The Effects of Witness Viewpoint Distance, Angle, and Choice on Eyewitness Accuracy in Police Lineups Conducted in Immersive Virtual Environments

Jeremy N. Bailenson, Alexandra Davies, Jim Blascovich, Andrew C. Beall, Cade McCall, Rosanna E. Guadagno
Department of Communication, Stanford University, Department of Psychology, University of California, Santa Barbara
{Bailenson@stanford.edu, AyDavies@gmail.com, Blascovich@psych.ucsb.edu, Beall@psych.ucsb.edu, McCall@psych.ucsb.edu, Guadagno@psych.ucsb.edu}

Abstract

The current study investigated the value of using immersive virtual environment technology as a tool for assessing eyewitness identification. Participants witnessed a staged crime and then examined sequential lineups within immersive virtual environments that contained three-dimensional, virtual busts of the suspect and six distractors. Participants either had unlimited viewpoints of the busts in terms of angle and distance, or a unitary view at only a single angle and distance. Furthermore, participants either were allowed to choose the angle and distance of the viewpoints they received or were given viewpoints without choice. Results demonstrated that unlimited viewpoints improved accuracy in suspect-present lineups but not in suspect-absent lineups. Furthermore, across conditions, post-hoc measurements demonstrated that when the chosen view of the suspect during the lineup was similar to the view during the staged crime in terms of distance, accuracy improved. Finally, participants were more accurate in target-absent lineups than in suspect-present lineups. Implications of the findings in terms of theories of eyewitness testimony are discussed, as well as the value of using virtual lineups that elicit high levels of presence in the field. We conclude that digital avatars of higher fidelity may be necessary before actually implementing virtual lineups.

1. Introduction

Our goal was to examine the use of immersive virtual environments (IVEs) as a tool for eyewitness identification and to explore theoretical issues underlying the behavior of eyewitnesses. Indeed, a recent issue of the journal *PRESENCE: Teleoperators and Virtual Environments [5]* was dedicated to papers exploring the interplay of IVEs and the legal system. Given the unique capability of IVEs to provide experimental control in terms of the amount and type of facial visual information presented to witnesses, the ability to correctly identify a perpetrator should increase as a result of better matching of visual cues sensed by the witness during the lineup to those sensed during the crime. Given that virtual humans have reached a state technologically to achieve high levels of copresence, it is possible to begin studying their use in applications that take advantage of the presence that IVEs provide.

1.1. Eyewitness Identification and Police Lineups

Police and prosecutors have long relied on eyewitnesses to crimes to identify criminals, and their testimony has a unique and powerful influence on juries and judges during criminal trials. In fact, such identifications are considered direct evidence, rather than circumstantial evidence—to put this in perspective, Wells [48] points out that even fingerprints are not considered direct evidence. Unfortunately, eyewitness testimony is not only one of the most compelling types of direct evidence to which a jury is exposed, but as many studies have shown, it can also be quite unreliable [49] . If the results of experiments using staged crimes are any indication, false identification (i.e., instances in which the witness incorrectly identifies someone other than the actual perpetrator in a lineup) occurs at rates potentially as high as 70% [31] , though this percentage varies according to testing situations. This problem is compounded by the fact that false identifications are often asserted with as much, if not more, confidence than accurate identifications [6] . While there has been much work examining ways to improve on these techniques, here we focus on reviewing research that relates theoretically to the manners in which IVES can potentially ameliorate the deficiencies of eyewitness testimony in lineups.

1.2. Prior Research on Improving Lineups Relevant to IVEs

1.2.1. Context Reinstatement. It has often been proposed that providing contextual cues to eyewitnesses of a crime (e.g., taking the witness back to the scene of the crime) will help them remember details about the crime and, in particular, facilitate accuracy in identifying the perpetrator of a crime. Context is expected to enhance recall because it provides memory retrieval cues [28] .

The idea that context reinstatement will enhance the accuracy of eyewitness recognition grew out of research on context effects on recognition memory. Research in this area has indicated that pairing faces or words with contextual cues will enhance performance on recognition tasks [35] [36] [37] [39] Thus, it seems reasonable to expect that these results may generalize to eyewitness identification.

There are several dimensions relevant to context reinstatement. The dimension most relevant to the present investigation is the physical or visual environment in which the encoding occurred. Methods commonly utilized to examine context reinstatement include the following: photographs of the environment [16] , objects from the environment [28] , guided recollection [33] , and mental contextual reinstatement cues [24] [17] .

Relevant to the current work, a small number of studies have examined physical context reinstatement and found that returning participants to the scene of the crime does enhance performance in facial recognition. For instance, two studies by Smith and Vela [45] examined this issue by staging a memorable event and asking participants to identify the confederate while in the context in which the event took place or in a different context. The results revealed that recognition performance was better when the recognition task took place in the same place as the memorable event.

However, results have been mixed across different context reinstatement methods. For instance, some have found that context reinstatement facilitates recognition performance (e.g., [34]) and others have found a null or weak relationship between context and recognition accuracy [17] [18] [40] . A meta-analysis on facial identification and eyewitness identification studies indicated that there was a significant effect for context reinstatement in two directions [42] . Context reinstatement increases overall correct identifications but it also increases false alarms. Additionally, the authors reported that the magnitude of improvement via context reinstatement was greater in lifelike situations than in laboratory studies.

Often times, it is impractical or impossible to return an eyewitness to the scene of a crime owing to changes in season, weather, lighting, etc. However it is possible that a virtual recreation of the crime scene could produce the same context reinstatement effects as the less practical option of returning an eye-witness to the physical scene of a crime even to the extent of recreating seasonal, weather, and lighting effects. The idea of using IVEs to recreate the scene of a crime was first investigated by Guadagno, Bailenson, Beall, Dimov, and Blascovich [21] . These authors staged a live crime and the examined eye-witness accuracy in the same or different context in which the crime took place that was either a physical room or a virtual recreation of the room. The results revealed that simultaneous line-ups (i.e., lineups with all the suspects present at once) that took place in either the virtual or physical scenes of the crime produced more accurate identifications of the perpetrator of the staged crime than did comparable line-ups in a different physical or virtual room.

