Arousing memory:

Memories obtained from virtual reality are as correctly recalled as memories obtained from conventional two-dimensional screens.

Master thesis conflict, safety & risk

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Abstract

The current study examined if there is a difference between remembering facts that are obtained from watching a crime in a virtual reality environment versus watching a crime on a conventional two-dimensional computer screen. Furthermore, it was examined if the eye-closure technique improves the retrieving of facts. The 123 participants were divided into several conditions were a distinction was made in the type of screen (virtual reality head-mounted display vs. conventional two-dimensional screen) and eye-closure vs. non eye-closure. The participants were eyewitnesses of a crime and were interviewed using the Cognitive Interview. Unlike expected, no significant results were found for remembering facts (number of hits) and type of screen. There were also no significant results found for the improving of remembering facts (number of hits) and eye-closure. Although, a significant result was found with the exploratory analysis were a regression analysis was conducted. The regression showed that when participants had a higher level of arousal at the time of encoding (part one), the participants made more false alarms. Finally, it was discussed that the resolution of the screen of the virtual reality head-mounted display was low and the size of the head-mounted display was smaller than the screen of the computer. Besides, the differences in weather and temperature could have caused an error in the data collection with the Empatica E4. Overall, this research is, due to the implications, strengths and limitations, a first important step into the research of virtual reality.

Keywords: eyewitnesses, virtual reality, arousal, eye-closure, Cognitive Interview

Arousing memory: Memories obtained from virtual reality are as correctly recalled as memories obtained from conventional two-dimensonal screens.

Imagine: watch a movie or give your best friend a tour trough the new house you bought from your own couch without leaving your house. This seems impossible at first sight, but is already possible with the use of virtual reality (VR). The use of virtual reality is becoming more widespread and popular in different branches of science including psychology (Kim, Park, & Lee, 2014). Although it is still a developing technology, it has been successfully introduced in several aspects of medicine and psychological treatments (Schultheis, 2001). A key characteristic of VR is the high level of interaction between the user and the tool, as well as the enriched experience for the user (Kim, Park & Lee, 2014). VR is an advanced form of human-computer interface in a way that allows the user to interact with and submerse in a virtual environment. It differs from watching a movie due to the realistically virtual experience and through technology such as head-mounted displays (HMD) (Schultheis, 2001). The environment can be computer generated but there are several immersive environments that are not entirely synthesized by the computer (Mujber, Szecsi, & Hashmi, 2004). The use of VR does not only provide a more realistic real-time experience but it also increases the ecological validity of the experiment by exposing participants to a stimulus closer to reality than that would be obtained using a conventional two-dimensional screen (2D-screen) (Kim, Park, & Lee, 2014). The possibilities are endless which makes virtual reality not only a gadget or a gamer experience but it's possible to also be used in policing, were VR may be a useful tool to study eyewitness memory.

The current research focuses on the last mentioned: policing. One of the main sources in policing, the forensic processes and criminal justice system, are the eyewitnesses and their memories and statements (Davies & Beech, 2012). The current research will examine if eyewitnesses can remember more or fewer facts when a memory is obtained from virtual reality than when it's obtained from a conventional two-dimensional computer screen. The influence of reducing cognitive load with eye-closure on remembering facts will furthermore be researched. The next section will explain the working of the memory of eyewitnesses, arousal, the Cognitive Interview and the eye-closure technique.

Eyewitnesses memory

Eyewitnesses are important in policing and in some cases the only clue in the investigative process (Davies & Beech, 2012). They can influence the direction of an entire investigation process (Perfect et al., 2008). Unfortunately the memory of eyewitnesses is not that accurate and reliable as people think. Several variables can affect memory negatively during encoding and retrieval. Research has indicated that stress and anxiety may be such variables, which can be encouraged by the use of VR because the realistic experience. This can influence the encoding and retrieval process were cognitive overload can also influence the retrieval of memories. On top of the imperfect memory of

eyewitnesses, people such as jurors, judges, police and teachers weigh eyewitness evidence too highly, because it's the most convincing and direct evidence they have (Davies & Beech, 2012).

