# Investigating Graphical Realism in a Virtual Environment for Threat Identification

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## ABSTRACT
Virtual environments are commonly used for training simulators. As virtual reality technology improves there is increasing potential for military and law enforcement training systems related to marksmanship, threat identification and time critical decision making. However, building highly realistic simulators can be expensive. In this paper we explore the effect of altering graphical realism on user performance for a threat identification task in a first-person virtual environment. Realism was manipulated by changing graphic veracity across three levels, namely, low, medium and high, while participant performance was measured by the proportion of correct and incorrect identifications made. Participants in a user study were required to identify non-player characters as threatening based on objects being carried. The results indicated that altering graphical realism had no effect on user performance in the virtual threat identification task or on the average distance required within the environment for successful identifications. However, post-task questionnaires suggested that improved graphical realism leads to increased user task engagement.

### Author Keywords
Graphical realism; threat identification; virtual environment; user experience; game technology.

### ACM Classification Keywords
H.5.1. Information Interfaces and Presentation (e.g. HCI): Multimedia Information Systems—*Artificial, augmented and virtual realities*

## INTRODUCTION
As virtual reality technology improves there is increasing potential for military and law enforcement training systems related to marksmanship, threat identification and time critical decision making. However, building highly realistic simulators can be expensive. There are hardware and software overheads for high performance rendering and the need for detailed graphical assets, e.g. 3D objects, avatars and environment textures. This is on top of the generally time consuming nature of virtual environment development [17].

One typical question here is of how realistic an environment needs to be. This will depend on the aim of the simulation, but two common tradeoffs involve environment realism versus perceptions of user experiences.

Realism, as defined in [16], can be broken down into three components, namely geometric realism, illumination realism and behavioural realism. Geometric realism and illumination realism together make up graphical realism. Geometric realism is measured by how realistic the shape and dimensions of objects in an environment are when compared to the real world. Supporting geometric realism may involve changing attributes such as shape, size, number of textures, tessellation count, detail of models, and model representations of polygon meshes. Illumination realism refers to the realism of the lighting model used in an environment. It could be altered by changing the light rendering method, type or presence of shadows, or the type and nature of light sources. In the work described here, we are primarily interested in changing geometric realism and the effect on graphical realism.

Graphical realism is an important factor to consider because it effects the emotional response of humans to virtual environments [9, 23], for example the level of anxiety in response to standing on the edge of a virtual deep precipice [14]. Increasing the emotional response of humans to virtual environment training makes for a more effective training tool because users respond more realistically to what they see and therefore the skills learnt in a virtual environment can be better transferred to the real world [19].

Stanney et al. [19] consider the importance of understanding the factors that affect human performance at tasks in virtual environments and that this understanding can be used to help create virtual environments that maximise the efficiency of human task performance. This is particularly important when virtual environments are used for training simulators.

In this paper we consider the effect of altering graphical realism on user performance for a threat identification task in a first-person virtual environment. Specifically, we have focused on identifying humans who are carrying threatening objects as this task is an important skill for military, national security and local security forces [13]. We have explored


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the hypothesis that *altering graphical realism within a virtual environment will affect participant performance at a task to identify human avatars as threatening or not threatening based on the object they are holding*. Two relevant areas of previous work include virtual environments for high-risk tasks and issues of realism and the user experience.

## RELATED WORK

### Virtual Environments for Simulating High Risk Scenarios

Virtual environments give the benefit of being able to simulate and train for high risk situations that are not feasible to reproduce in the real world. For this reason virtual environments are increasingly being used in a variety of high risk domain areas, for example simulating fire evacuations [18], weapon usage [7], suspect deception detection [12], laparoscopic surgical training [4] and first responder training when dealing with terrorist attacks [20].

Greenwald et al. [7] used a desktop virtual environment to examine the effects of race on responses to weapons holders. They conducted task-based experiments where participants were required to observe a mixture of black and white non-player characters (NPCs) representing police officers, criminals and civilians. The NPCs in the virtual environment were holding either guns or harmless objects and the participants were to shoot those holding guns. By recording the number of correct decisions and incorrect decisions made by participants they were able to evaluate if the decision to shoot was affected by racial bias. The task considered in the work described here is similar to the Greenwald et al. task except we have considered graphical realism rather than racial bias.