1.2.2. Facial Information Processing. Research suggests that while the memory of a familiar face is sufficiently abstracted to allow for recognition despite a variety of transformations, the memory of an unfamiliar face (a face seen for the first time) depends heavily on the image upon which that memory is based [10] . An early meta analysis [42] of the literature on the recognition of unfamiliar faces concluded that across studies successful recognition was significantly influenced by the degree to which the images used in training materials matched those used at testing. Specifically, consistency of pose, context, and viewing angle proved important. Even in matching tasks where memory was not an issue, participants frequently failed to match images of unfamiliar faces at varying angles and lighting [25] . Given this sensitivity, we might expect an improvement in recognition rates if subjects are given the opportunity to select an angle that matches the angle of their original exposure.

Another potential advantage of active exploration of a three dimensional head is that it allows transformations of view. Schiff, Banka, and de Bordes Galdi [41] found that participants were better at recognizing targets in dynamic “mug shots” (in which the targets were videotaped rotating 180 degrees) than from static mug shots. Similarly, Christie and Bruce [11] found a slight advantage for recognition of unfamiliar faces when those faces were moving (either by nodding or shaking from side to side) than from nonmoving faces. If, as these data suggest, movement across views provides additional information that aids recognition [11] , we might expect the viewpoint transformations created by the witness’s own movement around the digital version of the suspect to produce similar effects.

1.2.3. Comparing Media of Suspect Representation. Some of the theoretical questions of the current study concerning amount of facial information presented in the lineup have been addressed via other media. As technology has advanced, particularly in the last twenty years, photographic and, more recently, video lineups have largely begun replacing live lineups for the purpose of eyewitness identification. A recent survey has found that a majority of lineups conducted by police jurisdictions in the US are not live (27% live, 73% photographic; [51]). In terms of the effectiveness of the various types of lineups, research comparing the methodologies is quite mixed, with most studies finding no large differences while others finding advantages and disadvantages.

For example, some studies have demonstrated that live lineups typically lead to minimally higher levels of accuracy than mediated lineups [19] [13] On the other hand, photographic lineups have been shown to lead to more correct identifications compared to live lineups, the latter leading to more false identifications [42] . According to Cutler, Berman, Penrod and Fisher [12] , the conservative conclusion based on available research findings at the time is that witnesses viewing live lineups, videotaped lineups or photo arrays perform similarly (see also [43] [14] .

On the other hand, Valentine and Heaton [47] found that video lineups are more fair than their live counterparts for a variety of reasons, including facilitation of large databases for distracters, avoidance of the physical collocation of witness and suspect in order to reduce witness anxiety [1] , and provision of video editing to prevent subtle, unintentional behaviors as in live lineups that could potentially bias the witness [51] . Furthermore, there is the risk that some of the important details of a suspect's appearance are lost in a photograph compared to a live or video lineup, as evidenced by lower accuracy rates found in studies such as Egan, Pittner and Goldstein [19] and Cutler and Fisher [13] .

In sum, there do not seem to be extremely large differences in patterns of results between live, photographic and video lineups. However, in the following section we discuss the use of IVEs, which provide a media that is a hybrid of photographic, video, and live lineups, perhaps combining the various advantages of the aforementioned three types of lineups.

1.2.4. The Potential of IVEs in Police Lineups. Bailenson, Blascovich, Beall, & Noveck [4] have discussed the potential for IVEs as a tool to improve eyewitness identification as well as other legal processes. An IVE lineup might feature the witness entering some type of digital environment that includes *virtual busts*, digital reconstructions of the suspects and distracters. Previous work has outlined the specific methodology of constructing IVEs and virtual busts [2] , and has provided empirical evidence that current technology is sophisticated enough to produce busts that highly resemble suspects. Immersive virtual environments offer a number of possibilities for improving lineups that are not as easily or effectively achieved with live and photographic lineups.

For example, in terms of context, reconstructing a virtual representation of the crime scene is easily and effectively achieved. Rather than being shown photographs of the crime scene prior to viewing the lineup or given instructions to imagine the crime scene (tactics often utilized to generate context reinstatement) - the witness could be placed in a virtual re-creation of the crime scene, and view the lineup from within that virtual world. Thus, if the crime occurred in a liquor store, the witness could view the lineup in that liquor store virtually without ever having to physically return to the scene of the crime. This is particularly useful when it would be traumatic for the witness to return to the actual crime scene, or when the crime scene no longer exists; for example if the offense is arson.

If one considers context on a perceptual level, IVEs offer an extremely valuable advantage in terms of representing suspects and distractors. With databases of photographs used in lineups, there is often variance in terms of the distance from the camera to the person as well as the camera angle. However, using IVEs one can lock the viewpoint and make it identical across all lineup members, thus maximizing the ability to control lineup fairness. Furthermore, using IVEs, lineup members can be made to appear identical in all ways except for the criteria on which the eyewitnesses should be trying to differentiate them; for example, all of the lineup members can be shown wearing identical clothing, hairstyles, and accessories. To illustrate, if the perpetrator had a beard at the time the crime was committed, but shaved it prior to the lineup, that might pose a problem for the eyewitness trying to identify him [38] . In a virtual lineup, that beard can be easily reinstated on the suspect, and all the lineup members, so that the witness can see them as they would have looked when the crime was committed.