We use metaphors to understand and describe the complex world in which we live and for the processes in our memory. An example of a popular metaphor is that the memory works like a computer or an Ipod (Roediger, 1980). But in contrast to the idea that we can just search for a file and find the right memory and information where no errors can occur, is encoding and retrieving memories a difficult and complex process where lots of errors can happen. This error can occur in three stages, which will be explained in the next paragraph. The current research will focus on the encoding and retrieving stage, but all three stages are important in eyewitness testimonies.

As said, the process of making a memory can be divided into three stages: encoding, storage and retrieval. The first step is that eyewitnesses need to notice and pay attention to the event, so they can see what is happening. That information will be registered in their memory, this process is called encoding. Once the event has been encoded, memories must be stored in the brain for recall at a later time (Costanzo, 2013).

Memories appear to deteriorate over time and become increasingly susceptible to distortion and corruption (Flin, Boone, Knox, & Bull, 1992; Schacter, 2013). One of the main problems concerning storage of memories by eyewitnesses is that there can be a delay of days or weeks between the moment they witness the crime and the time the investigator ask them to identify the likely perpetrator (Costanzo, 2013). When the eyewitnesses are interviewed about the crime they witnessed, they need to retrieve their memories and remember certain details. Post information can also affect people's encoding, storage, retrieval and reporting of events, which is often referred to as the misinformation effect. Such post information can influence memory due to social and psychological factors. Talking with another eyewitness who was in error can cause this error to spread to others. This process is called memory conformity (Jaeger et al., 2011). In the current research is only a small delay of time of thirty minutes until the participants will be interviewed to reduce the chance for these errors in retrieving. Furthermore, the participants won't talk to others to reduce the misinformation effect and memory conformity.

Besides aforementioned effects, countless variables can negatively influence the encoding and the retrieval process of memories (Kim, Park, & Lee, 2014). It is necessary to pay attention to what is happening and the particular details of forensic importance in order to have a good memory of the event. People can only encode a small percentage of the information in their visual field. An example of an error in the encoding process is the 'weapon focus effect' that describes the process of how a weapon attracts attention during a short duration event, so there is not enough time to encode the perpetrator's face or other details (Loftus & Palmer, 1974). This can be explained by two factors; first, a weapon distracts the attention of the face of the perpetrator as the eyewitness only noticed the gun and second, cognitive abilities will be worse when an event is highly emotional (Deffenbacher et al., 2004). People can only pay attention to one event at the time and have a selective attention, what can

cause difficulties in remembering facts obtained from VR. Eyewitnesses see more details when they watch a crime in VR than from a conventional two-dimensional screen what can distracts the participants so they don't pay attention to the crime. The current research will compare the retrieving of memories obtained from a conventional two-dimensional computer screen and from a virtual reality environment. Taking into account people's abilities of encoding it is likely that participants who watched a crime in virtual reality will find it harder to remember the facts due to the quantity of information and details they receive.

Arousal

Besides errors that can occur at all of the three stages of the memory, eyewitness memory can also be influenced by arousal. The eyewitness literature often claims that stress leads to impairment in memory and that details of unpleasant emotional events are remembered less accurately than details of everyday events (Christianson, 1992). Previous research had different results on the effect of emotional arousal. Some researchers claim that arousal has negative effects on memory, like attentional narrowing based on the cue utilization hypothesis (Kim, Park, & Lee, 2014; Easterbrook, 1959). This hypothesis implies that increased arousal leads to focused attention on central details, which decreases memory for peripheral details, for example the weapon focus effect. Stress or emotional arousal experienced by the eyewitness at the time of the incident can lead to automatic physical end emotional changes that can occur during the fight or flight response to danger or threats (Taylor, Klein, & Lewis et al., 2000). Kim, Park and Lee (2014) on the other hand conclude that other research had shown a positive effect of arousal on memory. Brown and Kulik (1977) found for example that when the eyewitness experienced a highly arousing incident that their memories are detailed and vivid which can be labeled as 'flash bulb memory' (Hirst & Phelps, 2016).

