenges of CIs are summarized and presented in the key themes in section *Key themes*. These are then addressed in a high fidelity VR design presented through video recordings and illustrations seen in section *VR design*. Besides CIs, the VR design could benefit prosecutors by enabling them to visualize the crime scene the same way that CIs would. It could also act as a presentation tool in court in a more "filtered" way as compared to the CIs design. CSIs do not benefit a VR design in the same manner as CIs and prosecutors. This is because their need to be at the physical crime scene to secure evidence cannot be replaced. However, the VR design could act more as a collaboration tool between CSIs and colleagues. By visualizing a crime scene and its documentation in a holistic and realistic manner VR can act as a complement to traditional photos and video recordings. By adding features that enable communication and collaboration, VR can add coherency to digital investigational material. The needs, wishes and challenges of CIs can thus be addressed in a VR design developed as a compiled visualization and collaboration tool.

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