Most importantly, IVEs are unique in allowing eyewitnesses to view suspects from any angle or distance without compromising the witness's anonymity or forcing the witness to get near the criminal. In live lineups, witnesses are unable to approach lineup members and view them close up because being in the same room as the suspect could be dangerous or emotionally traumatic. While video lineups potentially allow this action to take place, it is unrealistic to expect stock video footage to cover every single angle and distance between potential witnesses and the foils. On the other hand, from a single IVE digital model, an infinite pattern of examinations are easily and safely achieved, as IVEs allow witnesses to view suspects from any angle or distance chosen—from six centimeters away if they prefer—without ever placing the witness and suspect in the same physical room. Such features allow witnesses an active, unlimited exploration of lineup members that would never be possible in the physical world or from stock video footage.

Currently a majority of studies, as well as actual police procedures, rely on photo lineups or live lineups where the eyewitness views the targets from a distance [6] . These types of lineups afford the eyewitness small degrees of visual information (i.e., limited viewing angles and level of detail) compared to a virtual lineup where they can see the target from any angle and any distance.

One might expect that unlimited examination (i.e., examining the lineup members from whatever viewpoints the witness chooses) would allow for better recognition cues than for limited exploration (i.e., looking at a single snapshot of a suspect). On the other hand, unlimited visual information about the witness may be counterproductive if the information available at time of retrieval was not actually present at the time of encoding. For example, if an eyewitness witnessed a crime and only saw the face of the perpetrator from one specific angle, seeing the lineup members from other viewpoints might prove distracting; using IVEs we can ensure that the original viewpoint is the only angle from which both the suspect and all the distractors are displayed. Consequently, witnesses would not receive extraneous information from mug shots which likely contribute to false identifications, and on the other hand they would receive information that may be essential but not included in a mug shot (e.g., the back of someone's head). Therefore, IVEs may provide a mechanism to achieve a new level of context reinstatement.

One unique aspect of IVEs is that users may actively and freely move about an environment to examine the suspects and distractors. Consequently, a lineup may be improved by allowing an eyewitness to recreate the dynamic motion of the suspect's criminal behavior (or of the eyewitness himself) during the IVE lineup procedure. Research demonstrates that the processes governing perception of human faces have a substantial spatial gestalt component [20] [46] . These researchers provide evidence that not only are the local features of a face important in recognition but also the global configuration of those local features, which shifts at different angles and distances. Consequently, exploration of faces may be similar to exploration of other objects, to which studies show that *active* navigation results in superior performance compared to passive measures [26] . By allowing an eyewitness to explore a digital environment containing suspects, as opposed to merely looking at photographs, IVEs could take advantage of the manners in which humans encode and retrieve information about faces.

2. Overview of Experiment

We examined the possibility that allowing witnesses to set the specific angle and distance between themselves and the suspects during lineups would improve accuracy. Participants witnessed a staged crime in vivo and subsequently participated as an eyewitness in a sequential lineup, containing 7 suspects, within a digital IVE.

Three independent variables were manipulated via the sequential lineup: *view*, *exploration mode*, and *perpetrator presence*. There were two levels of *view (unlimited, limited)* such that participants in the unlimited condition were free to view the suspect from any distance and any angle (similar to a face-to-face examination). Participants in the limited condition were only able to view the suspect from a single distance and angle (similar to a 3D photograph). There were two levels of *exploration mode* (*active, passive*) such that participants in the active condition could walk and turn their heads naturalistically to manipulate their viewpoint. Participants in the passive condition were yoked (i.e., linked) to the archived movements of a previous participant and could not choose their distance or viewpoint; their viewpoints were updated by the system as if they were watching a stereoscopic movie based on the movements of another participant. There were two levels of *perpetrator presence (present, absent)*.

We hypothesized that lineup accuracy would be greater for participants with unlimited views than those with a limited view because this would increase the chance that the visual cues they encoded during the staged crime would actually be available for recognition cues during the lineup.

We also predicted better accuracy for participants in the active exploration mode than the passive exploration mode. Previous work has demonstrated better memory with active examination of stimuli than with and passive navigation through both physical space [44] and in VEs [23] [27] [9] . Furthermore, if there was variance in the angles in distances from which participants viewed the staged crime due to sitting in different seats, leaning in different directions, etc., then an active viewpoint choice should allow witnesses to best match the viewpoint (i.e., angle and distance between them and the suspects) of the lineup to that of the crime.

We predicted that participants would be more accurate in target absent lineups than in target present lineups, as previous work utilizing sequential lineups had indicated high accuracy of correct rejections [15] [30] .

3. Method

3.1. Participants

Ninety-eight adult participants (52 males, 46 females) were recruited from the undergraduate population at Stanford University. They received either course credit or a payment of $10. Their mean age was 19.80 (*SD* = 1.83). Participants were randomly assigned to one of eight conditions based on the crossing of the independent variables with approximately the same gender ratio in each condition.

3.2. Design

The experimental design was a 2 (view: limited vs. unlimited) x 2 (exploration mode: active vs. passive) x 2 (suspect-presence: present vs. absent) between-subjects factorial with twelve participants in each of the eight conditions. Each participant in the passive condition was yoked to a previous participant in the active condition, such that across the active and passive conditions the amount of visual information received was identical. Two confederates served as suspects for this study, with half of participants seeing a staged crime committed by Confederate A, and the other half seeing the crime committed by Confederate B. The confederates were balanced across conditions such that each one appeared in each of the eight between-subjects conditions for approximately half of the participants. Participants witnessed the staged crime either alone or in groups of two.