Such highly detailed and vivid memories were considered in the current study, and it was established that the participants who watch the crime in VR experience the event more realistically whereby they can experience more arousal. The level of arousal can be determined with the help of different measurements. The physiological responses to environmental chance can be set to measure heart rate deceleration, heart rate acceleration, heart rate differentiation and electrodermal activity (EDA) (Heuer & Reisberg, 1990). EDA measures the level of arousal valid, precise and objective (Egan et al., 2016). The current research, will for those reasons, use a sensor to measure EDA to establish the physiological arousal.

EDA refers to electrical changes that are measured at the surface of the skin. This arises when the skin receives signals from the brain. If someone experience emotional activation, physical exertion or an increased cognitive workload, the brain sends signals to the skin to increase the level of sweating. It's possible that the person doesn't feel any sweat on the skin, but the electrical conductance increases in a measurably significant way as the pores begin to fill below the surface (Poh, Swenson, & Picard, 2010). EDA is considered to be a valid and sensitive indicator that responds to the smallest variation in arousal (Groeppel-Klein & Baun, 2001).

Because of the realistic experience of VR, it is plausible that the participants feel more arousal than the participant who watched the 'crime' on a two-dimensional computer screen. A higher level of arousal or stress can have an impact and affect the ability of the eyewitness to provide accurate and detailed descriptions of the perpetrator, the crime event and later to correctly identify the perpetrator from a line-up. People who witness a crime live have higher levels of stress and arousal than people who were exposed to a videotaped crime (Pozzulo, Crescini, & Panton, 2008). This is relevant for the current research, because it might show that when participants who watch the crime in VR experience more arousal what can affect their ability to retrieve accurate memories.

Cognitive Interview

The Cognitive Interview (CI) theory was developed to gain more accurate information from eyewitnesses during interviews (Fischer & Geiselman, 1992). The current research will use CI to prevent errors in retrieval that can occur with biased or suggestive questioning and a biased line-up. CI addresses three psychological processes that underlie interviews with cooperative witnesses; social dynamics between the witness and interviewer, the witness' and the interviewer's cognitive processes and the communication between the witness and interviewer (Fischer, Milne, & Bull, 2011; Fischer, 2010). Important factors in these processes are building rapport, active witness participation, asking open-ended questions, encouraging the witness to reinstate the environmental and psychological context and search for new information by thinking through different perspectives, asking neutral questions, tailoring questions so they are compatible with the mental representation and instructing the witness not to guess if they are uncertain (Fischer, Milne, & Bull, 2011; Fischer, 2010).

Eye-closure

Eye-closure is a technique whereby eyewitnesses are asked to close their eyes, which can reduce their cognitive load. Eye-closure is an ideal technique for the police to use during interviews, because it's simple, requires no special training, can be applied to the entire population of potential witnesses and has, above all, an effect on correct memory reports, with no corresponding increase in false details (Perfect et al., 2008). Previous research shows that when eye-closure was instructed it can benefit both cued-recall and free-recall for visual and auditory input (Perfect et al., 2008). Furthermore, eye-closure reduces cognitive load (Vredeveldt, Hitch, & Baddeley, 2011). This is also known as the cognitive load hypothesis which proposes that environmental interference will be reduced by eye-closure so the cognitive resources are released and the eyewitness can invest in recollecting past events (Nash et al., 2015). On the other hand the modality-specific interference hypothesis proposes that cutting out visual interference from the environment promotes mental visualization of the witnessed past event. This will improve recall of the visual details (Vredeveldt, Hitch, & Baddeley, 2011; Nash et al., 2015). The eye-closure technique can well be combined with the Cognitive Interview (Fischer & Geiselman, 1992) and will be used in the current research to gain information and details from the eyewitnesses.

The current study

Eyewitness memory processes are complex and errors can occur at all stages of making a memory. Arousal can influence the encoding and retrieving processes of eyewitnesses in a positive and negative way. The eye-closure technique is going to be used in the current research to reduce the cognitive load and the level of arousal of the participants. The goal of the current study is to explore if there are any differences in retrieving memories when the memories are obtained from virtual reality or when they are obtained from a conventional two-dimensional screen. Furthermore, the effect of the eye-closure technique will be researched and additionally, the effect of arousal on the encoding as well as on the retrieving process of the participants. The participants are randomly divided into four conditions; eyes open vs. 2D screen, eyes open vs. VR, eye-closure vs. 2D screen and eye-closure vs. VR. The research questions are: *'Is there a difference between remembering facts obtained from watching a crime in a virtual reality environment or watching a crime on a two-dimensional computer screen'* and '*Does the eye-closure technique improve remembering facts?*' The corresponding hypotheses are:

H1: Eyewitnesses can recall fewer memories from the crime obtained in virtual reality than obtained from a two-dimensional computer screen.