Smith and Trenholme [18] employed a virtual environment to simulate fire drills by adding building content and fire behaviour scripting to an environment developed using the Source game engine (as used in the game Half-Life2). The participants in a user study navigated from the burning building using a first person viewpoint and were required to find a suitable escape route. Smith and Trenholme identified how virtual environments can be used for training in fire drill evacuations with the added realism of fire and smoke but without the cost and dangers of simulating a fire in the real world.

Knerr [10] acknowledges that the benefits of training soldiers both as individuals and as groups in virtual environments has been recognised for over a decade. Knerr presents the results of examining how soldiers compared virtual environment training with live exercises and found that outdoor movement, identification of types of people, identification of tactically significant areas, and individual weapon use were the most effective training features of virtual environment training in this context.

Finally, Li [11] describes the architecture, implementation and, evaluation results of a police training system using virtual environments and demonstrates how it is a useful and effective training method for police officers. Li demonstrated how both simple and complex environments can be used for training situations ranging from basic criminal identification to hostage saving situations.

### Realism and Presence in Virtual Environments

Higher levels of virtual environment realism are said to give users a greater feeling of enjoyment and increase their immersion within virtual environments. There is ongoing debate on the definitions of immersion and presence, see for example [2, 3, 8, 15]. Here, we are concerned with users perception of realism and how this affects their virtual environment experience, i.e. having immersion/presence closer to the Brown and Cairns [3] view of an increasingly focused user experience through engagement, engrossment and total immersion phases. The increased realism and immersion within such environments can help skills learnt in training transfer into the real world tasks [21]. In addition to the realism definitions noted earlier [16], Ferwerda [6] describes three definitions for graphical realism as (i) physical realism that provides the same visual stimulation as the scene, (ii) photo-realism that provides the same visual response as the scene and (iii) functional realism that provides the same visual information as the scene. Functional realism is adopted by flight simulators in virtual environments where the relevant details for training act like they would in the real world but do not look the same. In effect, reducing graphical realism in support of better task transfer.

Cheng and Cairns [5] examined the relation between realism and immersion. Immersion or presence refers to a user's unbroken concentration in a virtual environment and can be measured at different levels. By altering the character graphics, environment graphics and physics behaviour of a virtual environment created using the Unreal 2003 games engine, Cheng and Cairns tried to break user immersion. Using questionnaires to collect results, they found that graphical realism had a higher potential than behavioural realism for breaking users immersion in the virtual environment. It was also observed that high graphical realism produced more consistent immersion than low graphical realism that caused very varied immersion levels depending on the user.

Slater et al. [14] examine the effects of illumination realism on user presence by using a virtual environment task where the participant is required to walk to the edge of a deep precipice. One group of participants had a virtual environment rendered with ray casting which has no shadows or reflections and the other group had a virtual environment rendered with ray tracing which has shadows and reflections. Slater et al. measured the participant's heart rate and skin conductivity levels to measure presence. They discovered that the ray-tracing group with higher illumination realism led to an increase in bodily reaction to the precipice and therefore higher presence to the virtual environment experience.

## THREAT IDENTIFICATION ENVIRONMENT

We have developed a virtual environment to support a threat identification task.

### Task Domain

The threat identification task takes place in a virtual environment representing a busy alleyway located on an industrial estate during working hours. Within the alleyway NPCs enter and exit via both ends of the alleyway as well as from entrances along each wall. Each NPC carries an object that is either threatening or not threatening, for example a gun or a soft drink can. It is the job of the user is to recognise those NPCs carrying threatening objects and to identify them as threatening while leaving the NPCs carrying non-threatening objects unmarked.

The user assumes the role of a CCTV camera operator. The CCTV camera is located at a fixed high vantage point in the virtual alleyway. The user controls the CCTV camera from a first person viewing perspective using the mouse to look around the alleyway. There is a crosshair in the centre of the screen allowing the user to line up and identify NPCs that are perceived to be threatening. The alleyway virtual environment layout is shown in Figure 1.

