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Distance estimation to flashes in a simulated night vision environment

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Abstract

The Canadian Forces have recognized the importance of simulator training as a cost-effective alternative to real training; yet the effect of display simulation on visual perception is not fully understood. Eighteen subjects participated in an experiment to determine if training, in the form of immediate feedback, improved distance estimation to muzzle flashes in a simulated NVG environment. Testing was performed on a PC desktop computer using software that simulated a large open grassy field. Subjects were exposed to three flash types; five flashes, single flash, and a prolonged flash. Flashes were presented to the subjects both above and below the horizon. Significant improvement was shown in the experimental group's accuracy; this accuracy persisted over two weeks but with notable deterioration. Contrary to expectation the perception of a single flash resulted in significantly greater accuracy than the prolonged flash. This experiment reinforces the effectiveness of simulation as a tool in preparing soldiers. A bibliography of the topic is included.

Résumé

Les Forces canadiennes reconnaissent l'importance de la formation sur simulateur à titre de substitut économique à la formation réelle; cependant, les effets de la simulation de l'affichage sur la perception visuelle demeurent mal compris. Dix-huit personnes ont participé à une expérience visant à déterminer si la formation avec rétroaction immédiate améliorait l'appréciation des distances de lueurs de départ dans un milieu de simulation observé avec des LVN (lunettes de vision de nuit). Les essais ont été réalisés sur un ordinateur de bureau à l'aide d'un logiciel qui simule une vaste étendue (champ). Les participants ont été exposés à trois types d'éclairs : une série de cinq éclairs, un éclair unique et un éclair prolongé. Les éclairs étaient générés au-dessus et en-dessous de l'horizon. Des améliorations importantes ($p \leq 0,05$) ont été observées dans la précision de l'information fournie par le groupe étudié; la précision a été maintenue pendant deux semaines, mais s'est tout de même détériorée considérablement au cours de cette période. Contrairement aux attentes, la distance de l'éclair unique a été perçue avec une précision beaucoup plus grande ($p \leq 0,05$) que celle de l'éclair prolongé. Cette expérience est venue confirmer l'efficacité de la simulation comme outil de préparation des soldats.

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Executive summary

Distance estimation to flashes in a simulated night vision environment:

Garrett Morawiec; Keith K. Niall; Kathleen Scullion; DRDC Toronto TR 2007-143; Defence R&D Canada – Toronto; December 2007.

Introduction or background: Distance estimation is a fundamental skill that must be mastered by all combat arms soldiers. New recruits to the Canadian Forces (CF) are taught to estimate distance during their Army Soldier Qualification (ASQ) course. The use of technologies such as night vision (NV) devices (image intensifiers) gives the CF a tactical advantage. The Canadian Forces has recognized the importance of simulation training as a cost effective alternative to live training; however, the effects of simulator on visual perception are not yet fully understood. A simulated NV environment was used to determine if participants could be trained to estimate distance accurately from their own position to muzzle flashes. Eighteen participants (n = 18) volunteered for the study: sixteen males and two females. Participant ranged in age from 19 to 49 years (*M* = 31.45, *SD* = 7.38). Thirteen participants were military personnel: eight had previous experience with night vision devices. Testing was performed on a PC computer using software that simulated an open field with textured grass as the ground plane, and clouds in the sky. Participants could see a horizon line which appeared where the ground and sky met. Flashes of light would appear on the display either above or below the horizon. Participants were exposed to three different flashes: 1) five consecutive flashes 2) a single flash or 3) a prolonged flash. The flashes of light could appear anywhere from 5-300 meters away from the participant, in five meter increments. Each participant completed four sessions; pre-training, training/no training, post-training and two week post-training. The first, third and fourth sessions (pre-training, post-training and two week post-training) required the participants to estimate the distance from themselves to the flashes, with no feedback. In the second session the experimental group was provided with feedback, in which the participant was told the actual distance to the flashes, after they entered their distance estimate in numbers on a keyboard. The control group received no feedback.

Results: The experimental group improved their distance estimation from the pre-training sessions after they received training in the form of immediate feedback. This improvement in distance estimation is significant when compared to the control group. A single flash resulted in significantly greater accuracy than a prolonged flash. Participants in both groups consistently overestimated the distances to the flashes in almost all conditions, which is at odds with the majority of previous findings on errors of distance estimation. There was a three-way interaction effect, consisting of Session x Horizon x Group. The experimental group's distance estimates during the training, post-training and two-week post-training sessions were an improvement over their pre-training session. Another significant difference within the three-way interaction was between the experimental group and control group. The experimental group was significantly more accurate than the control group in several conditions. There was a significant improvement between the experimental group's pre-training session compared to the rest of their sessions. These improvements were greatest when estimating distance above the horizon.

Significance: It is recommended that training in the form of immediate feedback is an effective way to prepare soldiers for the challenges they face, in estimating distances to an enemy location. This study reinforces the effectiveness of simulation as another tool in preparing soldiers.

Sommaire

Appréciation de la distance des éclairs dans un environnement simulé observé avec des lunettes de vision de nuit:

Garrett Morawiec; Keith K. Niall; Kathleen Scullion; DRDC Toronto TR 2007-143; R & D pour la défense Canada – Toronto; Décembre 2007.

L'appréciation de la distance est une aptitude fondamentale qui doit être maîtrisée par tous les soldats utilisant des armes de combat. Les nouvelles recrues des Forces canadiennes (FC) doivent apprendre à apprécier les distances pendant la durée du cours Qualification – Soldat de l'Armée (ASQ). L'utilisation de technologies, comme les dispositifs de vision nocturne (VN) (intensificateurs d'image), donne aux FC un avantage sur le plan tactique. Les Forces canadiennes reconnaissent l'importance de la formation sur simulateur à titre de solution de rechange économique à la formation réelle; cependant, les effets de la simulation de l'affichage sur la perception visuelle demeurent mal compris. Un environnement simulé observé avec des VN a été utilisé dans le but de déterminer si les participants pouvaient recevoir une formation permettant d'apprécier la distance de lueurs de départ avec précision à partir du point d'observation. Dix-huit participants (N = 18) se sont portés volontaires pour l'étude (seize hommes et deux femmes). Leur âge se situait entre 19 et 49 ans (*moyenne* = 31,45, *écart-type* = 7,38). Treize d'entre eux étaient militaires, dont huit avaient déjà utilisé des dispositifs de vision de nuit. Les essais ont été réalisés sur un ordinateur PC à l'aide d'un logiciel simulant un champ avec de l'herbe texturée comme fond d'écran, ainsi que des nuages dans le ciel. Les participants pouvaient distinguer une ligne d'horizon qui se trouvait à la jonction du sol et du ciel. Des éclairs de lumière apparaissaient sur l'écran soit au-dessus ou en-dessous de l'horizon. Les participants ont été exposés à trois séquences d'éclairs différentes : 1) cinq éclairs consécutifs 2) un éclair unique, ou 3) un éclair prolongé. Les éclairs de lumière pouvaient apparaître n'importe où à l'intérieur d'une distance de 5 à 300 mètres du participant, par accroissements de cinq mètres. Chaque participant a suivi quatre sessions : formation préparatoire, formation/absence de formation, post-formation et post-formation après deux semaines. La première, la troisième et la quatrième session (formation préparatoire, post-formation et post-formation après deux semaines) exigeaient des participants qu'ils apprécient la distance les séparant des éclairs, sans rétroaction. Au cours de la deuxième session, le groupe étudié a reçu de la rétroaction, au cours de laquelle on disait au participant quelle était la distance réelle des éclairs, après qu'ils aient saisi au clavier leur estimation de la distance. Le groupe témoin n'a reçu aucune rétroaction. Le groupe étudié a amélioré ses estimations de la distance par rapport aux séances de formation préparatoire après avoir reçu de la formation avec rétroaction immédiate. Cette amélioration dans l'appréciation de la distance est importante lorsqu'on la compare au groupe témoin. L'exactitude des estimations a été plus grande dans le cas de l'éclair unique que dans le cas de l'éclair prolongé. Les participants des deux groupes ont tous surestimé les distances qui les séparaient des éclairs dans presque toutes les conditions, contrairement à la majorité des résultats antérieurs d'appréciation de la distance. On a organisé les interactions selon trois catégories (Session, Horizon et Groupe). Les estimations de la distance par le groupe étudié durant la formation, la post-formation et la post-formation après deux semaines étaient meilleures que celles de la session de formation préparatoire. Une autre différence importante relativement au regroupement en trois catégories a été observée entre le groupe étudié et le groupe témoin. Le groupe étudié était beaucoup plus précis dans ses

estimations que le groupe témoin et ce, dans plusieurs conditions. On a remarqué une amélioration notable entre la session de formation préparatoire du groupe étudié et leurs autres sessions. Les améliorations ont été les plus notables lorsque l'estimation de la distance se faisait au-dessus de l'horizon. Il est recommandé que de la formation avec rétroaction immédiate soit donnée, car elle est efficace pour préparer les soldats à relever les défis qui les attendent, soit estimer les distances les séparant de l'ennemi. La présente étude reconnaît l'efficacité de la simulation comme étant un autre outil de préparation des soldats.

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1 Introduction

Distance estimation is a fundamental skill that must be mastered by all combat arms soldiers. New recruits to the Canadian Forces (CF) are taught to estimate distances during their Army Soldier Qualification (ASQ) course. According to the CF lesson plan for distance estimation, a soldier is required to be able to estimate distances in order to: (1) adjust his own fire accurately; (2) assist others in adjusting their fire; (3) indicate enemy positions accurately; (4) prepare range cards; and (5) call for supporting fire (e.g. artillery) [1]. Distance estimation becomes increasingly difficult in night operations. Night operations, however, are crucial to modern Infantry survivability. Through the use of technology, night vision goggles (NVGs, an image intensifier) give the modern force a tactical advantage. An understanding of NVG characteristics and the effect on a soldier's perception is essential to performance with a complex piece of equipment. This human-machine interaction can be complicated by the involvement of a second machine, the simulator. Simulators are training aides that reduce training costs and allow users to be placed in situations that would otherwise be deemed too dangerous for training.

As the Canadian Forces operate all over the world in complex and often dangerous environments, there has been increased emphasis on simulator training. The Director of Air Requirements has identified a requirement to train their pilots on deployable simulators before conducting specific missions overseas. Defence Research and Development Canada (DRDC) is working on a project called the Advanced Deployable Day/Night Simulation – Technical Demonstration (ADDNS-TD). The objective of the ADDNS-TDP, according to its Project Charter, is "to aid [the Canadian Forces] operational readiness by advancing the visual simulation capabilities of training simulators for deployment in mission rehearsal" [2]. These capabilities include the ability to rehearse using simulated NVG in a variety of environments.

DRDC has conducted several experiments to determine the effects of NVGs on perception and distance estimation. The majority of NVG research at DRDC focuses on the difficulties in estimating distances while using NVGs, in field studies and in simulated environments, such as simulated fields and laneways. The studies have focused on distance estimation between two static light sources or objects (exocentric distance estimation). In the present experiment, a simulated NVG environment was created to determine whether the subjects could be trained to estimate distance accurately from themselves to muzzle flashes. This is referred to as egocentric distance estimation, that is, distance estimations from an individual to an object. There are several factors in understanding the perception of distance in an NVG environment. They include: theories of perception, cues to distance estimation, and NVG design and characteristics. After an examination of these factors, a review of recent research in the area of distance estimation will be presented to set the stage for research questions and hypotheses.

1.1 Visual perception

An understanding of visual perception is crucial to understanding psychophysiological factors that influence human ability to judge distances. The intent of the current experiment is not to analyze individual defects or medical problems surrounding perception. Instead, the focus will be on the factors that have a bearing on distance estimation in particular. At the core of understanding visual perception is the problem of depth perception [3]. The problem is that the 3-D information we receive from the ambient optic array (the reflected or emitted light in the environment) is projected onto a 2-D surface at the back of the eye. When the ambient optic array is projected onto the 2-D surface the third dimension (depth) is lost. Depth is the distance from the observer to the reflective surfaces in the environment. The problem is that the human visual process is susceptible to misinterpretations of the world around us as we try and retrieve this third dimension. These misinterpretations or illusions hamper our ability to estimate distances effectively. Gibson and Flock discuss an illusion that many are familiar with, the apparent distance of mountains [4]. A mountain may give the illusion that it is very near when in fact it is very far. Perceiving the 3-D information from a 2-D retinal image begins with an understanding of the physiology of the process.