H1a: Eyewitnesses can recall fewer hits (correct memories) from the crime obtained in virtual reality than obtained from a two-dimensional computer screen.

H1b: Eyewitnesses recall more false alarms (incorrect memories) from the crime obtained in virtual reality than obtained from a two-dimensional computer screen.

H2: Eye-closure improves remembering facts.

H2a: Eye-closure improves the recall of hits (correct memories).

H2b: Eye-closure decreases the recall of false alarms (incorrect memories).

Additional hypothesis

H3: Eyewitnesses experience more arousal when they watch a crime in virtual reality.

Method

Participants and design

There were 123 subjects participating in this study (66 females, 57 males; with a mean age of 34.87, *SD* = 11.53). The participants were divided in categories on their education level, with 21% low educated, 39% middle educated and 39% high educated (low = primary education, middle = secondary education and high = bachelor or master).

Participants were randomly assigned to one of the four conditions of the two-by-two between participants design (type of experience: two-dimensional vs. virtual reality and technique; eye-closure vs. non eye-closure).

The participant could win a voucher worth €50,- (approximately $55,78 in U.S. currency) by participating and the bachelor students obtained from the participant pool got 'Sona' credits.

Procedure and materials

Participants were invited to join a study about virtual eyewitnesses with the help of 'Sona' (a participant pool). The researcher placed an advertisement on 'Sona' inviting people to become participants. Friends and relatives were also asked to participate. The referral, or 'Snowball', method was also used to allow subjects to recruit new participants by asking their social network.

The participants were received in public places, the lab or the researcher went to their home. Care was taken that the setting was always quiet and peaceful. The participants were first asked to read and sign an informed consent before the experiment started. The researcher introduced the experiment and explained that it consisted of three different parts. The first part consisted of watching various movie clips. The second part consisted of solving little puzzles, which usually take fifteen minutes to be solved. The third and last part consisted of a Cognitive Interview that was being held on the computer. The participants were instructed that their voice was recorded and they should answer loudly so the researcher could listen and analyze their answers afterwards. The last part took approximately fifteen to twenty minutes depending on the elaboration of the answers of the participant. Finally, the participants were instructed that the Empatica E4 wristband measures their electrodermal activity (EDA).

The experiment started after the instructions and the researcher assisted the participants with the Empatica E4 and the VR-glasses. The movie clips in virtual reality where shown with the 'Bobo VR Z4 2.0' VR glasses. In the first part the participant watched a short movie clip to get used to the virtual reality and to allow them to get used to the VR-glasses. After this, the VR-conditions watched the 'crime' movie and the last four movie clips also in virtual reality. The 2D-screen condition watched the 'crime' movie on a 2D, 13' inch computer screen ('Kolor Eyes 1.6', Fisheye projection, see appendix A) and the last four movie clips also in virtual reality. The last four movie clips served as filler tasks and contained; swimming with sharks, 1.43 minutes; Circle of life, 5.01 minutes and two rides in two different rollercoasters, 1.23 and 1.00 minutes (all obtained from the application named 'Vrideo'). This part took approximately 18 minutes.

In the second part they were given nine riddles and were asked to answer them in fifteen minutes. The participants could type their answers on the computer. The content of the riddles didn't have any meaning for the experiment but are used together with the four short movie clips to distract the participant's attention from the 'crime movie' and also served as a filler task.

The third and last part consisted of the online Cognitive Interview. The participants were instructed that they could play the questions themselves and answer out loudly. Participants in the eye-closure condition were asked to close their eyes for the entire interview. The participants at the non eye-closure condition received no instructions regarding their eyes but received the same questions as the participants in the eye-closure condition. The Cognitive Interview consisted of twelve questions.