### Test Environment

Virtual environment development is a time consuming and expensive process [17]. However, computer game technology can provide many of the tools necessary to develop virtual environments and many include assets that can be reused to speed up the development process.

A virtual environment was developed using the Unreal Tournament 3 game engine[1]. Game technology is ideal for supporting the rapid development of robust and usable virtual environments. Many modern video games come with customisable games engines with provision for reusable assets such as 3D models, graphical textures and NPC behaviour scripts. Such systems can be used to produce high quality virtual environments and are easily available for non-commercial use [22].

The Unreal 3 game engine was chosen for the development of this system because it has advanced graphics capabilities, a comprehensive virtual environment editor, uses UnrealScript and has a first person game already implemented that can be reused and modified. UnrealScript is an object oriented high level programming language that is similar to C++ and JAVA and provides, among other things, the NPC behaviours in the task scenario here.

## LEVELS OF REALISM

### Environment Realism

Geometric realism [16] was manipulated by adjusting the vertical and horizontal dimensions of the virtual environment textures. This was achieved by increasing the scale of each texture beyond its optimum size compared to the geometry on which it was placed. This meant it was possible to change the visible proportions and therefore geometric realism across three environments with low, medium and high levels of realism. The most realistic proportions were used for the high realism setting. The dimensions of the textures were increased by fifty percent from high to medium and a further one hundred percent from medium to low. This created a slightly distorted and less graphically realistic set of textures for the medium setting and a highly distorted and blurred set of textures for the low setting. In order to isolate a dependant variable to test, in this case geometric realism, illumination levels were kept constant across the three environments developed. Figure 2 shows a comparison of the implemented low and high realism virtual environments.

### NPCs and Threats

As part of the threat identification task it was necessary to create NPCs representing humans that could be controlled using scripted behaviour to give the impression that the virtual alley was populated with humans passing through. It was decided to use 3D models representing white adult males as the only type of NPC. This was to reduce possible biases by participants during the user study concerning identifying NPCs as threatening based on their age, gender or race. Each NPC used in the alley virtual environment consisted of a textured 3D model[2], walking animations and UnrealScript code for NPC movement through the virtual alleyway and NPC spawning. It was necessary to control the spawn time of each NPC in relation to how many NPCs were already in the virtual environment and to consider what paths in the alley were currently in use. Delay timers were used to control when NPCs would spawn in the alley so that it was not overcrowded or that NPCs did not become bottlenecked at any alley location. All the NPCs spawned outside the view of the CCTV operator.

A variety of different handheld objects commonly associated as threatening or not threatening were used to create a set of NPCs that would be perceived as threatening or not threatening during the user study. Each NPC was randomly assigned an object at a ratio of sixty percent non-threatening objects to forty percent threatening objects. There were a total of twenty six NPCs in each test scenario. In each test 15 from 26 NPCs were non threatening while 11 from 26 were threatening. The above ratio of threatening objects and non-threatening objects was used to ensure that differences in participants scores would be noticeable. It was reasoned that if the percentage of threatening objects used was too low then it would be likely that there would not be enough variation in the results obtained and therefore it would be difficult to show any subtle changes in participant performance at the threat identification task.

### NPC Realism

To adjust the geometric realism of the NPCs and handheld objects the polygon count of each 3D model was reduced using an automatic function in the graphics modelling tool 3ds-MAX. The initial models used were of the highest realism and the polygon count of these models was reduced twice to create medium and low realism models. The polygon count was reduced by twenty five percent at each level. Using polygon reduction a set of NPCs and objects was created at low, medium and high geometric realism levels. Figure 3 shows a comparison of the implemented NPCs at low, medium and high realism settings.

[1]Unreal Engine 3: http://www.unrealengine.com/features [access date: 11/02/2012].

[2]Downloaded from http://www.turbosquid.com [last access 11/02/2012].