3.3. IVE System

The specific technology utilized to render the IVE is described in detail in previous research [3] and is depicted in Figure 1. Participants' physical movements along X,Y,Z spatial dimensions were tracked by optical sensors (Worldviz PPT X4, update rate 60 Hz) and head rotations were tracked by accelerometers in the physical room (Intersense IS250, update rate of 150 Hz). Perspectively-correct stereoscopic images were rendered by a 1700 MHz Pentium IV computer with an NVIDIA 5950 graphics card, and were updated at an average frame rate of 60 Hz. The system latency in the head-mounted display (HMD) was 45 ms maximum. The software used to assimilate the rendering and tracking was Vizard 2.17. Participants wore an nVisor SX HMD that featured dual 1280 horizontal by 1024 vertical pixel resolution panels that refreshed at 60 Hz. The display optics presented a visual field subtending approximately 50 degrees horizontally by 38 degrees vertically.

Figure 1: A depiction of the immersive virtual environment system. The components are 1) WorldViz PPT position tracking cameras, 2) Virtual Research V8 head-mounted display and Intersense orientation tracking sensor, and 3) image generator.

3.4. Perpetrators (i.e., Confederates)

The two confederates were physically similar (see Figure 2) allowing for a single set of suspect foils (i.e., distractors), weighing approximately 88 kilograms and having a height of approximately 1.8 meters.

Foils were selected using a match-description strategy [50] . Thirteen judges unfamiliar with the confederates read a brief written physical description of the perpetrator: "Caucasian male, between the ages of eighteen and twenty-two, sandy blond or light brown hair, blue or green eyes, athletic build, 5'10 to 6'2". The judges (7 males and 6 females) then examined a set of forty screenshots of male virtual busts (i.e., a virtual three- dimensional model of head and shoulders) created using modeling software (3dMeNow) and frontal and profile photographs (see [2] for more information about the virtual busts).

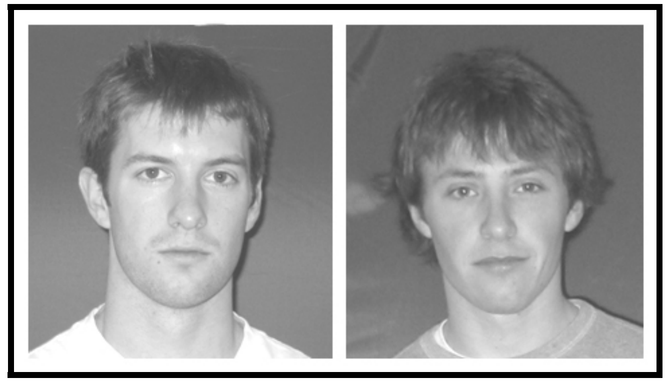

Figure 2: Photographs of the two confederates used in the study.

The software created a three-dimensional mesh to fit the shape of a person's head and then wrapped a texture which is the result of two photographs stitched together around the mesh. The forty busts were selected by the experimenters a priori from a large database because they roughly fit the physical description of the suspect. Each judge rated how well they thought each of the forty faces matched the description on a seven-point scale with higher numbers indicating a better fit. The six faces that received the highest mean scores (M = 5.16, SD = .42) were used as foils (see Figure 3). In the perpetrator-absent condition, the confederate who had not committed the staged crime was included as a foil as well.

Figure 3: The eight heads used in the lineups. The rightmost two heads on the bottom are models of the two confederates depicted in Figure 2.

3.5. Procedure

Upon arrival at the lab, each participant was taken into a lab room, seated, and asked to read and complete a consent form as well as a demographic questionnaire containing items concerning race, gender, and other personal characteristics. Participants were run either individually or in groups of two.

Next, the experimenter told the participant(s) that one more participant would be arriving. After waiting two minutes, the experimenter said that she would go downstairs to find the last participant. The experimenter left a purse with a wallet sticking out of it on a chair approximately 2 meters in front of the participants. Immediately after leaving the room, the experimenter cued the confederate who waited one minute before he entered the room. The confederates were blind to experimental condition.

The confederate walked into the room where the participant(s) were waiting, established eye contact, asked "Is this the virtual reality study?" and then asked "Are you the person running the study?" The participant typically replied that he or she was only participating, and that the experimenter had gone to look for the last participant and would be back shortly. The confederate proceeded to get visibly agitated, raising his voice and exclaiming that he had "no time to just wait around for the experimenter to return." While speaking, the confederate began to stare at the purse and wallet. After proclaiming that he could "not wait any longer!" the confederate grabbed the wallet and ran from the room. Overall, the confederates spent between 45 and 60 seconds in the room with the participants.

Immediately after the confederate exited, the experimenter re-entered and explained that the theft had been staged. The experimenter indicated that for the time being the participants should behave as if they had actually witnessed a crime, and explained that the participant(s) would be asked to identify the perpetrator in a lineup. When there were two participants, one sat in a chair in the hallway during the ten to fifteen minutes it took the other participant to view the lineup. Eighty of the 98 participants were run in pairs; the ratio of participants who went first to participants who went second was held constant across the eight between-subjects conditions.

The virtual room that contained the lineup was a digital representation of the room in which the crime occurred (same dimensions, blank walls, similar carpeting, etc.). Once they donned the HMD, participants were given a brief tutorial that explained how to use the gamepad to enter responses to questions while inside the virtual environment. They were then given a practice session to ensure that they understood how to use the gamepad. Next, all participants received the same basic instructions:

We are interested in whether you can accurately identify the perpetrator who you saw steal the wallet. To do this, you will view a lineup of suspects in a virtual room. The perpetrator may or may not be present in that lineup. You will view each member of the lineup individually, and after seeing each one it will be your job to determine whether or not he is the perpetrator. Once you make a decision, you cannot change it. After making each selection, you will be asked how confident you are in your response on a scale of 1 to 7, 1 being "not at all confident" and 7 being "extremely confident."

Participants were not told the number of suspects that would appear in the lineup in advance. After hearing the instructions, participants were asked if they had any questions. Most did not, and those that did almost uniformly wanted clarification that the presentation of the lineup would be sequential rather than simultaneous. Participants were then instructed to notify the experimenter if at any point they began to feel uncomfortable in the virtual environment. Then, depending on each participant's experimental condition, they were read one of the following additional sets of instructions:

Passive-Limited:

We would like you to stand here, without moving, and view the suspects. You will not be able to look around the room, or view the suspects from any angle other than the one you see initially, so there is no need to move your head or body.