The first four questions are about mental reinstatement of the context of the event, requiring the participants to report every detail, to recall the witnessed event in different orders and to report them from another perspective. After that, five additional questions are asked and the participant is asked to give a brief summary of everything that they could remember and have told during the interview. Then a line-up followed where the participant was asked if they recognized someone that was concerned with the crime. The line-up consisted of twelve photos, eight men and four women. One of the twelve photos was one of the three actual perpetrators. The riddles and the online interview were created in a survey with a program called 'Qualtrics'.

At the end, the participants were asked for their age, level of education and email address. The participants were thoroughly debriefed by the researcher and additionally received a written debriefing by mail. The participants were thanked for their participation and their time.

Materials

The 'crime' movie was recorded with the Ricoh Theta S. A 360° spherical camera with 12 megapixels and Full HD option. The camera has one lens at the front and one lens at the back and stitches this frames together witch 15 frames per second (6 Mbps).

The 'Bobo VR Z4 2.0' VR glasses were used to create the virtual reality in combination with an iPhone 6 with a 4.7' inch screen with 1334 x 750 pixels. The field of vision from the Bobo VR ZV 2.0 is wide because of the distance between the lens and the smartphone and reached an angle of 120 degrees. The glasses weigh 760 grammes and have an integrated headphone.

The Empatica E4 wristband measures real time physiological signals with the help of an EDA, PPG, accelerometer and infrared thermopile. The wristband weighs only 25 grammes, which makes the wristband unobtrusive. The data was be streamed from the wristband to the computer and saved in the Empatica data manager and downloaded to the researcher's computer. The electrodermal activity (EDA) was measured to capture electrical conductance across the skin. This was achieved by passing a miniscule amount of current between two electrodes in contact with the skin and measured in microSiemens (μS).

Analysis

The voice recording of the online interview is the main input for the results. The answers were analyzed by the researcher and scored by a standardized score form. The score form is divided in different subgroups; general/environmental, arguing, clothing/description attackers and the line-up. Examples of indicators are 'black t-shirt' or 'walking bystanders'. Every indicator has a raw score. When the participants gave answers that deviated from the reality they got a false alarm (raw error) on the concerned indicator.

The data from the Empatica E4 was analyzed with the help of Windows Office Excel. The average EDA level of each participant was calculated with Excel and used as the level of arousal.

Results

The expectation was that participants would be able to recall fewer memories when they had watched the crime in virtual reality then when they had watched the crime on a two-dimensional computer screen (H1). It was furthermore expected that eye-closure would improve recalling memories (H2).

Contrary to expectation the 2x2 ANOVA with screen-type and eye-closure as independent variables yielded no main effects on the number of hits (correct memories). Screen type did not influence the number of hits (correct memories), $F(1, 119) = .89$, $p = .35$, $\eta_p = .01$. This means that participants who saw the movie on a two-dimensional computer screen had an equal number of hits ($M = 19.94$, $SD = 8.50$), compared to participants in the VR-condition ($M = 18.51$, $SD = 8.32$). Moreover, there was no main effect for eye-closure $F(1, 119) = 1.13$, $p = .25$, $\eta_p = .01$. Participants who were asked to close their eyes (eye-closure condition, $M = 20.11$, $SD = 8.43$) could not remember more hits than participants who had received no instructions (non eye-closure condition, $M = 18.35$, $SD = 8.36$). Finally, there was no interaction effect between the screen type and eye-closure, $F(1, 119) = 1.34$, $p = .25$, $\eta_p = .01$.

A 2x2 ANOVA with the screen type and eye-closure was performed on the number of false alarms (incorrect memories) as a dependent variable. Unlike expected, this ANOVA showed no main effect of the screen type on the number of false alarms, $F(1, 119) = .00$, $p = .99$, $\eta_p = .00$. This means that participants who saw the movie on a two-dimensional screen had an equal number of false alarms ($M = 2.89$, $SD = 2.27$) compared to participants in the VR-condition ($M = 2.82$, $SD = 2.20$). There was also no main effect for the eye-closure condition $F(1, 119) = .03$, $p = .87$, $\eta_p = .00$. The participants in the eye-closure condition (M = 2.85, $SD = 2.17$) had no more false alarms than the participants that had received no instructions ($M = 2.85$, $SD = 2.30$). Eventually, there was no interaction effect between screen type and eye-closure, $F(1, 119) = .01$, $p = .93$, $\eta_p = .00$.