1.1.1 Physiology of vision

The physiology of vision begins when the information contained in the ambient optic array is projected onto a section of the back of the eye called the retina. This light is "absorbed by visual pigment molecules and transduced (transfer of energy contained in the ambient optic array) to electrical neural signals by the photoreceptor cells of the retina" [5]. The neural signals leave the retina and travel along the optical nerve. The majority of the optical nerves end at the lateral geniculate nucleus (LGN), where they are organized for further transmission to the primary visual cortex (V1) and beyond, to the more than 30 cortical areas for visual processing [5]. Frishman explains that the visual information follows two general streams: a ventral stream, which concerns itself with object identification, form, and colour, and a dorsal stream, which is concerned with location in space and motion. Although brief, this describes the general physiological pathway that information from the ambient optic array takes within the brain. How does the firing of neurons in the brain lead to perception? This is the realm of psychology; the following theories have dominated the field for years.

1.1.2 Indirect perception

The logic behind theories of indirect perception is the premise that perception is the result of internal mental processes, which take the proximal stimulus, the image on the retina, and derive veridical perceptions of the environment. This concept is in sharp contrast to the theory of direct perception, which argues that all information necessary for the veridical perception of the environment is contained within it. One of the first theories of indirect perception, which has influenced theorists since, is Hermann von Helmholtz's theory of *unconscious conclusions or unconscious inference* [6]. The starting point for his theory is that through experience, or learning, we can begin to perceive and come to conclusions about objects in the environment without conscious thought. Helmholtz's empiricist view is at odds with the nativistic view where perception is a result of innate processes. As Helmholtz explains, unconscious conclusions "are based upon a sequence of experiences, each of which had long since disappeared from memory and entered consciousness only in the form of sensory impressions" [7]. New sensory impressions occurring in perception are unconsciously influenced by previous observations. Helmholtz uses language as an example [7]. Children can only learn the meaning of words and sentences by hearing others use them. As the children grow up, they understand these words and sentences without any effort or knowing when and where they learned them. Visually, this means that as the result of experience and learning, humans move throughout their environment rarely giving conscious thought to the objects that surround them. Similarly with experience: interpretation of the environment can also occur as a result of taking incomplete retinal images and arriving at the most probable conclusion. Palmer refers to this as Helmholtz's *likelihood principle* [3]. What is unclear about Helmholtz's theory is how "impressions" become thought. Later in Helmholtz's career, he moved away from using the terminology of unconscious conclusions or unconscious inference and used instead *inductive conclusion*. Helmholtz had received much criticism for the former terms as an inference or conclusion implies consciousness [8]. However these terms persist today, much like the theory behind it.

Irvin Rock was another proponent of the theory of indirect perception, and a follower of Helmholtz [9, 10]. Much like Helmholtz and all indirect perception theorists, Rock hypothesized that perception was the result of internal mental processes. Unlike Helmholtz, who emphasized prior learning and the likelihood principle, Rock's theory on perception emphasized cognitive processes which result in perception. Central to his theory on perception is the problem solving required in order to arrive at final perception. Rock recognized that not all perception required such problem solving, as in unconscious inferences. The proposition that initial perceptions usually precede final perception, when a perception is derived from a problem-solving process, is essential to Rock's theory. This problem-solving process is also referred to as a perception-perception chain. A first perception, which Rock called "literal", is highly correlated with a stimulus in the environment. The second perception which follows may be instantaneous or it may require some problem solving. Simply, the mind has taken the literal perception and constructed the second perception, which results in a preferred final perception. This perception-perception chain is particularly noticeable given ambiguous stimuli. Rock provides an example using the stereokinetic effect to demonstrate how one perception depends on another [9]. In the stereokinetic effect, a disk is rotated on which circles are eccentrically drawn surrounding other circles (see Figure1).

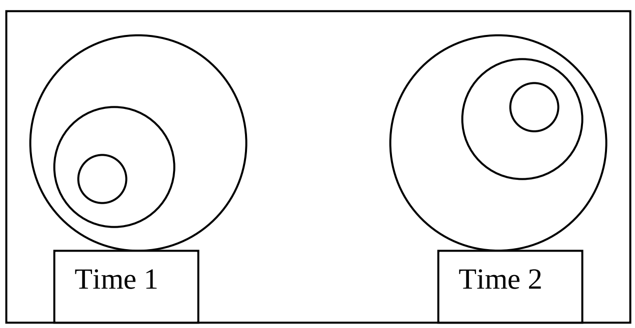

Figure 1. The stereokinetic effect demonstrates a transformation in perception over time from 2-D circles rotating around each other to 3-D cones wobbling. Reprinted from "The logic of perception" by I. Rock, 1983, Cambridge, MA: MIT Press.

At first, most observers perceive the circles as rotating within each other. As a result, no depth effect is achieved. Eventually, most observers begin to perceive the circles not as rotating within each other but rather changing their locations sideways and vertically all the while keeping their orientation. Once the perception of static orientation relative to the other circles occurred, the perception of depth soon follows. The observer now sees a cone wobbling around a centre axis.

Although this is considered indirect by the nature of internal mental processes, a more specific way of looking at it is that final perception has been derived from previous perceptions rather than directly from the retinal image itself. Thus it is indirect. The final perception is not highly correlated with the stimulus. Alternatively, final perception in the theory of direct perception *is* highly correlated with the stimulus. The theory of direct perception would have difficulties explaining this example as it explains differences in perceptions as the result of differences in retinal images.

1.1.3 Direct perception

James Gibson takes a radically different approach to perception [11]. His theory, called *direct perception* or the *ecological approach*, describes perception as “the activity of getting information from the ambient array of light…this is quite different from the supposed activity of getting information from the inputs of the optic nerves” [11]. Unlike the indirect approach in which internal mental processes must take incomplete retinal information and convert them into perception, Gibson argues that all of the information necessary to perceive the environment is taken directly from it. Some depth information is provided by our movement through the environment. Specific visual stimulation is controlled by the surrounding environment and has an effect on our spatial behaviour [12, 13]. Gibson explains that the primary pieces of information retrieved from the environment are invariants [11]. Invariants are constant properties that we detect from the optic array necessary for accurate perception. Gibson explains that “the ecological approach to visual perception…begins with the flowing array of the observer who walks from one vista to another, moves around an object of interest, and can approach it with scrutiny, thus extracting the invariants that underlie the changing perspective structure and seeing the connections between the hidden and unhidden surfaces” [11]. Gibson’s explanation of an invariant is still vague. Niall explains “the cross-ratio…is the fundamental invariant in projective geometry” [14]. A cross-ratio is a mathematical scalar that yields constants from the proximal and distal stimulus (object). In figure 2, Cutting uses a schematic display to explain cross-ratios [15].

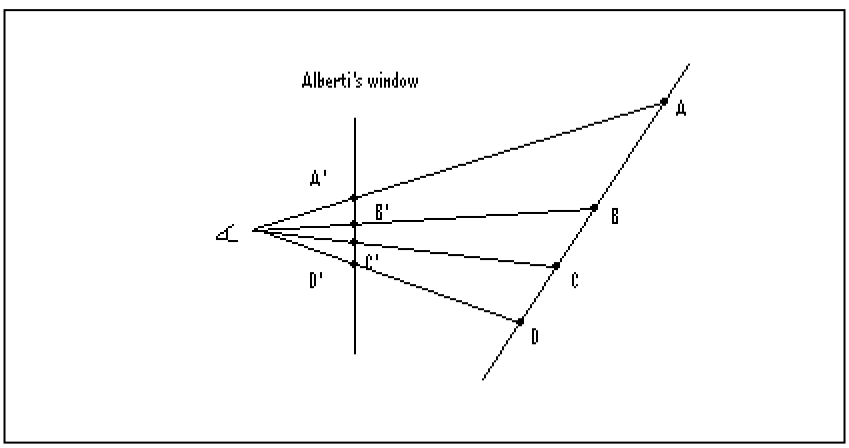

Figure 2. Alberti’s window illustrates the concept of invariance, that is, the same constant is derived from A’B’C’D and A’B’C’D’ ((AB • CD) / (AD • CB) = $(A'B' \cdot C'D') / (A'D' \cdot C'B')$). Reproduced from “Perception with an eye for motion” by J.E. Cutting, 1986, Cambridge, MA: MIT Press.

Although Cutting uses Alberti’s window (see Figure 2) as the projection surface, the reader can also imagine it as the back of the retina. According to Niall, “the theorem works for spherical arcs as well as straight lines” (personal communication, August, 2007). The constant is the number yielded by either side of the following equation;

$$(AD*BC)/(AC*BD) = (A'D'*B'C')/(A'C'*B'D') \quad (1.1)$$

The object in the environment (left side of the equation) yields the exact same constant as the object’s projection onto the back of the retina (right side of the equation). Once there, the brain can then recognize an object by its constant, no matter which way an object moves or rotates.

It is important to understand that there is no definitive explanation how we process the information we receive into perceived distance. The projections of a 3-D environment onto a 2-D surface within the eye present us all with a problem of depth perception. While theories of direct and indirect perception present convincing arguments, they are abstract in that they are difficult to validate. A more pragmatic approach is the theory of cues to distance estimation, or depth cues. While cues to distance estimation can be incorporated into the indirect approach, most literature on the subject addresses it independently.

1.1.4 Cues to distance estimation

There are cues we derive from the 2-D retinal image of the 3-D environment. These include ocular information, stereoscopic (or binocular) information, and monocular cues, which can be derived from the effects of perspective projection. At any given moment the environment can contain a large number of cues from which the brain must process and derive depth. What happens when different cues allow different perception? Which cue dominates? Two theories, which seek to explain how the brain determines the most important cue, will be examined below.

1.1.5 Ocular information

The first set of cues is based on the location of the eyes themselves, or what Palmer described as *ocular information* [3]. The first type of ocular information is called *accommodation*. Palmer defines accommodation as the process by which the ciliary muscles in the eye control the optical focus of the lens by temporarily changing its shape [3]. By being able to change the focus and thickness of the lens, becoming thick for close objects and thinner for farther away objects, the visual system receives an indication of absolute distance to the object. This cue, however, is only useful to a depth of six to eight feet; the lens does not get any thinner beyond this point, and no further information can be provided [3]. The second piece of ocular information, also a source of absolute distance, is *convergence*. Convergence is referred to as a binocular cue obtained when both eyes focus, or fixate, on an object in the distance. Depth information is derived from the angle formed by the line of sight from each eye converging on the object. The angle is larger for close objects and smaller for objects that are farther away. Like accommodation, convergence is only functional up to a few metres [3].

1.1.6 Stereoscopic information

The next set of cues are based on stereoscopic information. Sedgwick refers to *stereoscopic information*, or *stereopsis*, as the perceptual use of the information provided by the differences between the similar but separate fields of view of each eye [16]. The difference between the two fields of view is referred to as *binocular disparity*. The closer the object, the greater the binocular disparity; as the object moves farther away, the disparity decreases. The other stereoscopic cue is called *Da Vinci stereopsis*. Da Vinci stereopsis refers to the binocular viewing of objects in which part of the object may only be present in one of the eye's field of view. This monocular portion of the viewed object is always part of the surface that is farther away, giving information on depth. Once again, these cues give absolute distance estimation [3].