Passive-Unlimited:

We would like you to stand here and view the suspects. You will be able to see the suspects from different angles and distances, but you will not be able to choose what viewpoints you see them from, so there is no need to move your head or body.

Active-Limited:

We would now like you to view the suspects. You may walk around to view the suspects from different angles and distances. At first you will only be able to see a plaster head. Once you decide from what angle and distance you would like to view the suspect, press the "Right" button on your gamepad and you will then be able to see the suspect clearly from your chosen viewpoint, for as long as you like. You will be able to choose a different viewpoint for each suspect you see.

Active-Unlimited:

We would now like you to view the suspects. You may walk around the suspects and view them from whatever angle or distance you like, for as long as you like.

After seeing the lineup, participants were given a suspicion probe to determine if they knew about the staged crime in advance. None of the 98 participants had any prior knowledge of the crime. The whole process took approximately one hour.

3.6. Measures

3.6.1. Accuracy. Participants received a score of one if they answered no in the target absent condition (correct rejections) or if they correctly identified the suspect in the target present condition (hits). Otherwise they were scored with a zero. Overall, the accuracy rate was 34 percent. Although it is not possible to do any formal signal detection analysis because each subject only contributed a single score, the Appendix breaks down the responses across subjects to allow interpreting the data by hits, misses, false alarms, and correct rejections.

3.6.2. Confidence. Participants rated how confident they were in their decision after viewing each person in the lineup on a scale from one to seven, with higher numbers indicating higher confidence. We took the mean confidence score of the seven responses (Cronbach's alpha =.61). The mean score was 3.57 (*SD* = 5.59). This factor was included to assess the relationship between confidence and accuracy across the different conditions.

3.6.3. Interpersonal Distance. We recorded the minimum distance in meters between each participant and the suspect over the seven trials he or she traversed (or was led in the passive condition) the virtual lineup. The mean minimum distance was 1.32 (*Max* = 3.00, *Min* = .28, *SD* = .73).

3.6.4. Suspect Presence. We also recorded the number of times participants indicated the suspect was present (i.e. "yes" responses) in the one of the seven sequential trials versus absent in the lineup. Participants had a slight bias to give "no" responses 55 percent of the time.

4. Results

Post experimental interviews indicated that not a single participant was aware prior to the experiment that a staged crime would be occurring and that none of the participants were aware that the confederate was acting. There were neither statistically significant differences nor notable trends between participants run alone or those run in groups of two. We also tested for a) order of receiving lineup (first versus second) for instances in which there were two participants, and b) confederate (A or B) and found no significant differences on any of our measures.

We ran a 2 (view: limited or unlimited) x 2 (exploration mode: active or passive) by 2 (perpetrator presence: present or absent) ANOVA with accuracy score as the dependent variable. The dependent variable was either a 0 or 1, and consequently was not normally distributed. While ANOVA is resilient against this assumption violation [29] , to be sure we repeated every analysis reported using a nonparametric, binary logistic regression. The patterns of significance (and non-significance) were identical. For the sake of simplicity, we report the ANOVA data.

There was a main effect for perpetrator presence, $F(1, 90) = 19.95$, $p<.001$, partial Eta Squared = .19. As Figure 4 depicts, participants were more accurate in suspect-absent lineups than in suspect-present lineups. There was also a significant interaction between view and perpetrator presence, $F(1, 90) = 6.40$, $p<.01$, partial Eta Squared = .07.

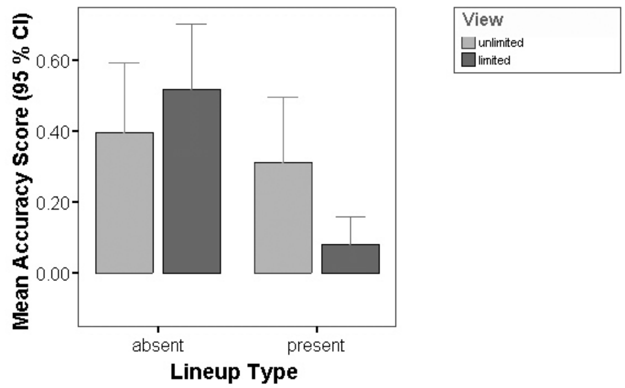

Figure 4: Accuracy scores by condition.

As Figure 4 demonstrates, having unlimited information improved participants score in suspect-present lineups but not in suspect-absent lineups. There was no significant effects involving exploration mode.

We had hypotheses concerning the distance participants maintained between themselves and the virtual suspects; consequently we repeated the above ANOVA with including interpersonal distance as a linear covariate. None of the effects from the original ANOVA changed, however there was a significant effect of interpersonal distance, $F(1,85) = 3.98$, $p<.05$ partial Eta Squared = .05, with large minimum distances signaling high accuracy. Note that the degrees of freedom are slightly lower in this analysis because distance data from three subjects was lost due to equipment failure.