Arousal

The expectation was that eyewitnesses would experience more arousal when they watched the crime in virtual reality (H3). Unlike expected the 2x2 ANOVA of screen type as independent variable on the level of arousal for the first part of the experiment did, however, not yield any main effect $F(1, 113) = .77$, $p = .38$, $\eta_p = .01$. [1] This means that participants who saw the movie on the two-dimensional screen had an equal level of arousal ($M = 3.00$, $SD = 3.80$) as the participants in the VR-condition ($M = 3.72$, $SD = 4.81$). The level of arousal was measured in μS.

[1] Five participants were removed because their score was more than three times the standard deviation above the average. With these outliers included, the ANOVA did not reach a different conclusion.

Additional analysis

A 2x2 ANOVA with screen-type and eye-closure as independent variables and the level of arousal for part three as a dependent variable also yielded no main effects. Eye-closure did not influence the level of arousal, $F(1, 118) = .31$, $p = .58$, $\eta_p = .00$. This means, seen in the context of hypothesis two, that participants who saw the movie at the two-dimensional screen had an equal level of arousal in comparison to the participants in the eye-closure condition.

To asses if there was a link between arousal and recall performance (part three) such as Easterbrook (1959) described in the cue utilization hypothesis we regressed arousal at part three on recall performance in this study. First, the regression on the number of correct memories (number of hits) yielded no significant results, $F(1, 117) = .66$, $p = .42$ with an R^2 of .01. Moreover, the regression also showed no results for the number of false alarms $F(1, 117) = .80$, $p = .37$ with an R^2 of .01.

To explore if there was a link between arousal at the time of encoding (part one) we regressed arousal at part one the time of encoding. First, the regression on the number of correct memories (number of hits) yielded no significant results, $F(1, 117) = .46$, $p = .50$ with an R^2 of .00. Moreover, the regression did show that when arousal at part one, the time of encoding, was high participants made more false alarms, $\beta = .09$, $t(1, 117) = 3.17$, $p = <.00$, $R^2 = .08$. This means that when the participants had a higher level of arousal, they made more false alarms.

Discussion & conclusion

The goal of the current study was to research if there are any differences in remembering facts obtained from watching a crime in a virtual reality environment or watching a crime on a two-dimensional computer screen. The expectation was that the eyewitness would be able to recall fewer memories from the crime obtained in VR than obtained from a two-dimensional computer screen. Furthermore it was expected that eyewitnesses would experience more arousal when they watched the crime in virtual reality and that eye-closure would improve remembering. Contrary to expectation the results did not show any significant differences in remembering facts on the basis of the type of screen used (virtual reality vs. two-dimensional computer screen) nor for the difference between eye-closure and for the difference in the level of arousal between the participants who saw the ‘crime’ movie in VR or on a conventional two-dimensional computer screen. Below some of the theoretical and practical implications will be outlined together with the strengths and limitations of this study.

A key characteristic of VR is the high level of interaction between the user and the tool (Kim, Park, & Lee, 2014). At the same time, however, the high level of interaction ensures a diffusion of attention. People can only encode the information that is in their visual fields and can only encode a small percentage of that information (Loftus & Palmer, 1974). In line with this theory the people in the VR-condition are expected to remember less than those in the 2D-condition. But the results of the current study showed none differences between the two screen types.

This inclines with the study that was conducted by Pozzulo et al. (2008). They conducted research in whether it made any difference if eyewitnesses identify the suspect live or with the help of live video. This is a bit different but comparable to the current study where only video material was used but in two different ways: virtual reality vs. two-dimensional. Eyewitness identification accuracy may not be greatly affected by the mode of the target exposure, but the rate of correct rejections may be overestimated using a videotaped methodology (Pozzulo et al., 2008). Their dependent measure was identification accuracy with correct identifications for target-present line-up and correct rejections for target absent line-ups. The current study conducted a Cognitive Interview in combination with a line-up. Pozzulo et al. (2008) state that the fact that participants were told that it was a crime simulation might account for the non-significant findings. This is in line with the feedback of a few participants in the current study. They described that they felt a low level of stress or arousal because it didn't feel like a realistic experience, even when they watched the crime in virtual reality.