1.1.7 Monocular information

The third set of cues is referred to as monocular cues. These are cues to distance estimation that can be derived from a single retinal image. Motion is one way for humans to perceive such distance. The general term for this is *motion parallax*. Palmer defines motion parallax as "the differential motion of pairs of points due to their different depths relative to the fixation point" [3]. Another set of monocular cues fall under a heading referred to as *perspective projection*. Due to perspective projection, a flat 2-D surface captures several cues that allow the observer to perceive 3-D. A good painting or photograph provide examples. Perspective projection is based on geometric principles, and consists of a number of cues including: a) convergence of parallel lines or linear perspective; b) position relative to the horizon; c) relative size and familiar size; d) texture gradient; e) occlusion; f) shadows; and g) aerial or atmospheric perspective.

a. *Convergence of parallel lines*, or *linear perspective* - Parallel lines in perspective projection do not remain parallel but rather converge in the distance, toward a vanishing point on the horizon [3].

b. *Position relative to the horizon* – "the trigonometric relationship wherein the further an object on the ground is, the higher in the field of view it looks, with an object at infinity being seen at the horizon" [17].

c. *Relative size* and *familiar size*- Relative size, with all else being equal, refers to how objects that are farther away appear smaller than objects that are closer, while familiar size refers to the depth cue taken from viewing objects of known size [3].

d. *Texture gradient* - The texture on a surface area, such as blades of grass or stones on a road, becomes less detailed the further away it is from the observer. For example, while blades of grass can be individually recognized near the observer's feet, they become a sea of green a few hundred metres out, blending in with the rest of the surface area [3]. When an object is placed onto the texture gradient, cues to distance estimation can be obtained by its relation to the scale of the ground texture [18].

e. *Occlusion* - Sedgwick explains occlusion as the depth information obtained as the result of the placement of objects within the environment in relation to other objects [16]. Depth information is obtained by objects partially obstructing other objects, which provides relative distance or order of depth.

f. *Shadows* - A cue to distance can be given by the way an object's shadow falls on another object or surface [3].

g. *Aerial*, or *atmospheric, perspective* – refers to the increasing indistinction of objects with distance. In other words, there is a decrease in contrast with distance, converging to the colour of the atmosphere, which is determined by the moisture and/or pollutants between the person and object [19].

Given the vast amount of depth information that can be presented to an observer in any given environment, how does the brain determine which of the cues are the most important? There are several theories, two of which will be presented here. Cutting and Vishton touch on an old classification system in which cues are simply designated as primary or secondary cues depending on their importance [20]. They list the primary cues as being motion perspective, convergence, accommodation, and binocular disparity. The secondary cues include; occlusion, relative size, relative density (which concerns the projected retinal density of a cluster of objects), height in the visual field, and aerial perspective. One can think of the secondary cues as being pictorial sources of information. Some cues have been left out of this list (e.g. texture) as Cutting and Vishton felt that they are a combination of the cues already listed. A more modern theory is examined by Jacobs in which the distance cues are weighted [21]. He explains that when there are multiple cues in the environment, we must be able to integrate them efficiently by assessing the reliability of each cue. The more reliable the cue, the more weight the observer places on it. A "cue is regarded as reliable if the inferences based on that cue are consistent with the inferences based on other cues in the environment…this hypotheses assumes that consistency among cues is unlikely to occur by accident" [21]. Cues are unreliable when they have greater ambiguity. This ambiguity can result from atmospheric or optical blurring. Once the cues have been "weighted" from least reliable to most reliable, we can confidently perceive depth.

1.1.8 Summary of the theories of perception

At this point, it would be useful to summarize the indirect, direct and cues to distance theories and how they relate to one another when perceiving depth. To recap, indirect theories of perception postulate that humans perceive the third dimension (depth) through internal mental processes that begin when the ambient optic array contacts the 2-D surface of the retina. The primary sources of information in the environment used in this theory are the cues to depth perception [15]. According to Cutting, the word "cue" was first used in a sixteenth century theatre document to mean a way to prompt an actor. In this way, the word "cue" alone implies an inferential (indirect) approach as it implies incompleteness. The direct theory argues that all of the necessary information to perceive depth is available in the ambient optic array, or the environment [11]. The primary sources of information derived from the environment are the invariants, the mathematical constancies of an object, which do not change from the distal to the proximal stimulus [14, 15]. The perception of depth is achieved when the brain recognizes that although the constant for a particular object (e.g. car) is the same at any given point in time, the constant does get larger or smaller as it travels to or from the observer. The observer's brain recognizes when a constant is small and therefore in depth or large and therefore nearby. Finally, the third, and most practical theory on depth perception is, distance cues. There are several cues which humans use to derive the third dimension including relative size, horizon line, and texture gradient.

In the present experiment, flashes of light will be presented to the subject in a reduced-cue simulated NVG environment. Subjects will be required to estimate the distances from themselves to the flashes of light. By examining the three theories of perception (indirect, direct and cues to distance) one can begin to imagine how a champion of each theory might explain the outcome of the experiment. Direct perception theorists would argue that all of the information necessary to accurately estimate the distances may be present in the form of invariants. However, since the subjects cannot explore the environment, and the environment is a virtual one (meaning that invariants may not be precise), estimations may not be accurate. The accuracy of the invariants is in question because a simulation is susceptible to error and imperfections. Since the accuracy of the invariants are in question and subjects do not explore the simulated environment, proponents of the direct perception theory may say that no improvement would be made in the subject's estimations. The indirect perception theorists would say that initial estimations may be inaccurate because of the reduced cue environment. Subsequently, subjects would learn through feedback and the internal mental processes taking place, how to perceive the distances accurately. Perception theorists that focus on cues to distance would say that accurate estimations would be very difficult as there are only a few cues in the simulated environment. However, since the horizon line cue has been shown to be a strong cue, accurate distance estimation may still be possible [22]. With the addition of simulating the characteristics of NVGs in the virtual environment, perception theorists would argue that NVGs would only amplify the affects of the virtual environment, further deforming the invariants and reducing the distance cues available. Since NVGs degrade distance cues, their characteristics will now be examined as they lead to further difficulties in the perception of depth.

1.2 Characteristics of night vision goggles (NVGs)

Night vision goggles provide an enormous advantage on today's modern battlefield to those who possess them. In an environment like Afghanistan, where insurgents have very little night vision capability, access to NVGs provides Canadian and Allied troops a decisive tactical advantage. Although NVGs are used extensively throughout the military, this experiment focuses on the infantry soldier. How NVGs amplify light is beyond what a soldier is required to know; however, they are aware that NVG's allow the user an illuminated view of an otherwise dark environment. The advantage provided by night vision devises unfortunately comes at a price. The components and characteristics that provide the illumination also degrade the perception of depth by reducing visual acuity and the number of distance cues available [23]. Therefore, the components and characteristics of NVGs are an important topic for review.

1.2.1 Components of NVGs

NVGs amplify low levels of light, typically from light sources such as starlight, moonlight and man-made sources. There are several types of NVGs, including different generation models. The generation classification tells the user whether they are using older less sensitive NVGs (generation II) or newer ones (generation III). Currently, the military is using both generation II and III models; the NVGs in this experiment simulate a generation III model. NVGs are generally constructed using similar components. These components include the image intensifier tube, the objective lens, and the eyepiece. The image intensifier tube consists of a photocathode, a micro-channel plate (MCP), a phosphor screen and a fibre optic twister. The process of light amplification begins when the light photons reflect from surfaces in the environment and enter the objective lens. The image is inverted when it passes through the objective lens and hits the photocathode tube, which turns the light photons into electrons. These electrons enter the MCP and begin striking its walls. The MCP, which contains millions of glass pores, releases several electrons every time a single electron hits it. In turn, the released electrons hit the wall once more releasing more electrons. This cascading effect occurs in each of the glass tubes of the MCP [23, 24]. These electrons will then exit the MCP and strike the phosphorus screen, where they are converted back into visible light (photons) as the result of the phosphor being excited by the absorbed electrons. Finally, the image is inverted upright again by the fibre optic twister and exits through the eyepiece lens [25].

1.2.2 Factors that degrade the effectiveness of NVGs

The process of light amplification described above results in an image which has been transformed by the components of the NVG, making it an indirect representation of the real world. In many respects the indirect image has been enhanced; however, in other aspects it has been degraded. This degradation is of primary concern to the users of NVGs and to those that study their effects. As NVGs are complex pieces of equipment, there are many technical and psychophysiological factors affecting the performance of even the most advanced NVGs. Factors which degrade NVG effectiveness compared to the naked eye include: a) reduced field of view (FOV); b) distortions; c) light spectrum sensitivity; d) scintillation; e) automatic gain control; f) input/output relationships; g) "halo" effects; h) monochromatic vision; i) bright or dark spots; and j) luminance differences.

a. *Field of view* (FOV) - The FOV for a normal human being is around 200 degrees horizontally and 120 degrees vertically. This is significantly larger than the 40 degrees horizontally and vertically that the NVG FOV provides. This restriction in the FOV reduces the amount of visual cues to which the user is exposed to, and degrades the user's ability to perceive distance [23]. Another problem identified, is the trade-off between a larger FOV and resolution [24]. Since there are a finite number of pixels available, the increase in FOV would cause the limited pixels to be dispersed over a larger area, resulting in a decrease in resolution.

b. *Distortions* - Distortions can cause the user significant problems in trying to determine distances. There are several types of distortion, which include: *barrel*, *pincushion*, and *shear* or *"S" distortions* [24]. Pincushion and barrel distortion result in otherwise straight lines appearing curved. This can occur when the fibre optic twisters in each tube twist in differing directions. While looking at the image, the effects of these distortions seen by the user can be conceptualized by the following images of a square lattice:

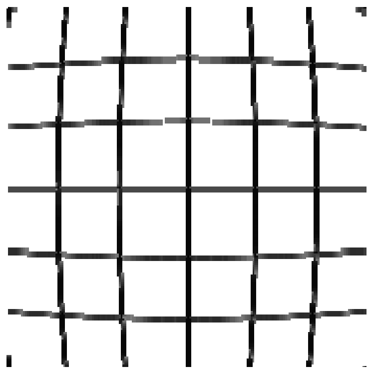

Figure 3(a): Barrel distortion.

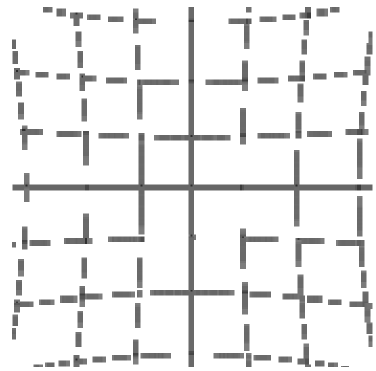

Figure 3(b): Pincushion distortion.

c. Another common distortion is shear or “S” distortion. Task explains that “S” distortion is caused by a less-than-perfect 180 twist in the NVGs fibre optic twister [24]. The twister is necessary to rotate the inverted image back to its original alignment before exiting the eyepiece. As the name suggests, straight-line inputs into the NVG turn into “S”-shaped outputs.

d. *Light spectrum sensitivity* – Due to the “spectrum sensitivity of the photocathode, a light source may appear the same to an aviator using NVGs, whether it is bright and close or dim and far away”[25].

e. *Scintillation or noise* - Another factor that reduces the image quality in all NVGs, refers “to the random sparkling especially evident to a user under high gain conditions and is due to thermal emission from the photo cathode” [26].

f. *Automatic gain control* - Sudden bright light may also cause significant problems to image quality. NVGs attempt to manage fluctuations in light through the automatic gain control, however, as bright light forces the automatic gain control circuit to turn down, the image quality will decrease [23].

g. *Input/output relationships* – Another problem that can arise due to the automatic gain control occurs when the NVG nears the end of its life cycle. When the NVG is new, the gain, which is the ratio of the signal input to signal output, remains constant. Therefore, when the gain is increased, both the signal and noise level will increase to the same amount. However, when the NVG nears the end of its life cycle, an increase in the gain will result in a higher increase in the noise level than the signal level [25].

h. *Halo effects* - Bright light, sudden or otherwise, can cause a “halo” effect. A halo is visible to the user as insular bands of light surrounding the bright object [23]. The United States Aviation Training Center’s (ATC Mobile) NVG User Guide 2003 presents several halo characteristics which may cause confusion when attempting to determine distances [27]. Some of these characteristics are that: bright lights will appear closer than dim lights even if they are at the same distance; lights of different colour will produce different halo sizes even at the same distance; at low illumination levels the autogain will intensify the halo effect, causing the halo to appear closer; and obscurants have a variety of effects on halos. For example, moisture will cause the halo to be larger but less intense while smoke can result in smaller halos by blocking some of the energy. Furthermore, halo sizes do not change as distance increases or decreases from the observer to the halo (see appendix A).

i. *Monochromatic vision* - The virtual image that the user sees through NVGs are composed of shades of green; this causes difficulties in distinguishing colour-coded information in the environment [23]. For an infantry soldier, this could be problematic, as platoons often identify themselves with different coloured glow sticks behind their vehicles.

j. *Bright or Dark Spots* - Image defects can occur during the manufacturing process which result in bright or dark spots in the optics [23].

k. *Luminance differences* - Luminance differences between the two tubes can cause the Pulfrich effect. The Pulfrich effect is the classical phenomenon in which an “object oscillating back and fourth in a frontal plane appears to move along an elliptical path in depth when images are delayed in one eye” [28]. The classical explanation of this effect is caused when the information about the oscillating object, contained in the optic array, passes through an attenuating filter in front of one eye. As a result, a time delay is caused as the optic array takes longer to hit the retina with the filter than the eye with no filter. This causes the object on the filtered retina to appear to lag behind the image of the same object on the non-filtered retina (see fig 3). Combined, the brain perceives the object as being in between the two retinal positions and either closer to the observer while traversing right or farther away while traversing left resulting in the perception of an elliptical path [29, 30]. With NVGs, the luminance difference between the two tubes can cause this effect. Only a luminance difference ratio of 1.26 is required for the effect to be seen [31].