To further explore the notion of distance, we computed the viewpoint from the average distance and angle from which all participants (in the active condition) chose to view the suspect. Figure 5 depicts this mean viewpoint. Interestingly, this viewpoint features a smaller ratio of head-to-image than most photographs utilized in most traditional photo-lineups. Indeed, participants were more accurate when their distance was farther away from the face of the suspect. In order to examine this effect further, we examined a random sample of the videos of the confederates committing the staged crimes, and established that on average, the confederates had left between approximately two and three meters between themselves and the participant(s) due to the placement of the chair with the money on it. The confederates had been instructed to maintain such a large distance in order to prevent a situation in which a participant might feel tempted to physically attempt to stop him from

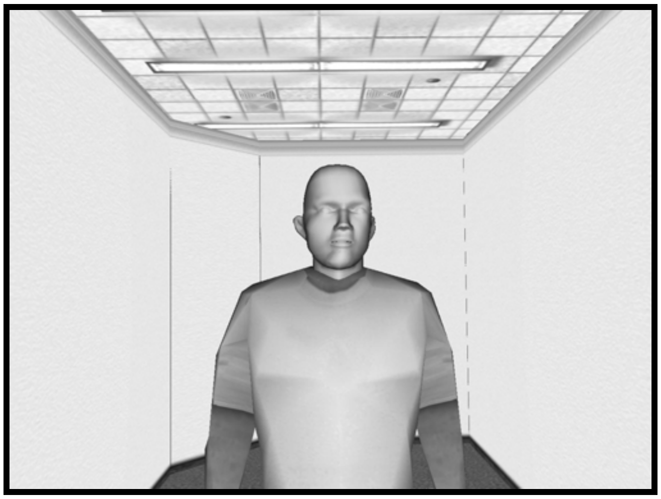

Figure 5: A suspect with a plaster head displayed to participants before they chose an angle and distance in the limited condition shown at the overall average viewpoint chosen by participants.

taking the money. Consequently, one explanation for the distance effect is that participants who maintained similar interpersonal distance levels while witnessing the crime and the lineup (i.e., between two and three meters) were more accurate than those who received disparate visual information.

It is important to note that there are other potential explanations for this result. For example, it could be the case that the virtual busts have visual artifacts that are inaccurate only when viewed up close. Alternatively, people who are truly accurate may not need to move close to the suspect because they have already made their decisions. Our distance/viewpoint matching explanation, though certainly intuitive given the data, is ad-hoc.

We next repeated the above ANOVA with confidence scores as the dependent variable. No effects approached significance (All *F*'s < .5, all *p*'s > .5). However the correlation between confidence and accuracy was positive, $r(98) = .24$, $p < .02$, such that people who were correct were more confident in their decision.

In terms of suspect presence (i.e., yes or no responses), we ran an ANOVA with view (limited or unlimited), exploration mode (active or passive) and perpetrator presence (present or absent) and accuracy score as the dependent variable. There was a marginal effect of view, $F(1,90) = 3.20$, $p < .08$, partial Eta Squared = .03, with a trend towards more yes responses with unlimited views (See the Appendix). No other effects approached significance (All *F*'s < 1.5, all *p*'s > .2).

5. Discussion

In the current experiment, we examined the use of IVEs for police lineups, and predicted that active compared to passive exploration would increase eyewitnesses' correct identifications of criminal suspects, and that an unlimited view would provide better recognition than a limited view. Both of those predictions share a common underlying process assumption—that unlimited, active view choices would best match visual information during encoding and during retrieval on the part of witnesses. Our results showed some support for this underlying prediction. An unlimited view led to better accuracy than a limited view in the suspect-present condition, regardless of whether or not the witnesses chose the viewpoint. Similarly, matching the lineup distance (between the suspect and the witness) and the staged crime distance improved accuracy. Finally, similar to previous research utilizing sequential lineups, participants were more accurate in suspect-absent lineups than in suspect-present lineups.

Interestingly, participants often chose to examine viewpoints that were different from the viewpoints at which they actually witnessed the crime. Hence, giving a witness active control over their viewpoint may be counterproductive without instructing them to only attempt to view the potential suspects from their original viewpoint. Future research should examine this phenomenon by providing eyewitnesses with specific instructions about viewpoint choice.

One unexpected finding was the extremely large size of the main effect of suspect presence. Participants were much more accurate when the suspect was absent (i.e., correct rejections) than when the suspect was present (i.e., hits). Our explanation for this disparity is necessarily ad hoc. Previous research that has utilized a sequential lineup procedure has also demonstrated high rates of correct rejections [15] [30] . What is surprising in the current work is the extremely low rate of correct identifications (i.e., hits). Participants had an extremely difficult time identifying the suspect in the limited condition in which they could only see the virtual busts from a single view.

This finding potentially stems from the fact that our three-dimensional models were not perfect analogs of the suspects, as a comparison between Figures 2 and 3 reveals relatively large disparities between the photographs of the confederates and the avatars of the three-dimensional models of the confederates. Undoubtedly, as technology improves, IVEs will become an increasingly viable alternative to both photographic and live lineups. In the meantime, IVEs have the capability to aid researchers in illuminating the positive and negative aspects of live and photographic lineups because it allows the isolation of variables such as viewpoint and context. The results of this study indicate that there are attributes of virtual lineups (such as recreating a range of viewing distances) that are beneficial to eyewitness identifications that cannot be equivalently reproduced using other, more traditional techniques.

The ease with which lineup members can be depicted in a variety of outfits, hairstyles and even locations is unparalleled, and has potentially profound advantages for eyewitness identification. In the future, it will be possible to program lineup member avatars to literally go through the motions of crime commission, exactly as the witness remembers the crime to have occurred, in a high-presence, virtual re-creation of the original context of the crime scene. The possibilities that arise with IVE technology can potentially revolutionize lineup creation and eyewitness identification. It is imperative, then, as technology advances, to periodically evaluate virtual lineups compared to real-world lineups to determine when virtual reality can be considered a feasible, perhaps even superior, alternative to live and photographic lineups.

Conclusions

In the current study, we demonstrated the potential for improving lineups with IVEs. Although there were limitations with the current data due to the fidelity of the virtual busts given current technology, the possibilities that arise with IVE technology can potentially revolutionize lineup creation and eyewitness identification. It is imperative, then, as technology advances, to periodically evaluate virtual lineups compared to real-world lineups to determine when virtual reality can be considered a feasible, perhaps even superior, alternative to live and photographic lineups.