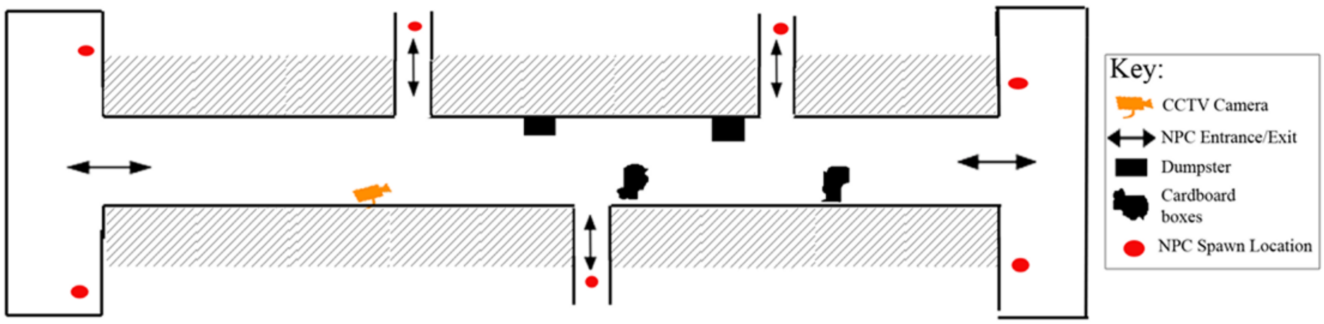


**Figure 1. 2D view of the threat identification environment.**

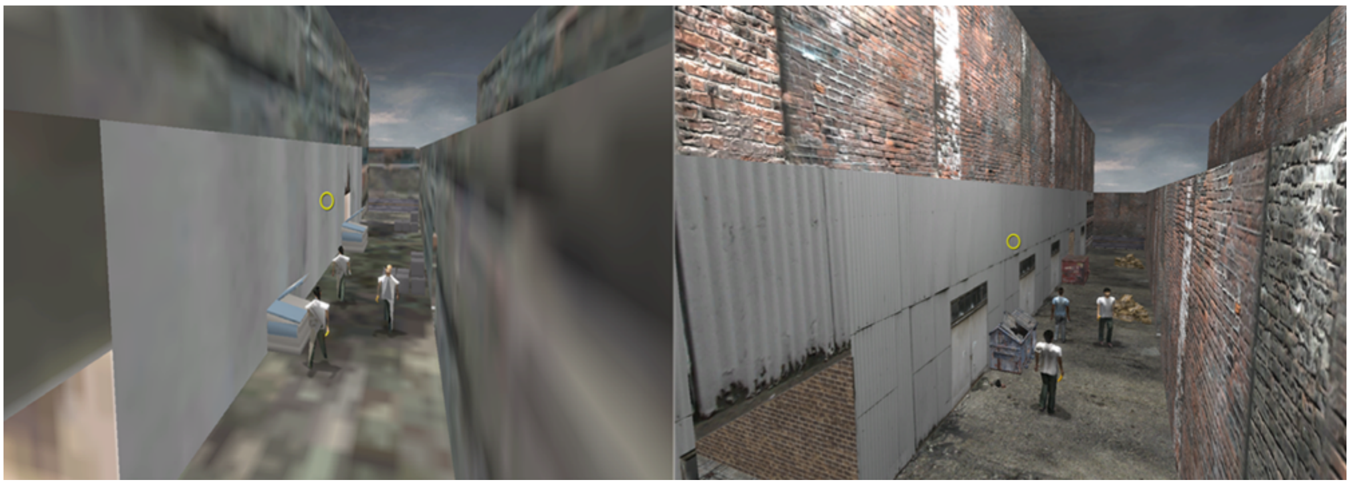

**Figure 2. Low realism (left) and high realism (right) views of the virtual alleyway.**

**Figure 3. NPC avatar heads in low, medium and high realism levels.**

## USER STUDY

To test the main hypothesis that *altering graphical realism within a virtual environment will affect participant performance at a task to identify human avatars as threatening or not threatening based on the object they are holding* a user study was conducted.

### Participants

The sample population consisted of twelve University level students (seven male) aged between 18-25. All the participants used computers on a daily basis and three quarters of the participants played computer games.

### Procedure

At the start of an evaluation session, each participant completed a consent form and a pre study questionnaire to collect basic information for example age, gender and previous virtual environment experience. Each participant was provided with task instructions and allowed the opportunity to ask any questions. The participant was then given a final verbal instruction briefing from the demonstrator to ensure the task was well understood. The participant then completed a set of three threat identification tasks at different levels of graphic realism.