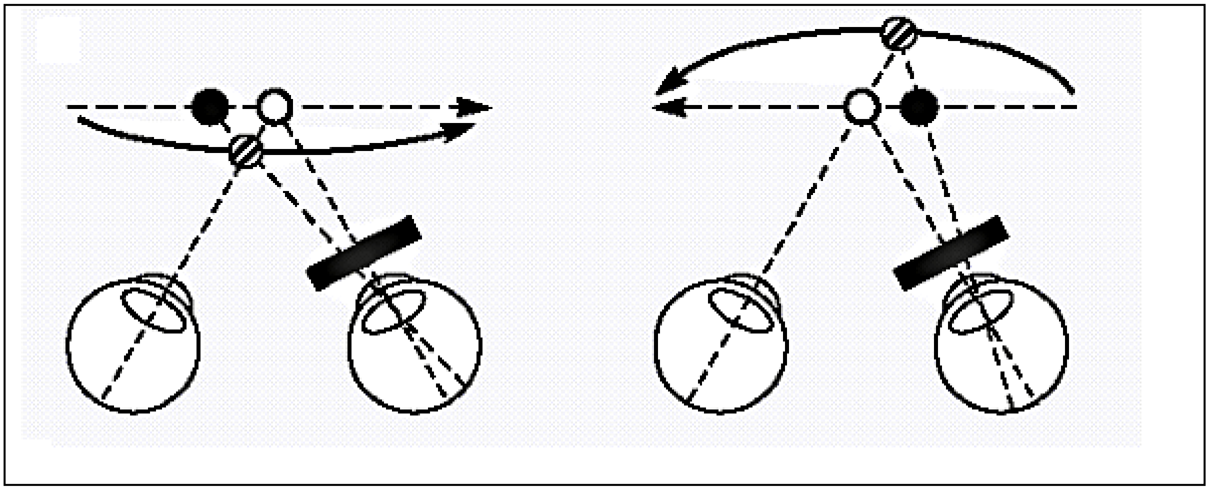

Figure 4. The Pulfrich effect. An object osculating back and fourth appears to traverse in an elliptical path as the result of a delay in one eye. Reproduced from "Joint-encoding of motion and depth by visual cortical neurons: neural basis of the Pulfrich effect" by A. Anzai, I. Ohzawa, and R.D. Freeman, 2001, Nature Neuroscience, 4(5).

While NVGs improve visual acuity in low light levels, they can also lead to degradation of depth cues, reducing the user's ability to accurately estimate distances. Since distance estimation is a critical skill that soldiers must possess in order to effectively engage the enemy, researching the effect of NVGs on distance estimation is essential. As the overall aim of the ADDNS-TD project is to provide a new simulation with night vision capability, an understanding of distance estimation in the simulated environment is also imperative. The research outlined below presents findings in the areas of distance estimation, feedback training, NVGs and simulated environments. This includes the differences between several types of distance cues, distance estimations with simulators versus real world or NVGs, various methods of training and how long the training persists. These topics lay the groundwork for the present experiment.

1.3 Research review

1.3.1 Previous research

NVGs are often used in extreme environments where the lives of the men and women using them depend on knowing and understanding their effects. The majority of experiments conducted with NVGs have focused on making improvements to flight safety for pilots, however, a great many of the experimental findings can be applied to other aspects of the military where NVGs play a critical role. This experiment seeks to address questions about distance estimation by infantry soldiers using NVGs in a simulated environment. In earlier sections, we have explored psychophysiological and mechanical factors that affect human vision and NVG use. The focus of this part of the review is to examine prior research as it applies to distance estimation and NVGs or a simulated environment. Research will be outlined in chronological order, laying the groundwork for the experiment.

Reising and Martin were the first to examine the effects of training on distance estimation while using NVGs [32]. They wanted to determine if pilots and navigators could be trained to accurately estimate distances while wearing NVGs in a real-world environment. They determined that the critical distance for this experiment was 40-60ft, since this represented the typical range of rotor blade lengths. Although previous studies had come to the general conclusion that estimations were significantly worse while wearing NVGs, Reising and Martin wanted to determine if subjects could be trained to accurately judge these distances. Reising and Martin also tested to see whether or not there was a significant difference between egocentric and exocentric distance estimations. The results determined that training was effective in reducing estimation errors (48% reduction), however, there were still significant errors made in the critical distances (40-60ft). Results showed a tendency to underestimate egocentric distances and to be more accurate with exocentric estimates. The experiment used a "calibration training procedure" in which the subjects were brought to a training area (after the pre-test in which baseline scores were determine) and shown what the various distances looked like before going back to the test area for the post-test. This form of training may not be the most effective, as was recognized in their conclusion. As well, the post-test was administered immediately after the training. This puts into question whether training can persist over a period of time. Finally, Niall explains that the dependent measure used in this experiment, the mean absolute error, resulted in significant effects where there were none significant [33, 34]. When the absolute error was used there was an interaction between the test and group means. This interaction was interpreted as an improvement when, in fact, it was the result of the variability of error scores. When using the signed error as the independent measure, which distinguishes the mean tendency of errors from their variability, most of the results became non-significant. The one effect that remained between pre and post tests was that the variability of signed errors became lower for the treatment group.

To better understand the effects of training in a reduced-cue simulated environment, Witmer and Kline studied distance estimation both in a simulated environment and in the real world [35]. They were particularly interested in the importance of texture and object size cues (a cylinder object was used in this experiment) in performing perceived distance judgments. Perceived distance judgments refer to tasks in which static observers estimate distances between themselves and stationary or moving objects. Witmer and Kline manipulated the texture in the simulated environment in several ways. They presented the simulated hallway as having either texture or no texture (control). The texture itself was given elements (designs) that were either continuous or intermittent, as well as either coarse or fine. The size of an object could be either small or large, as a variable. When examining distance estimation in a simulated environment versus in the real world, Witmer and Kline found that subjects underestimated distances to a greater extent in the simulated environment than the real world. Overall, subjects in the simulated environment estimated 47% of the true distances, compared to subjects in the real world, who estimated 72% of the actual distances. This was determined by calculating the aggregate relative error;

Relative error = (Distance estimation – True distance)/True distance. (1.2)

The relative error was generally larger when the distance that needed to be estimated was longer. Real world performance tended to provide better estimates, as there were more distance cues than in the simulated environment. In the real world, subjects had access to motion cues such as motion parallax as they moved their heads, a wider FOV, and the presence of more familiar objects (e.g. office doorways in the hallway). Witmer and Kline also found that while the texture in the simulated environment did not significantly affect distance estimation, the size of the object did [35]. Participants greatly misjudged the distance to the large cylinder when it was viewed at a distance of 10ft compared to the smaller cylinder, than at greater distances. This caused an exception to the finding that relative error increased with distance. They postulated that when the large cylinder was viewed from a distance of 10 ft, it may have appeared so large relative to the farther distances that it resulted in the subjects perceiving it as much closer and larger than it actually was. This perception may have been what caused the participants to grossly underestimate the distance of the large cylinder at 10ft. Overall, their work implies that humans cannot effectively perceive distances in a reduced cue simulated environment in the absence of feedback.

Waller expanded upon the previous work of Witmer and Kline by examining exocentric distance estimations in simulated environments [36]. Waller manipulated several variables, including: conducting the experiment on a desktop computer as against an immersed virtual environment (display mode); conducting the experiment with either the presence or absence of a grid (a cue to distance estimation); and conducting the experiment to compare male and female subjects. The presence or absence of a grid significantly affected the accuracy of the estimations, however, display modes and gender did not. He also found that across all subjects there was significant overestimation of exocentric distances. At first this appears quite unusual compared to the commonly found result that estimations in virtual reality are underestimated. Waller explains, however, that for the first experiment he gave feedback to all of the subjects during the trials but did not introduce it as a variable. He noticed that on the first two trials distances were underestimated, for the remaining trials distance estimations were overestimated. He then speculated that subjects began to overcompensate for the rest of the trials as the result of the feedback. Waller then conducted a second experiment that examined the effect of feedback on distance estimation by giving feedback to one group but not the other. He also concurrently examined the effect of the subject's Field of View (FOV). The results clearly indicated that feedback had a highly significant effect while FOV did not. Waller concluded that, given proper feedback, a wide enough FOV and the ability to move in the environment, near perfect estimation could be achieved.

Niall, Reising, and Martin examined the effects of immediate and direct feedback on an outdoor distance estimation task while using NVGs [34]. The experiment manipulated variables that included making exocentric versus egocentric distance estimations, as well as making estimations from the ground plane versus an elevated platform. The experiment also evaluated whether the effects of immediate feedback persisted for up to one week. Results initially demonstrated that there was underestimation, but that subjects quickly learned through immediate feedback to estimate distances to near perfect performance. There was also a small difference in error between egocentric and exocentric distance estimation, with exocentric estimates being more accurate. Niall explained that these effects could have resulted from foreshortening of egocentric estimations, that is, the "aggregate effect of perspective that impedes estimation of distance" [34]. This foreshortening can also be expressed using the cosine function, which expresses the geometry of perspective foreshortening.

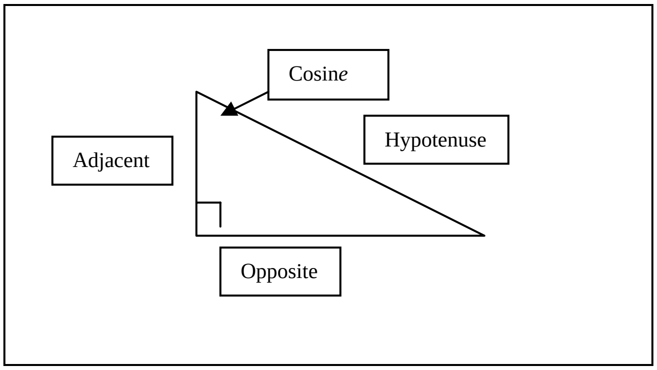

Figure 5. Cosine = Adjacent/Hypotenuse

The cosine in egocentric lengths is the angle found between the lines formed from the observer's feet and eyes (adjacent length) and the line formed from the eyes to the target (hypotenuse length). An increase in distance from the observer's feet to the object (the opposite length) results in a small change to the cosine. This results in a compression of distance as the observer is looking endwise to the object [34]. The cosine of exocentric lengths is the angle found between the line formed from the observer's eyes and the first object and the observer's eyes and the second object. In exocentric distances, when the distance increases between two targets (the opposite length), very little foreshortening occurred, resulting in greater accuracy than egocentric estimation. Niall concludes that egocentric and exocentric distance estimations differ from each other primarily as the result of geometry rather than psychology. Niall also reported no significant difference between subjects tested at eye-height and those tested on an elevated platform. Niall (personal communication, April, 2007) believes that the results obtained for the eye-height variable were insignificant because the elevated platform was not high enough. Finally, the effects of immediate feedback were found to persist for up to a week, which gives credence to the value of such training within a military context.