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References

[1] Ainsworth, P. B., & King, E. (1988). Witnesses' perceptions of identification parades. In M. M. Gruneberg, P. E. Morris & R. N. Sykes (Eds.), *Practical aspects of memory: Current research and issues, 1*. Chichester: Wiley.

[2] Bailenson, J. N., Beall, A. C., Blascovich, J., & Rex, C. (2004). Examining virtual busts: Are photogrammetrically-generated head models effective for person identification? *PRESENCE: Teleoperators and Virtual Environments, 13(4),* 416-427.

[3] Bailenson, J. N., Blascovich, J., Beall, A. C., & Loomis, J. M. (2001). Equilibrium revisited: Mutual gaze and personal space in virtual environments. *PRESENCE: Teleoperators and Virtual Environments, 10*, 583-598.

[4] Bailenson, J. N., Blascovich, J., Beall, A. C., & Noveck, B. (2006). Courtroom applications of virtual environments, immersive virtual environments, and shared virtual environments. *Law and Policy*, 28(2), 249-270.

[5] Barfield, W., Lauria, R., Mann, S., & Kerr, I. (2005). Special Section: Legal, Ethical, and Policy Issues Associated with Virtual Environments and Computer Mediated Reality Guest Editors' Introduction. *PRESENCE: Teleoperators and Virtual Environments, 14(6)*, iii-v.

[6] Behrman, B. W., & Davey, S. L. (2001). Eyewitness identification in actual criminal cases: An archival analysis. *Law & Human Behavior, 25*(5), 475-491.

[7] Beizer, D. (2005). Tech success: Round up the usual suspects. *Post News Week Tech.*

[8] Blascovich, J., Loomis, J., Beall, A., Swinth, K., Hoyt, C., & Bailenson, J. N. (2002). Immersive virtual environment technology as a methodological tool for social psychology. *Psychological Inquiry, 13*, 103-124.

[9] Brooks, B. M., Attree, E. A., Rose, D., Clifford, B. R., & Leadbetter, A. G. (1999). The specificity of memory enhancement during interaction with a virtual environment. *Memory, 7*(1), 65-78.

[10] Bruce, V., & Burton, M. (2002). Learning new faces. In Fahle, M., & Poggio, T., (Eds.), *Perceptual Learning* (pp. 317-334). Cambridge: MIT Press.

[11] Christie, F., & Bruce, V. (1998). The role of dynamic information in the recognition of unfamiliar faces. *Memory & Cognition*, *26*, 780-790.

[12] Cutler, B. L., Berman, G. L., Penrod, S. D., & Fisher, R. P. (1994). Conceptual, practical, and empirical issues associated with eyewitness identification test media. In Ross, D., Read, J.D., & Toglia, (Eds.). *Adult Eyewitness Testimony: Current Trends and Developments.* New York: Cambridge University Press.

[13] Cutler, B. L., & Fisher, R. P., (1990). Live lineups, videotaped lineups, and photoarrays. *Forensic Reports, 3*, 439-449.

[14] Cutler, B. L., Fisher, R. P., & Chicvara, C. L., (1989). Eyewitness identification from live versus videotaped lineups. *Forensic Reports, 2,* 93-106.

[15] Cutler, B. L., & Penrod, S. D. (1988). Improving the reliability of eyewitness identifications: Lineup construction and presentation. *Journal of Applied Psychology, 73*, 281-290.

[16] Cutler, B. L., Penrod, S. D., & Martens, T. K. (1987). Improving the reliability of eyewitness identification: Putting context into context. *Journal of Applied Psychology, 72*, 629-637.

[17] Cutler, B. L., Penrod, S. D., O'Rourke, T. E., & Martens, T. K. (1986). Unconfounding the effects of contextual cues on eyewitness identification accuracy. *Social Behavior, 1,* 113-134.

[18] Davies, G., & Milne, A. (1985). Eyewitness composite production: A function of mental or physical reinstatement of context. *Criminal Justice and Behavior*, *12*, 209-220.

[19] Egan, D., Pittner, M., & Goldstein, A. (1977). Eyewitness identification: Photographs vs. live models. *Law and Human Behavior, 1*(2), 199–206.

[20] Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is "special" about face perception? *Psychological Review, 105*(3), 482-498.

[21] Guadagno, R. E., Bailenson, J. N., Beall, A. C., Dimov, A., & Blascovich, J. (2005, May). Virtual line-ups: Can immersive virtual context reinstatement facilitate eye-witness recall? Hot topic talk presented at the *American Psychological Society* Convention, Los Angeles, CA.

[22] Guadagno, R.E., Blascovich, J., Bailenson, J.N., McCall, C. (2006, in press). Virtual Humans and Persuasion: The Effects of Agency and Behavioral Realism. *Media Psychology*.

[23] Harman, K. L., Humphrey, G. K., & Goodale, M. A. (1999). Active manual control of object views facilitates visual recognition. *Current Biology, 9,* 1315-1318.

[24] Hershkowitz, I., Orbach, Y., Lamb, M. E., Sternberg, K. J., & Horowitz, D. (2001). The effects of mental context reinstatement on children's accounts of sexual abuse. *Applied Cognitive Psychology, 15*, 235-248.

[25] Hill, H., & Bruce, V. (1996). Effects of lighting on matching facial surfaces. *Journal of Experimental Psychology: Human Perception & Performance, 22,* 986-1004.

[26] James, K. H., Humphrey, G. K., Vilis, T., Corrie, B., & Goodale, M.A. (2001). Active and passive object recognition in a virtual environment [Abstract]. *Journal of Vision*, *1*(3), 292a, http://journalofvision.org/1/3/292/, doi:10.1167/1.3.292.