A within subjects design was used with all participants experiencing the identification task in the low, medium and high realism environments. To counteract any learning effects, the order of realism tasks was counterbalanced between all participants. Thus, with twelve participants, there were two participants for each [low, medium, high] realism ordering.

An identification task in a single environment lasted for approximately two minutes and thirty seconds. During this time each participant was asked to identify any NPCs as they perceived as threatening until the time ran out. Each time the participant marked an NPC as threatening the system logged a set of measures, e.g. a time stamp, avatar type, threat/no threat type and distance to CCTV viewpoint.

Each task was followed by a post-task questionnaire to obtain feedback about the participants experience of the task that had just been completed. On average each participant took fifteen minutes to complete the study.

## RESULTS

### Identification Accuracy

Participant performance, in terms of identification accuracy, for the threat identification task at each level of realism was measured by the number of correct and incorrect NPC threat identifications made. A correct identification (true positive) was recorded if the participant identified a NPC who was holding a threatening object whereas an incorrect identification (false positive) was recorded if the participant identified a NPC who was holding a non threatening object. For each participant the normalised false positives were subtracted from the correct identification percentage to generate a score per realism level. Figure 4 shows the overall participant scores. The median average only varies by 0.5 from low to medium and from 0.3 from medium to high. Although there is a slight upwards trend in the median from low to high realism there is little evidence to suggest that altering graphical realism in this virtual environment affected participant performance.

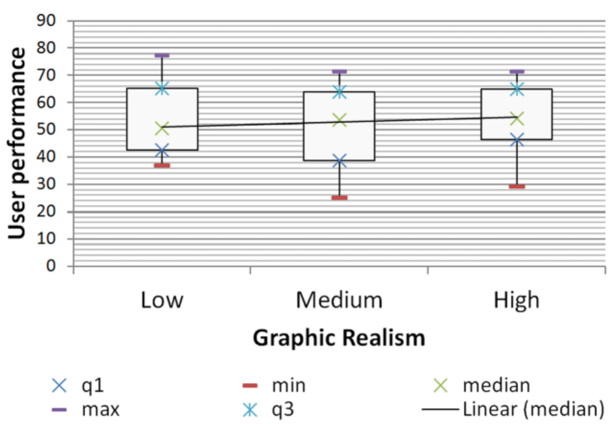


**Figure 4. Normalised score percentages for threat identification across the three levels of graphical realism.**

This was confirmed with an ANOVA analysis ($N = 12$) with repeated measures (the identifications across the three levels of realism) and the true positive, false positive and false negative scores. There was no significant main effect for *Realism* across the tests for true positives ($F(2, 22) = 0.06, p = 0.94$), false positives ($F(2, 22) = 0.62, p = 0.55$) or false negatives ($F(2, 22) = 0.06, p = 0.94$). Therefore the main hypothesis is rejected for identification accuracy.

### Distance and NPC Position Effects

Threat identification requires a judgement call that has a distance component, i.e. how close the threat, or perceived threat, is to the participant before they indicate that it is, in fact, a threat. The distance for all the threat identifications, both true and false positives, were collected during the user study. Initially we wished to identify clusters in the distance based identification decisions (see Figure 5). Although there is a distinct grouping of NPC identifications towards the middle of the alleyway, this was not surprising given the nature of the task and the scripted movements of the NPCs. Figure 6 shows the average distances for true positive and false positive identifications across the three tests. Although there was improvement with increased graphical realism with fewer false positives, this was not statistically significant.