Messing conducted experiments that sought to determine the effect of several cues on distance estimation [22]. In one experiment, he presented subjects with either a live, photorealistic video image of a hallway through a head mounted display or the real world hallway viewed through both restricted and unrestricted FOV monocular conditions. They were then asked to walk to a target located along the floor. The photorealistic video image condition resulted in significant underestimation, or compression, of distance estimation. Messing did not find a significant difference between restricted and unrestricted viewing conditions. This suggests that neither the restricted field of view nor the level of realism may be responsible for the underestimation. Messing hypothesized that it was perhaps the system's lens that caused the underestimation. The lens could not automatically adjust to where the eyes were focusing in the simulated environment and thus eliminated the accommodation cue (the process through which the ciliary muscles in the eye control the optical focus of the lens by temporarily changing its shape and thereby giving us an indication of absolute distance to the object). In the second experiment, Messing found that the manipulation of the horizon line affected both verbal and motor distance estimations. By lowering the horizon line, he reduced the angle from the object to the horizon, thus, resulting in the perception of an increase in distance from the observer to the object. Therefore, using basic trigonometry Messing demonstrated the importance of the horizon line as a distance cue.

In a recent study, Richardson and Waller conducted research into the effect of feedback training on distance estimation in a simulated environment [37]. Their first experiment aimed to answer several questions using a direct blindfolded walking task to estimate distances (instructed to walk to a target, blindfolded, after having time to visually analyze its position). They include: (1) would error-corrective feedback improve the accuracy of distance estimations in a simulated environment? (2) would training persist for one week? and (3) would feedback for one type of distance (e.g. exocentric judgments) influence the accuracy of another type of distance estimation? In their second experiment, subjects were given direct blindfold walking tasks and indirect blindfold walking tasks (blindfolded, instructed to cross a path oblique to the target and, when instructed, turn and face the target and walk several steps towards it). They wanted to determine whether giving error-corrective feedback during directed walking tasks also significantly improved indirect walking feedback. In both experiments the main dependent measure used was the subject's mean proportional error in judgment, defined as the estimated distance divided by the actual distance. The results of experiment one indicated that error-corrective feedback improved distance estimation in simulated environments. This was especially evident in egocentric distances, in which the subject's immediate post-test mean proportional error was 1.02, up from the pre-test estimation of .58. Exocentric estimation also improved from .90 to .98. Training persisted for a week, for both egocentric and exocentric estimations. Egocentric feedback, giving the correct distance to the subject immediately after their estimate, primarily improved egocentric estimations, and exocentric feedback, likewise, primarily improved exocentric estimations. In other words, when subjects were given exocentric feedback while performing egocentric estimations, there was little improvement. Richardson and Waller believe that these results support the notion that exocentric and egocentric distance estimations involve separate mental processes. Likewise in Experiment 2, direct and indirect blindfolded walking showed the same initial accuracy. After feedback training was provided, only the walking task that received feedback (in this case direct walking) significantly improved from .47 in the pre-test to .89. Richardson and Waller concluded that training did not affect perceived distances to objects, but rather how the subjects processed the visual information using a higher-level cognitive process. For example, if subjects were continually underestimating egocentric distances by half, a simple higher-level cognitive strategy would be to tell oneself to double the estimates no matter how far it really looks. This would also explain why transferring this strategy to exocentric distance estimations didn't work, because those estimates were significantly closer to the actual distances compared to egocentric estimations.

In another recent experiment, Allen and Rashotte conducted research to determine if pictures could train metrically accurate distance estimation and whether this training could transfer from a pictorial base to real world [38]. They did this by comparing three different feedback methods, including: direct verbal feedback in the field, indirect visual feedback consisting of presentation of labelled markers in the field, and indirect visual feedback consisting of presentation of labelled markers in pictorial depictions of the field. For all conditions, subjects were given a pre-training baseline, and then received one of the three training variables stated above. Finally, subjects were given a post-training test in a novel setting to see if the training had transferred. Once a session was completed, subjects were immediately escorted to the next one, time intervals between sessions were not recorded. There were also two control groups in this experiment. One group gave estimates in the field setting without any feedback while the other gave estimates in the pictorial setting, also without feedback. Allen and Rashotte hypothesized that while verbal and indirect feedback in the field setting would show comparable results, the pictorial condition would show slightly less effectiveness as the result of degradation or distortion of texture cues in pictures. The results showed that all three feedback methods yielded similar improvement in distance estimation skills despite the decrease in texture cues found in pictures. This skill also transfers from field to field and from picture to field. The control groups did not demonstrate these improvements. Allen and Rashotte conclude by pointing out that these results make it reasonable to believe that distance estimation skills can be readily transferred from virtual reality to the field. However, they also point out that much like Richardson and Waller it is more accurate to state that the results pertain to the specific feedback method used [37].

1.3.2 Research summary

The research reviewed indicates several well-established findings about distance estimation while using NVGs or a simulated environment. Primarily, distance estimations while using either NVGs in the real world or unaided vision in a simulated environment both resulted in an underestimation of distances [22, 32, 35, 36, 33, 34, 37]. Further, when subjects were given exocentric feedback while estimating egocentric distances, there was little improvement [37]. These findings suggest that egocentric and exocentric estimations may be processed differently in the brain [37]. This would mean that training would need to be specific to the type of estimation being made for there to be an effect. Feedback training also resulted in reduced errors in distance estimation while using pictures, NVGs or a simulated environment [32, 36, 34, 37, 28]. Research also suggests that the reduction of distance cues appears to affect distance estimation; yet, the impact of individual cues is not fully understood. Some cues, such as the horizon line appear to affect distance estimation more significantly than others [22] (for example texture, [35]). This may be because the horizon line is generally constant as is the angle formed from the observer’s feet to the horizon line. Changes to the angle formed from an object to the horizon are a strong cue for distance estimation. Research in this area has been contradictory; research that sought to examine the effects of a restricted field of view came to different conclusions regarding the impact of the FOV [22, 36]. A complete understanding is a long way off.

DRDC seeks to expand knowledge in the areas of science and technology in order to provide the Canadian Forces with new defence capabilities. This is evident in the present studies at DRDC in which the perception of distance in a simulated NVG environment is being studied. Other DRDC studies have focused on exocentric distance estimations between fixed sources of light. This study takes a different approach by examining egocentric distance estimations to flashes of light. In previous studies, the subject had time to study the target and formulate an estimate; the effect of having limited exposure to the stimuli has not been tested. Not only will the subjects be restricted by time and the need to use visual memory, but the light flashes may also give the subject insufficient time to focus on the flash, thus relying on the less visually acute rod photoreceptor cells. Time is an important aspect when trying to replicate real-life situations. In combat, soldiers do not always have time to access higher levels of cognitive processing to estimate distances.

There are several drawbacks and limitations to the present experiment. The first limitation is that not all factors that help in distance estimation can be replicated in our simulated environment, which may be available in more modern military simulators. For example, auditory cues cannot be replicated for this experiment. What soldiers know as “crack and thump” provides an extremely useful cue: when an enemy fires his weapon, a soldier can estimate how far away the enemy is by hearing the round ignite in the chamber (crack) and the sound of the round breaking the sound barrier as it passes by (thump). As well, the program is fairly accurate in its modelling of halos, but not blooming (the haze produced by lights while wearing NVGs). Another limitation is that light flashes will not be an exact replication of a real muzzle flash. The speed of a flash in the field is variable as the result of the type of round used, the temperature of the barrel, carbon build-up and the general wear and tear of the individual weapon (personal communication: Captain Bird, technical adjutant of CTC Gagetown, February, 2007). The speed of the simulated flash is therefore an estimation of an average real life small arms muzzle flash. The flash itself resembles a light source that had been programmed for earlier research, and has not been programmed to exhibit the exact characteristics of a muzzle flash.

We will be measuring egocentric distance estimation by verbal estimate. Some researchers feel that verbal estimates (including responses entered into the computer on a keyboard) are often not the best method to estimate distance compared to visually directed action, such as reaching, throwing, and locomotion [37]. The method of measuring the perception of distance will not play a factor in the present experiment. Soldiers will at no time estimate distances to the enemy by using visually directed action. Measurements will be taken from the subject's computer input by means of a keyboard.

1.4 Summary and statement of experimental intent

DRDC is conducting several experiments to investigate the effects of NVG use on perception. Much of the research has focused on the difficulties in estimating distances while using NVGs, both in field studies and in a simulated environment. The present experiment will build upon previous research to better understand human ability to judge distances in an environment simulating NVGs.

The research questions are:

1. Do subjects who have undergone training demonstrate greater accuracy in using NVGs to judge distances from themselves to a flash of light than subjects who have not undergone training?

2. Will there be a difference between the flash types as to the accuracy of the estimations?

3. Will there be a difference between the sessions due to training?

4. Is there a difference in the accuracy of the subject's estimations between flashes below the horizon and flashes above the horizon?

This experiment is significant to soldier training, as infantry soldiers must often judge distances from themselves to the enemy in order to accurately return fire and pass on the enemy's location. Muzzle flashes are one of the few ways of detecting the enemy at night. If it is shown that distance estimation training using a simulated environment is effective, it will provide support for investment into new simulators used in soldier and pilot training.

1.5 Hypotheses

Four specific hypotheses follow on the research questions:

1. Subjects who have received training will demonstrate greater accuracy when judging distances in a simulated environment than subjects who have not been given training.

2. There will be a significant difference between the flash types. Subjects will demonstrate greatest accuracy when presented the prolonged flash and least accurate when presented the single flash.

3. Subjects will show significant improvement between the pre-training session and the remainder of the sessions.

4. Subjects will demonstrate greater accuracy estimating distances to flashes below the horizon than above the horizon.

2 An experiment

2.1 Subjects

Eighteen volunteer subjects were tested in the experiment. Subjects were given a standard DRDC allowance of $28.38 for a two-day minimal risk study that took a total of two hours. There were no special characteristics of potential subjects. The following subject demographics were recorded; (1) age, (2) gender, (3) military or civilian status, (4) use of corrective lenses, and (5) previous experience with NVGs. Ages ranged from 19 to 49 with a mean of 31.4 years. Of these 18 subjects 2 were female and 16 were male, 13 were military and 5 were civilian, 12 wore corrective lenses and 6 did not (it was not made explicitly clear to the subjects that by indicating they wore corrective lenses meant they were currently using them for the experiment). Finally, 8 had previous experience with NVGs and 10 did not.

Subjects were Department of National Defence (DND) employees located at the DRDC building in Toronto and across the street at Denison Armouries. Denison Armouries consists of the Joint Task Force Central Area (JTFC) and Land Force Central Area (LFCA) Headquarters (HQ), 32 Canadian Brigade Group (CBG) HQ and various organizations within 32 CBG. Recruitment occurred by word-of-mouth and e-mail. A more active campaign which consisted of distributing call-for-subjects flyers was planned in case of difficulties recruiting by word-of-mouth alone. An example of a call-for-subjects flyer can be seen in appendix B. The experimenter recruited military subjects for the study, while the research assistant (RA) recruited civilians. Military subjects set up their appointment time through the experimenter while the RA did the same for the civilians. Throughout, the experimenter and RA maintained close communication to ensure there were no scheduling conflicts.

2.2 Design

In this experiment, the effects of four independent variables were examined in a simulated NVG environment. The screen captures in figures 2.1 and 2.2 illustrate the horizon line, an example of a flash and the ground and sky textures. The horizon was determined by where the ground plane meets the sky plane at eye level (set to be 1.5 metres). The independent variables were; (1) the sessions; pre-training, training, post-training, and two-week post-training, (2) flash location; whether the flashes were above or below the horizon, (3) training; whether training was received (experimental group) or training no feedback (control group), and (4) flash types; 5 flashes, a single flash, and a prolonged flash. The experiment was therefore a 2 x 2 x 3 x 4 mixed factorial design. The sessions, the flash location, and flash type were the within-subjects variable (with four, two, and three levels respectively). The training variable, training or no feedback, was the only between-subjects variable (with two levels).