The absence of any significant difference between VR and a conventional 2D-screen might be attributed to context dependent memory. The effect of the environment or context of recall on performance depends on the environment of learning. The recall of participants in the research was the best if the environment of the original learning was reinstated (Godden & Baddeley, 1975). The participants who watched the 'crime' in a virtual reality environment were interviewed with the help of a computer. The recall of their memories should be better based on the theory of context-dependent memory, when answering the question of the interview in a virtual reality environment.

Furthermore, the current research did not find any significant results for the improving of remembering facts with the help of the eye-closure technique in contrast to the findings of Perfect et al. (2008), Fischer and Geiselman (1992) and Nash et al. (2015). This can maybe be attributed to the Cognitive Interview that was held at a computer. The participants were asked to close their eyes, but needed to open their eyes when they had to push a button to go to the next question. This caused a discontinuity of closing the eyes what maybe caused non-significant results. It might also be the case that the participants in all of the conditions complied with the cognitive load hypothesis (Vredeveldt, Hitch, & Baddeley, 2011). Every participant was interviewed with the help of a computer. The participant was focused and concentrated on the computer whereby the participant's environmental interference and maybe also their cognitive load were reduced for that reason.

Strengths and limitations

It's a strength of the current study that participants watched different movies and were only told that they would have an interview at the end, but not what the content of the interview would be. This was done based on a suggestion of Odinot, Wolters and Giezen (2012) who discussed this as an important 'ecological' limitation of their study. In their study participants were forewarned that the event would have to be recalled. They state that this is unlike the real world where events happen suddenly and unannounced, which makes their results not simply generalizable.

An important limitation of the study is that virtual reality is a new technology and that for most participants it was the first time they saw a movie in virtual reality and wear a VR-glasses. The participants were impressed by the technology, which caused a lot of participants to be distracted from the crime in the movie. For example, they watched the sky or they sat in their chairs back to front to see what was happening behind them and thus, for example, missed the start of the conflict. At the same time, this can be called strength because the researchers expected the virtual reality condition to see more details whereby they could remember fewer facts.

Furthermore the quality of the 'crime' video clip was not very high, because the new technology of shooting a video in 360° after editing and stitching the resolution became low. This made it harder to recognize some details in the movie and could have caused a less strong experience of verisimilitude. This lack of resolution in combination with the screen size can also be a cause of the non-significant results for difference in arousal for different types of screen (4.7 inch for virtual reality condition vs. 13 inch for the two-dimensional condition). The resolution was low and the virtual reality condition watched the 'crime' movie on a smaller screen. For this reason it could also be harder for the virtual reality condition to distinguish details what caused a lower level of arousal.

The differences in weather and temperature formed another limitation of the study. The data collection was held in the summer, with some days of over thirty degrees. This resulted in divergent data with the lowest level of EDA between zero and one and the highest level of arousal above thirty. The researcher did not make any notes to test if the weather influenced the EDA significant. Moreover, for the current research we were not able to filter out the noise or compensation for outside temperature in the EDA signal. This makes the reliability of the data for the measured EDA questionable.

A recommendation for a study in the future is to compare the working of virtual reality with a real situation. VR is more similar to real situations than to a conventional two-dimensional screen. A possible follow-up study can create a more serious crime to possibly cause more arousal for the participants. Multiple participants emphasized that they did not feel any stress or arousal because the 'crime' was too low level and they suggested that a more serious crime would maybe cause a higher level of arousal. This can be done in the future to create more tension over a longer period of time in the video with professional actors. The participants suggested that maybe the use of a weapon would create also more arousal for the participants.

Virtual reality could be used to study eyewitness memory in a more ecological, valid and realistic way. Even though the current study, with its strengths and limitations, did not show any difference between VR and a conventional 2D-screen, it is a good contribution to scientific literature and one of the first attempts to study VR induced eyewitness memory.

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Appendix A: Fisheye Projection Kolor Eyes 1.6