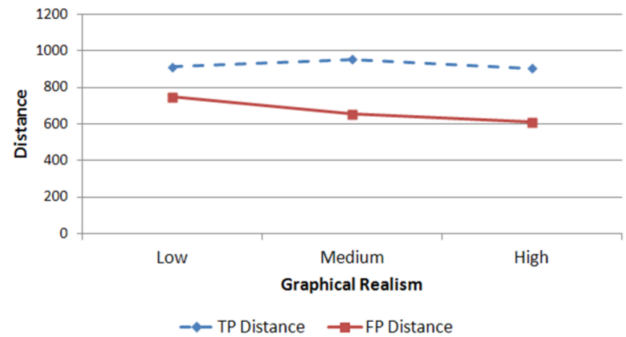


**Figure 6. Average distances across three levels of graphical realism for true positive (TP) and false positive (FP) threat identifications.**

We conducted an ANOVA analysis ($N = 12$) with repeated measures (the distance for identification across the three levels of realism) with true positive and false positive distance scores. Again, there was no significant main effect for *Realism* across the distances for true positives ($F(2, 22) = 0.56, p = 0.58$) or false positives ($F(2, 22) = 0.35, p = 0.71$). Therefore the main hypothesis is also rejected for distance-based decision making.

### Participant Perception of Realism

Participant perception of the threat task as collected in post-task questionnaires and their views on environment and NPC realism are summarised in Figure 7.

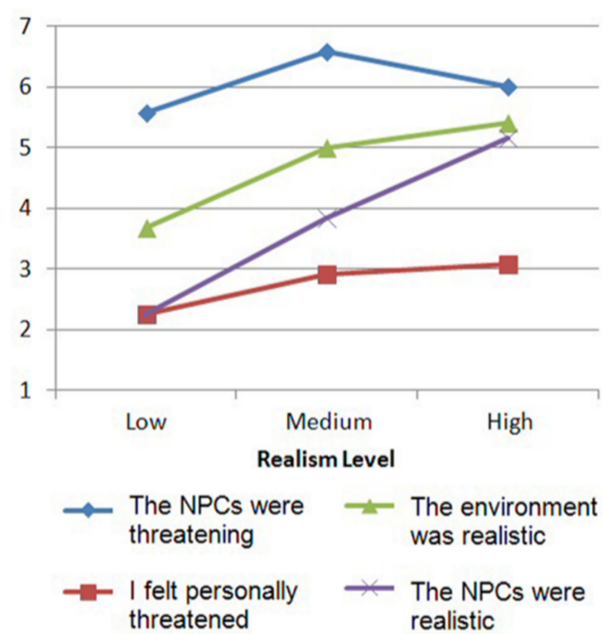


**Figure 7. Participant perceptions of the threat environment across three levels of graphical realism [1=strongly disagree and 7=strongly agree].**

Participants increased perceptions of realism, in the context of the environment and NPCs, was found to match increasing graphical realism. Participants agreed that the NPCs were

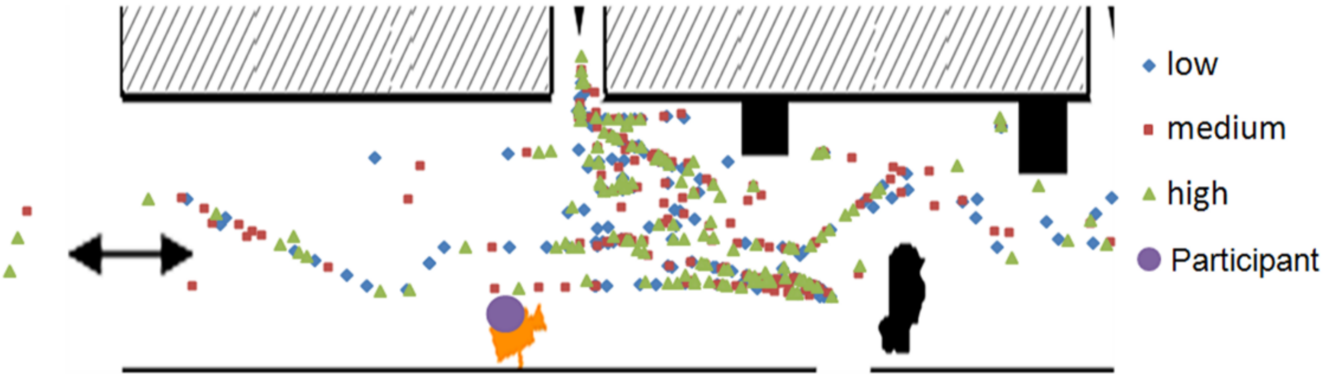


Figure 5. NPC identifications by distance and position.

threatening but that they did not feel personally threatened. The task, and likely the CCTV mechanism, insulated the participants from the environment threats. Also the threats involved were more passive, in that the NPC behaviour was not directed towards the participants. This indicates a good match between the planned scenarios and the user experience. An extension of this work would be to also consider more actively threatening behaviour by the NPCs towards the CCTV operator. However, such a testing environment would have ethical issues that would need to be carefully considered.