In each session, the subject was presented the flash type both above the horizon (see figure 6) and below the horizon (see figure 7) in order to determine whether there was a significant difference between estimating the flash against the ground texture or the sky texture.

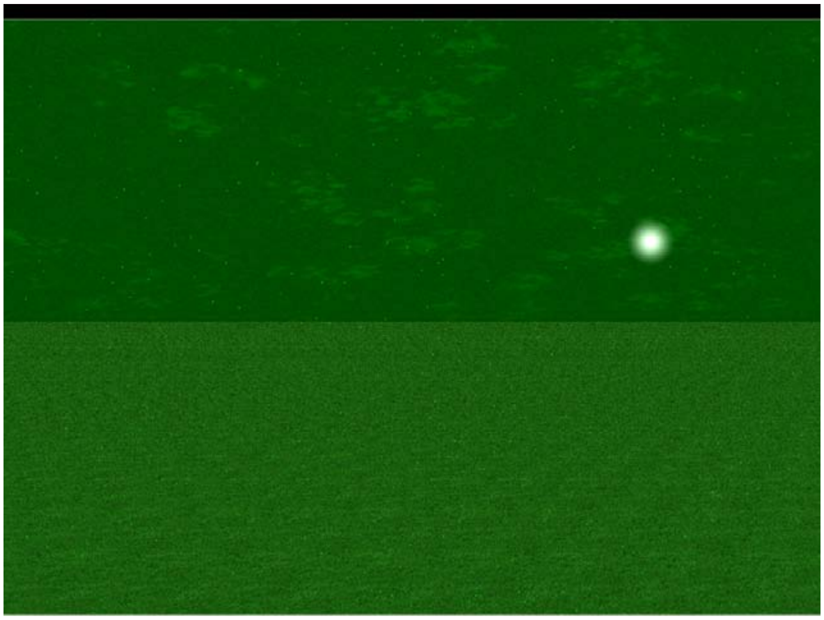

Figure 6. Above the horizon flash

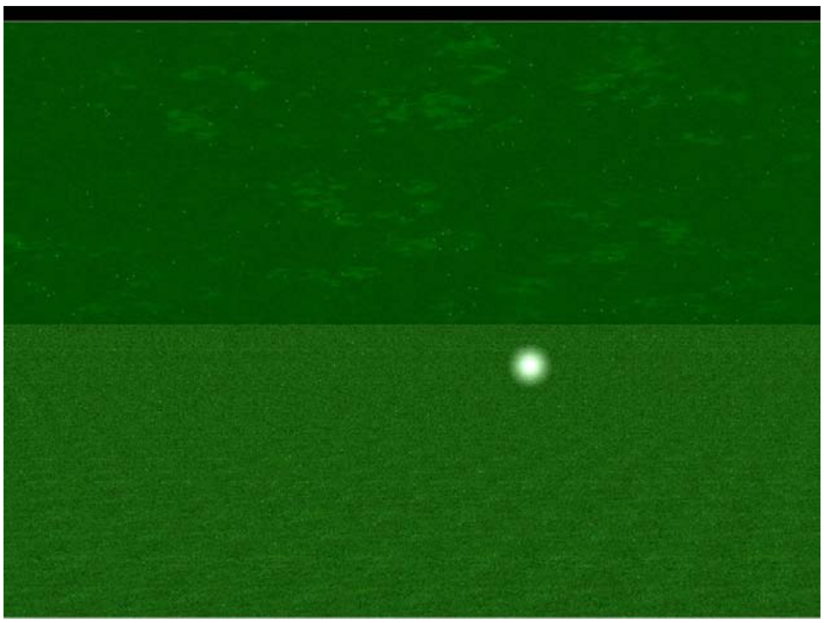

Figure 7. Below the horizon flash

In each session and flash location, subjects were given 10 exposures to each flash type. Therefore, each subject was exposed to 60 flashes per session for a total of 240 flashes for the entire experiment. The program could not randomize and balance when the flash occurred above or below the horizon. Instead, each session consisted of completing all of the above the horizon or below the horizon exposures separately. The order in which the subject received either the above the horizon or below the horizon was randomly determined (see appendix C).

Subjects were not provided training or feedback in the pre-test, post-test, and two-week post-test conditions. Feedback was provided during the training session to the experimental group but not the control group; this session was called “training, no feedback”. In the training session, the experimental group was provided the actual distance to the flashes of light immediately after the subject made his or her estimate. Feedback was given in the same dialogue window used to enter the estimated distance (see Figure 8). If feedback was not provided, the feedback box would read “no feedback” (see Figure 9). The placement of a subject in the experimental or control group was determined sequentially (i.e. the first subject received the training while the second subject did not; the third subject received training and so forth).

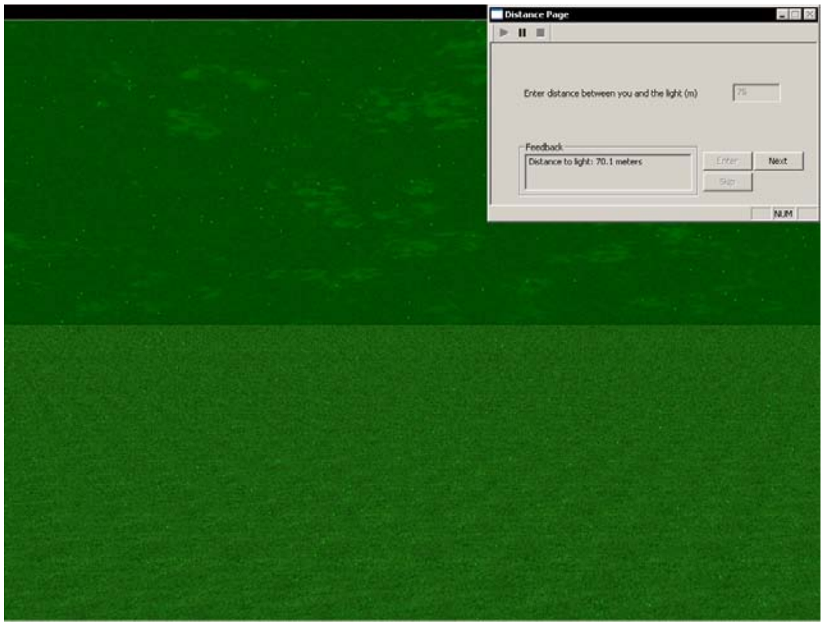

Figure 8. Dialogue window with feedback

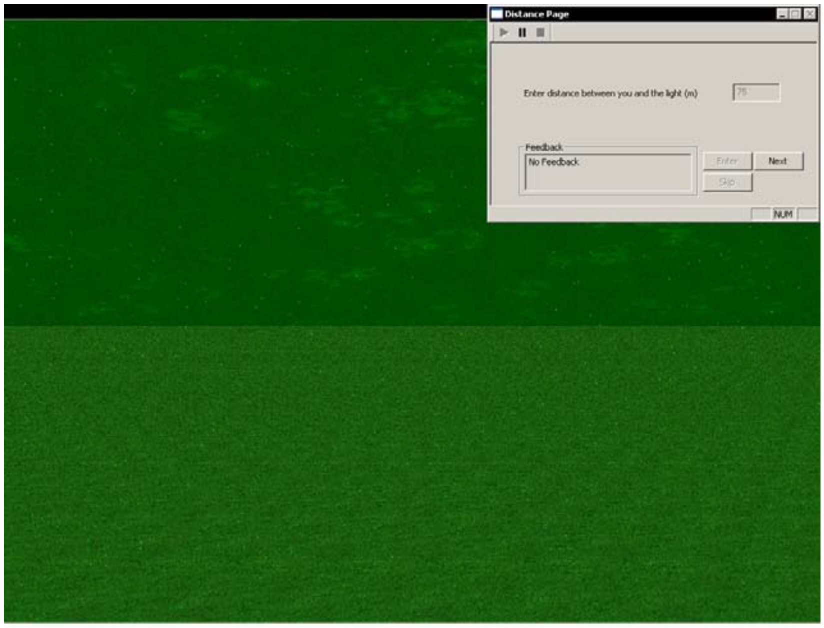

Figure 9. Dialogue window with no feedback

The computer software recorded the distance estimations which the subjects typed, and calculated the main dependent measure; estimated distance minus the actual distance, in meters. This measure is signed, meaning that it is a difference measure, which takes on both positive and negative values. After each session the computer produced a data file containing the main dependent measure. Each data file was also manipulated by the research assistant (RA) to include: the day the experiment took place, the difference ratio (estimated over actual distance), and the log of the distance ratio (see appendix D for an example of a data sheet). The format of the data file also contained the subject's demographic characteristics, Cartesian coordinates for the subject and flash (the location of the subject and flash relative to each other in the simulated environment), as well as information pertaining to which variables were present for each trial (i.e. above or below horizon, the flash type, etc).

2.3 Setting and Appartus

The experiment was conducted in a small lab, approximately 10 x 14ft, at DRDC Toronto. There are several desks in the room, one of which held the computer used in the experiment. As you enter the lab through the revolving darkroom door, the desk with the computer used in the experiment (and a back-up computer) is located to the immediate left. Several florescent lights are located on the ceiling and a small window is located above the research assistants' desks at the back of the room. In order to create an environment resembling night time conditions, the overhead fluorescent lights were shut off and the black vinyl blind over the window was shut. During the conduct of the experiment the desk and computer were situated such that the subject's back faced the RAs to avoid distractions. The arrangement allowed the RA to monitor the subject's progress and to know when a session had been completed.

The computer used was a Dell Optiplex GX280 3.20 GHz Pentium 4 desktop computer with a 19-inch Dell flat panel monitor, model number 1905FP; the tower was also located on the desk for easy access to the USB port. After the subjects were presented with the stimulus on the monitor, they entered their distance estimations on a conventional keyboard and mouse. There was no instruction given to the subjects as to how far they were to sit from the computer screen. Once seated, the subjects were free to adjust their positioning so that they were comfortable.

The software used in the experiment was created by Array Systems Computing Inc., contractor to DRDC. The simulated environment was an open field (see Figure 6) at night as seen through NVGs. There were very minimal distance cues available to the subject. Primarily, the subject had the horizon line and textured ground and sky planes. Within the simulated environment, the subject's eye height was 1.5 metres. The stimulus was a flash of light, presented as either five flashes in a row, a single flash, or an 8 second prolonged flash. The speed of each of the five flashes and the single flash was .10 seconds. The FOV was 40 degrees horizontal and vertical with the stimulus randomly presented from 5 to 300 hundred meters away from the subject. The stimulus was located either 5 meters above the ground plane when it was presented below the horizon and 3.8 meters above the ground plane when it was presented above the horizon (see Figure 10).

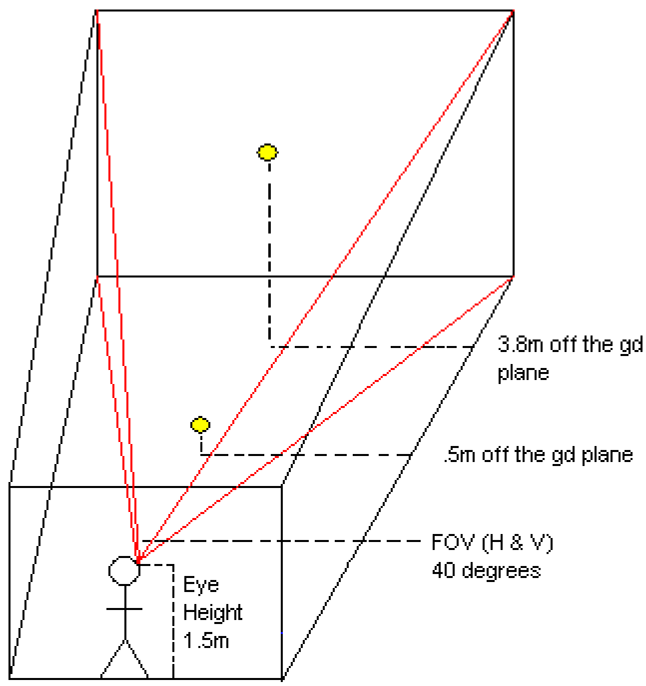

Figure 10. 3-D diagram of the simulated environment using perspective projection. Shaded dots indicate flashes.