[27] Klatzky, R. L., Loomis, J. M., Beall, A. C., Chance, S. S., & Golledge, R.G. (1998). Spatial updating of self-position and orientation during real, imagined, and virtual locomotion. *Psychological Science, 9*(4), 293-298.

[28] Krafka, C., & Penrod, S. (1985). Reinstatement of context in a field experiment on eyewitness identification. *Journal of Personality and Social Psychology*, *49*, 58-69.

[29] Lindman, H. R. (1974). *Analysis of variance in complex experimental designs.* San Francisco: Freeman & Co.

[30] Lindsay, R. C. L., Lea, J., Nosworthy, G., Fulford, J., Hector, J., LeVan, V., & Seabrook, C. (1991). Biased lineups: Sequential presentation reduces the problem. *Journal of Applied Psychology*, *76*(6), 796-802.

[31] Lindsay, R. C. L., & Wells, G. L. (1980). What price justice? Exploring the relationship of lineup fairness to identification accuracy. *Law and Human Behavior*, *4*, 303-313.

[32] Malpass, R. S. & Devine, P. G. (1981a). Eyewitness identification: Lineup instructions and the absence of the offender. *Journal of Applied Psychology*, *66*(4), 482-489.

[33] Malpas, R. S. & Devine, P. G. (1981b). Guided memory in eyewitness identification. *Journal of Applied Psychology*, *66*(3), 343-350.

[34] Malpass, R. S. & Devine, P. G. (1984). Research on suggestion in lineups and photo-spreads. In G. L. Wells & E. F. Loftus (Eds.), *Eyewitness Testimony: Psychological Perspectives* (pp. 64-91). Cambridge: Cambridge University Press.

[35] McKenzie, W. A., & Tiberghien, G. (2003). Context effects in recognition memory: The roll of familiarity and recollection. *Cognition and Consciousness*, *13*, 20-38.

[36] Memon, A. & Bruce, V. (1983). The effects of encoding strategy and context change on face recognition, *Human Learning*, *2*, 313-326.

[37] Parker, A., Gellatly, A., & Waterman, M. (1999). The effect of environmental context manipulation on memory: Dissociation between perceptual and conceptual implicit tests. *European Journal of Cognitive Psychology*, *11*, 555-570.

[38] Pozzulo, J. D., & Lindsay, R. C. L. (1995, June). Eyewitness identification procedures when appearance has been changed. *Society for Applied Research in Memory and Cognition*, Vancouver.

[39] Rainis, N. (2001). Semantic contexts and face recognition. *Applied Cognitive Psychology*, *15*, 173-186.

[40] Sanders, G. L. (1984). The effects if context cues on eyewitness identification responses. *Journal of Applied Social Psychology*, *14,* 386-397.

[41] Schiff, W., Banka, L., & de Bordes Galai, G. (1986). Recognizing people seen in events via dynamic mug-shots. *American Journal of Psychology*, *99*, 219-231.

[42] Shapiro, P. N., & Penrod, S. (1986). Meta-analysis of facial identification studies. *Psychological Bulletin, 100,* 139-156.

[43] Shepherd, J. W., Ellis, H. D., & Davies, G. M. (1982). *Identification Evidence*. Great Britain: Aberdeen University Press.

[44] Simons, D. J., & Wang, R. F. (1998). Perceiving real-world viewpoint changes. *Psychological Science, 9*(4), 315-320.

[45] Smith, S. M., & Vela, E. (1992). Environmental context-dependent eyewitness recognition. *Applied Cognitive Psychology*, *6*, 125-139.

[46] Tanaka, J. W., & Sengco, J. (1997). Features and their configuration in face recognition. *Memory & Cognition*, *25*, 583-592.

[47] Valentine, T., & Heaton, P. (1999). An evaluation of the fairness of police line-ups and video identifications. *Applied Cognitive Psychology, 13*, S59–S72.

[48] Wells, G. L. (1984). The psychology of lineup identifications. *Journal of Applied Social Psychology, 14*(2), 89-103.

[49] Wells, G. L., & Loftus, E. F. (2003). Eyewitness memory for people and events. In A. Goldstein, (Ed.), Comprehensive handbook of psychology, Volume 11, Forensic psychology. New York: John Wiley and Sons.

[50] Wells, G. L., Rydell, S. M., & Seelau, E. P. (1993). The selection of distractors for eyewitness lineups. *Journal of Applied Psychology, 78*(5), 835-844.

[51] Wogalter, M. S., Malpass, R. S., & McQuiston, D. E., (2004). A national survey of US police on preparation and conduct of identification lineups. *Psychology, Crime & Law, 10*(1), 69–82.

Appendix:

Proportions of Accuracy, Proportions of "Yes" Responses, and Mean Confidence Scores by Condition. The denominator of the ratios indicates the total number of participants in that condition.

	Confederate A				Confederate B			
Exploration:	active		passive		active		passive	
View:	limited	unlimited	limited	unlimited	limited	unlimited	limited	unlimited
				Proportion of accurate responses				
Perpetrator present:	0/6	2/6	1/7	2/6	0/6	1/6	0/6	1/6
Perpetrator absent:	4/7	1/6	6/6	4/6	4/6	2/6	2/6	3/6
				Proportion of "yes" responses to perpetrator presence				
Perpetrator present:	1/6	4/6	3/7	4/6	4/6	2/6	1/6	2/6
Perpetrator absent:	3/7	5/6	0/6	2/6	2/6	4/6	4/6	3/6
				Mean Confidence Scores				
Perpetrator present:								
mean	5.86	5.88	5.65	4.88	5.52	5.05	5.55	6.12
SD	0.48	0.49	0.75	0.69	0.72	0.99	0.78	0.71
Perpetrator absent:								
mean	5.80	5.74	5.76	5.76	5.02	5.60	5.67	5.60
SD	0.74	0.67	0.89	0.82	1.06	0.73	0.88	1.06