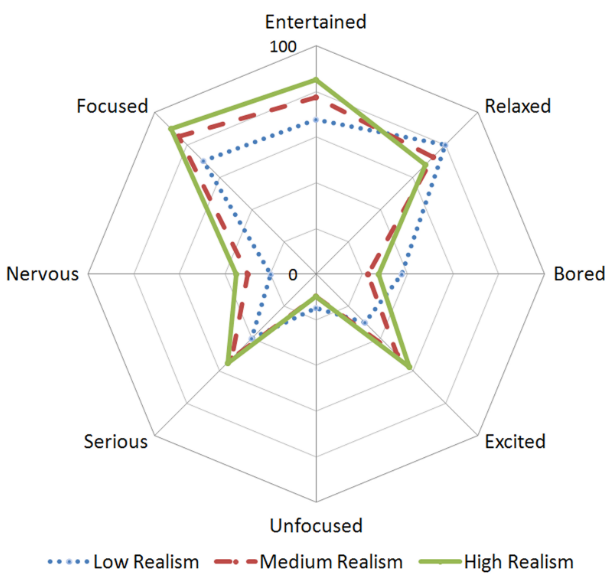


**Figure 8. Participant emotion radar chart across three levels of graphical realism.**

Post-task questionnaires also collected participants emotional state via a radar chart, based on a *semantic structure of affect* [1], and a summary across the three levels of graphical realism was compiled. Figure 8 shows that the more graphically realistic environments invoked a more emotionally provocative experience for participants. Higher graphical realism meant that participants perceived themselves to be more entertained, excited, attentive, nervous and serious. In contrast lower graphical realism meant participants felt that they were more relaxed, bored and unfocused. Similar to findings by [14], higher levels of graphical realism increases humans emotive responses to what they are experiencing. However, although participants perceived increased positive emotional engagement with higher realism environments, this did not lead to increased participant performance, also found by [23], in the threat identification task.

The results here indicate that graphical realism tradeoffs, in terms of development and performance issues, need to be clearly justified in the context of desired benefits when using virtual environments. For example, developers need to consider how graphical realism supports any primary aims of a system, whether it is for task performance improvements or to provide support for a better perceived user experience.

## CONCLUSIONS

We have presented a user study of a threat identification virtual environment where different levels of graphical realism were explored. It was found that altering graphical realism had no effect on identification accuracy as a measure of participant performance. A review of identification decision distances when participants identified NPCs as threatening was also found to not be effected by graphical realism. However, post-task questionnaires indicated that participant perception of graphical realism affected their engagement with the task environment.

High levels of graphical realism in virtual environment can require expensive 3D modelling, detailed texture features and high performance deployment technology. If there are limited performance benefits, as found here, the environment resources, both in product development and use, might be better spent elsewhere. However, we have only investigated one aspect of realism in a threat identification task. Thus there is scope for future work exploring other types of realism such as illumination realism in the environment and/or the behavioural realism of the NPCs.

Through this work, we have identified a number of areas that would benefit further investigation. Firstly, our user study had a limited selection of participants. Extending the study to incorporate a wider selection of participants over a more diverse age and skill range would be appropriate, particularly to target potential end users, for example law enforcement practitioners. Secondly, testing the threat identification task across different game engines, or other custom virtual environments, would ensure that the results are not simply indicative of the specific game engine used in this study. Thirdly, the NPC behaviour scripting was implemented using pre-configured scripts, i.e. the NPCs had set paths for movement through the virtual alleyway. Using more dynamic scripts or other human users as the NPCs could enhance the realism of the NPCs' behavioural aspects. Given the network capabilities of many game engines, using a mix of automated and human-controlled NPCs for realism-based evaluations is an exciting area for future research.

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