The height of .50 meters off the ground plane was necessary: anything less caused a distortion which resulted in the flashes on the side of the screen to appear larger than the centre ones. This distortion is caused by the conditions (i.e. height of stimulus of the ground plane, FOV etc…) of perspective projection by which the larger virtual world is projected onto a smaller computer monitor. The 3.8 meter height was chosen; anything higher than this caused the flash at 5 meters from the subject to appear off-screen.

2.4 Procedure

Once recruited by a member of the research team, a participant package was e-mailed to the subject (see appendix E) including the consent form. The experimenter and the RA would then set up a date and time for each subject. On the day of the experiment, the subjects would arrive at room 1007. The RA followed a checklist in order to ensure that each subject was treated identically, please refer to appendix F.

Once satisfied the experiment could proceed, the RA would provide the subject a paper with instructions (see appendix G) explaining the procedure for each of the sessions, including how to use the computer. Once the subject had a chance to read the instructions, the RA then provided the following information:

a. The subject is standing in a field (eye height 1.5m). The flashes of light below the horizon are simulating muzzle flashes from small arms. The flashes above the horizon is a variable introduced to compare the sky texture with the ground texture, it is not meant as a realistic engagement from small arms fire.

b. The distance from themselves to the flashes of light are anywhere from 10-300m, in 5m increments.

c. There was no perspective (size differences) given to the halos. Although most objects appear smaller as they move farther away, halo size remains constant whether the flash is viewed from a distant or in close proximity.

d. If the subjects find that they are getting tired/bored/frustrated, they must understand that they can pause the experiment to take a break at any time. It is undesirable for subjects to just enter numbers without trying to accurately gauge the distance in order to “get it over with”.

Before the session began, the subject had a chance to ask any final questions or address any concerns. All subjects completed a pre-training session to determine baseline scores (scores which have not been influenced by training or practise). Each session contained 60 flashes, 30 above and 30 below the horizon. In all sessions the participants were presented with 10 exposures of each flash type (both above and below the horizon), the five flash muzzle burst, a single muzzle flash, and an eight second prolonged flash. After each flash, the subject’s were asked to estimate the distance from their position to the location of the flash. The subjects entered their estimates into a window on the computer screen using the computer keyboard. The simulation software collected the subjects’ distance estimations and recorded them into a excel data file. After a short pause in order for the RA to download the next session, the subjects completed either the Training or Training no-feedback session. The experimental group received training in the form of immediate feedback of the correct distance (in metres), while the control group did not receive any feedback. Feedback was presented by the computer in the same window used by the subjects to enter the estimates. Once again, each subject was presented both above and below the horizon with 10 exposures of each flash type. After another short pause, both groups continued to the third, post-training session, which was identical to the pre-training session.

The first three sessions were run in one day and took approximately an hour and a half to complete. At the end of the first day, the RA reminded the subjects they would be returning in two weeks to conduct a post-training session. Prior to the end of the two-week period, the experimenter or RA contacted the subject to remind them of the session. The two-week post-training session took half an hour to complete; total experiment time was therefore two hours per subject. Throughout the conduct of the experiment, the RA would periodically take the data files contained in the computer used to conduct the experiment and download them onto a memory stick. The data files were transferred to the RA's computer and downloaded onto a master data file for future analysis using Statistica, a statistical software program.

2.5 Results

Training in the form of immediate feedback improves performance. The improvement persisted for two weeks; however, there was notable deterioration during the two-week session compared to the training and immediate post-training sessions. There were no missing values, as complete data sets were obtained for all eighteen subjects. The data was analysed using a 2 x 2 x 3 x 4 mixed factorial analysis of variance (ANOVA). The variables in this experiment were Group (experimental and control), Horizon (above or below), Flash type (5-flashes, single flash, or prolonged flash) and Session (pre- training, training or no training, post- training, and two-week post- training). The main dependent variable was the distance difference (the estimated distance minus the actual distance, in meters). A distance difference of zero was a perfect score. When the distance difference was averaged over all of the subject's scores, it was referred to as the mean error or mean error score.

Analyses of the dependent measure for 18 subjects revealed several characteristics. The total number of trials (each estimation) for the entire experiment was 4320, with a mean of 37.13m, a variance of $8560.64m^2$, and a standard deviation of 92.52. The curve was unimodal with a kurtosis (steepness or flatness) of 0.34, well within the acceptable score for an empirical approximation to the normal distribution. Also well within an acceptable value was the skewness (symmetry) of –0.07. The characteristics of the dependent measure show that the data collected was close to normal in its distributional form.

The analysis of the results showed several significant interactions and main effects. Analysis of variance (ANOVA) indicated a significant interaction between Session x Horizon x Group ($F(3, 534) = 6.75$, $p \leq .05$). A post hoc test (Scheffé) of the three-way interaction revealed a significant difference in the experimental group's mean error between sessions. The experimental groups mean error during the training, post-training and two-week post-training sessions were an improvement over their pre-training session (see Figure 11). There was one exception to this finding: the two-week post-training below the horizon session was not significantly different than their pre-training above the horizon session. Another significant difference within the three-way interaction was between the experimental group and control group. The experimental group was significantly more accurate than the control group in several conditions (see Figure 11). These conditions include: (1) the experimental group's training and post training sessions (both below and above the horizon) were more accurate than the control group's pre-training session (above the horizon) and (2) the post-training session for the experimental group (above the horizon) was more accurate than all of the control group's sessions (except the post training below the horizon). Overall, these results showed that there was a significant improvement between the experimental group's pre-training session compared to the rest of their sessions and that these improvements were greatest when estimating distance above the horizon.

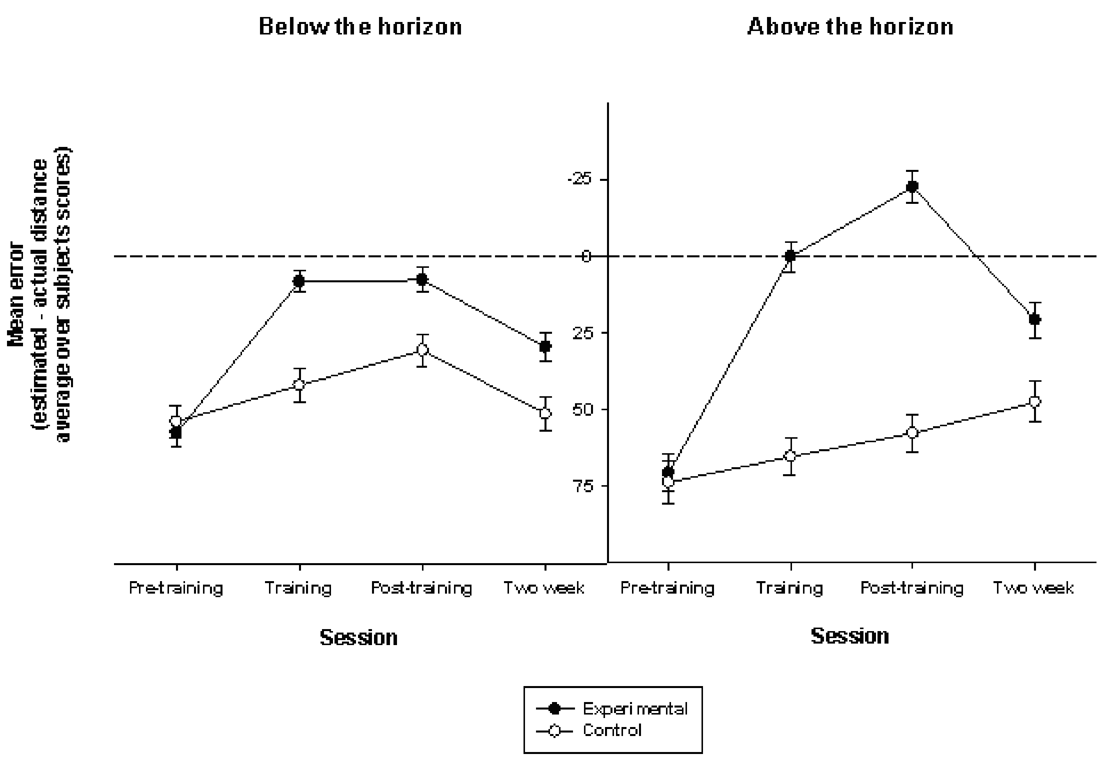

Figure 11. The experimental (solid dots) and control group's (open dot) mean error scores, in metres, plotted by session (pre-training, training, post-training and two week post training) both above and below the horizon. The dotted line at zero represents a perfect score. The experimental group does not depart significantly from zero during the training and post training sessions (unit is metres). The control group did not show significant improvement in either case.

There were several other interactions identified in the analysis. The ANOVA revealed a two-way interaction between: Horizon x Group ($F(1, 178) = 18.70$, $p \leq .05$), Session x Horizon ($F(6, 534) = 4.52$, $p \leq .05$) and a Group x Session ($F(3, 534) = 20.89$, $p \leq .05$). Post hoc tests (Scheffé) from the Horizon x Group interaction and the means showed that the experimental group above the horizon was significantly more accurate than the control group both above and below the horizon. As well, the experimental group below the horizon was significantly more accurate than the control group above the horizon. The post hoc tests from the Session x Horizon interaction, as well as the means, revealed a significant improvement from the pre-training session, both below and above the horizon, to the remainder of the sessions also below and above the horizon (with the exception of the pre-training and two-week post-training below the horizon). The Group x Session post hoc test and means demonstrated significant improvement from the experimental group's pre-training session to their training, post-training, and two-week post training sessions. The experimental group also showed significantly greater accuracy in their training and post-training sessions than all of the control groups' sessions.

Main effects were found for Group ($F(1, 178) = 20.83$, $p \leq .05$), Session ($F(3, 534) = 53.18$, $p \leq$ 05), and Flash ($F(2, 356) = 6.65$, $p \leq .05$) variables. The main effect of Group showed that the experimental group was significantly different than the control group. Figure 12 shows that the experimental group had greater improvement over the control group. The main effect of Session revealed that there was a significant difference between the sessions. Once again, figure 12 shows that there is a significant improvement in the experimental group's training, post-training and two-week post-training sessions compared to the pre-training session. The one exception was that there was not a significant difference between the experimental group's pre-training below the horizon and their two-week post training below the horizon. There was also deterioration in the two-week post-training scores compared to the training and post-training scores. The main effect of flash was unique in that it had no significant interaction with the other variables. The post hoc test revealed a significant difference between the single flash and the prolonged flash. The mean error ($M = 32.24$ metres) for the single flash estimates were better than the prolonged flash ($M = 42.31$ metres).

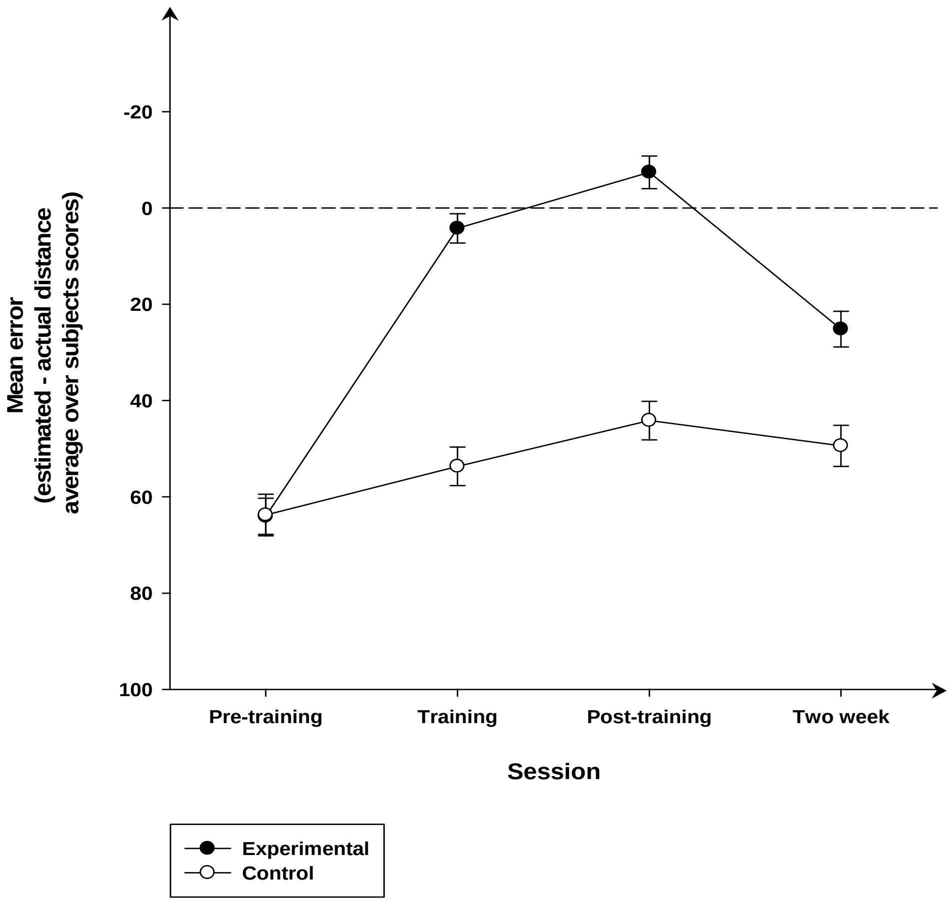

Figure 12. The experimental (solid dots) and control group's (open dot) mean error scores, in metres, plotted by session (pre-training, training, post-training and two week post training). Experimental group is significantly more accurate than the control group during and after the training session. The experimental group's training, post-training and two-week post-training sessions are significantly more accurate than its pre-training session (unit is metres).

Results also demonstrated that subjects overestimated distances on average. The experimental and control group had similar mean error scores during the pre-training session, with M = 64.04 metres and M = 63.77 metres respectively. Training improved the experimental groups mean error score to M = 4.23 metres, while the control group also showed some improvement with M = 53.66 metres. During the post training session, results showed that the experimental group began to underestimate distances but maintained rather accurate results, M = -7.40 metres. The control group also continued to improve slightly, M = 44.14 metres. The two-week post training session showed both groups once again overestimating the distances. Mean error scores deteriorated in both groups with the experimental group overestimating by M = 25.17 metres, and the control group overestimating by M = 49.31 metres.

Each subject's mean error score was compared to zero using a t-test. The t-test was conducted to determine whether improvements resulted in scores which did not depart significantly from zero, in other words, if these scores were near perfect. Table 3.1 reveals that only one out of nine of the experimental group's mean error scores were not significantly different from zero for the pre-training session. The training session showed seven subjects were not significantly different from zero. However, by the two-week post-training session subject's performance deteriorated as only three subject's mean error scores that were not significantly different from zero. The entire control group departed significantly from zero in all sessions with the exception of one subject who had a near perfect score in the post-training session.

Table 3.1: Individual t – value and mean error score differences from zero

Experimental Group	**Pre Training**		**Training**		**Post Training**		**Two Week Post Training**	
	t-value	**Mean**	**t-value**	**Mean**	**t-value**	**Mean**	**t-value**	**mean**
Subject 1	4.05*	39.08	-.897	-6.59	-3.37*	-24.67	1.92	12.99
3	2.66*	36.91	2.050*	12.91	.652	4.00	8.28*	54.91
5	2.48*	25.58	1.017	6.33	-3.49*	-16.92	-4.45*	-25.59
7	12.70*	128.91	2.413*	21.55	3.64*	39.43	15.00*	122.25
9	6.89*	60.41	.326	2.33	1.76	11.16	3.08*	24.493
11	0.77	5.10	-.836	-6.00	-3.41*	-34.92	-2.06*	-24.67
13	13.63*	125.82	.391	6.08	-2.01	-31.51	1.18	20.16
15	8.78*	86.08	-.268	-2.51	-1.24	-11.93	-1.74	-13.34
17	6.91*	67.58	.372	4.00	-.101	-1.26	6.77*	55.32
Group Mean		64.04		4.23		-7.401		25.17
Control Group								
Subject 2	6.79*	63.67	5.66*	43.41	2.79*	24.66	2.87*	20.74
4	-8.67*	-88.26	-8.15*	-84.01	-8.56*	-81.42	-8.23*	-78.59
6	9.13*	98.74	15.75*	127.08	13.54*	111.16	12.60*	119.08
8	4.63*	64.66	5.11*	60.50	7.36*	79.08	12.20*	104.33
10	11.30*	118.66	11.03*	119.41	11.38*	109.74	9.95*	106.08
12	5.32*	58.33	7.39*	61.08	5.60*	59.41	8.14*	74.16
14	4.85*	51.50	4.53*	51.16	2.64*	30.41	-3.03*	-36.09
16	8.49*	91.99	3.86*	38.08	.82	8.50	4.36*	56.24
18	16.41*	114.66	9.52*	66.24	8.56*	55.75	10.66*	77.83
Group Mean		63.77		53.66		44.14		49.31

* $p \leq .05$, subject's mean error score departs significantly from zero (perfect score).

The principal finding of this experiment revealed that, as expected, subjects that received training in the form of immediate feedback had greater accuracy than subjects who did not receive training. Although the experimental group's performance approached accuracy during the training and immediate post training sessions, the two-week post training session revealed deterioration in performance. Nevertheless, there was a significant improvement in the experimental group's estimations from before training to after training. These findings also demonstrated that distance estimation to flashes of light below the horizon were more accurate than above the horizon when subjects were not trained; however, once trained, subjects showed greater improvement above the horizon. Overall, there was not a significant difference between estimations below the horizon and above the horizon. Finally, flash type did affect the accuracy of subject's estimations. Results showed that contrary to hypothesis, the single flash was significantly more accurate than the prolonged flash.

3 Discussion and conclusion

When the experimental group was provided training in the form of immediate feedback, they significantly improved their distance estimations from the pre-training session. This improvement in distance estimation was significant compared to the control group who did not receive any training. The flash variable showed that contrary to expectation, a single flash resulted in significantly greater accuracy than the prolonged flash. Further, subjects in both groups consistently overestimated the distances to the flashes of light in almost all conditions. Finally, although there was not a significant effect with the Horizon variable, there was a three-way interaction consisting of Session x Horizon x Group.

The three-way interaction Session x Horizon x Group showed that this improvement was particularly noticeable when receiving training above the horizon and in comparing the improvement to the control group. Since the experimental group improved the most when they received training above the horizon, it has been demonstrated that the less textured sky plane had a more significant effect on the accuracy of the subject's estimations when given feedback than the more textured ground plane. The sky plane was solid green with a few clouds in the sky while the ground plane was filled with textured grass whose detail diminished as it got closer to the horizon line. The less textured sky plane initially led to more over estimation in distance as well as more variable estimates throughout. Perhaps the improvement was more significant above the horizon because estimations were initially more difficult for subjects in that condition. Once subject's received training, large improvements could be made in comparison to the below the horizon condition. Below the horizon estimates had greater initial accuracy. Despite deterioration in distance estimation after the two weeks, the experimental group's two-week post-training mean error scores were still an improvement from their pre-training mean error score. One hypothesis for the deterioration in performance in the two-week post-training session could simply be due to the minimal cues available in the environment. As distances increased, differences between the flashes became subtler. For example, a change of 50 metres between flashes is less noticeable past 200 metres than it is when the flashes appear less than 100 metres. With less cues, subject's had fewer reference points to gauge these changes. Perhaps a greater number of cues would not only improve initial estimates but it may help distinguish the more subtle changes at greater distances. Ultimately, this may strengthen the original training by providing more reference points for the subjects to remember at two weeks.

The main effect of flash revealed that subjects were significantly more accurate with their estimations when the single flash was presented compared to the prolonged flash. This is counter-intuitive as one would think that the more time a subject had to estimate the distance, the more accurate they would be. This result provides some evidence to support a hypothesis that perhaps both indirect and direct perceptions exist simultaneously. When given the time, the brain uses the internal mental processes characterized by the indirect theory of perception [9]. This is useful when the environment and stimulus are ambiguous, however, the disadvantage is that when the stimulus is not ambiguous subjects may "over think" what is being presented to them. Direct perception, as the theory states, extracts all of the required information directly from the environment. In this experiment, perhaps the accuracy of the single flash could be explained by the utilization of direct perception without the interference of "over thinking". Training merely reveals what direct perception offers.

Subject's consistently overestimated the distances to the flashes. The persistent overestimation of distance is consistent with Waller's findings ([36]), but in contrast to the majority of prior research [22, 32, 35, 34, 37]. The reason for overestimation is uncertain. In Waller's first experiment subject's overestimated distances only after receiving feedback. Waller hypothesized that subject's simply over compensated for the initial underestimations. In his second experiment, Waller introduced feedback as a between group variable. Once again, subjects overestimated distances, especially the control group. Waller did not give an explanation for the overestimation in the second experiment [36]. For the present experiment, one theory for the overestimation could be that by telling the subject the maximum distance will be 300 metres, it gave them their only reference point. As a result, the subject's focus may have been fixed at the horizon line, the farthest distance possible. As the flashes were presented, subjects scaled back from the 300 metre reference point, resulting in the tendency to over estimate as their thought process was already envisioning greater distances. Overestimation may therefore be the result of the design of the experiment rather than the simulated environment or the subject's perception.

There are several areas for future research that can be derived from this experiment. Further experimentation could be conducted to determine if increasing the number of available cues in the simulated environment would allow for near perfect accuracy of distance estimation over the two-week period and beyond. As this experiment determined, training is a powerful tool in improving distance estimation even in a reduced cue environment. Perhaps by improving the simulator's resolution and realism, training may persist for months. Another area for future research would be to study the effects of time when estimating distances. Does more time always result in less accurate estimations? Is less accurate estimations the result of an interaction between time and an ambiguous situation? Although not a result of this experiment, using sound for the perception of distance could be investigated. As part of combat inoculation in the current training system, soldiers are brought to a shooting range made to safely fire rounds over a soldier's head. The soldier hears what is termed "crack" (the ignition of the round in the chamber) and "thump" (the round breaking the sound barrier above the soldier's head). Although this is meant for inoculation and to some degree to train soldiers how to locate where the round is being fired from, there is no systematic means to train distance estimation using sound. With a simulator, soldiers could be trained to estimate distances using the "crack" and "thump" method. This could be used in conjunction with estimating distances to muzzle flashes. Future research can also look at bringing this experiment to an outdoor environment. Blank ammunition may be used to produce the muzzle flashes as a suitable substitute to live rounds. Small lights might also be an option as this would be the only way to reproduce the prolonged flash. Research on the effects of training on distance estimations during daytime conditions would be another area to explore. Daytime presents the soldier with the obvious advantage of increased visual acuity and number of available depth cues. It also makes for identifying where a flash originated more difficult as a flash is not as pronounced in daytime compared to night. Training in the form of immediate feedback may prove to increase accuracy in all of these conditions.

The results show that soldiers can be trained to estimate distances to muzzle flashes in a simulated NVG environment. This reinforces the results obtained in previous experiments [32, 36, 34, 37, 38]. However, the present study found that performance deteriorates over a two-week period; this is a new finding. Research needs to be conducted in order to determine if this deterioration was due to the number of cues available. It is recommended that training in the form of feedback as an effective way to prepare soldiers for the challenges they face, including the estimation of distances to an enemy location. This experiment reinforces the effectiveness of simulation as another tool in preparing soldiers for war.

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Annex A Halo size relative to distance

Error! Objects cannot be created from editing field codes.

Results from studies at the NRC and DRDC reveal that halo sizes do not change as distance increases or decreases from the observer to a halo source.

Annex B 'Call for subjects' flyer

SUBJECTS NEEDED:
Research on Simulation of Night Vision

Revised Protocol: #L-491, Amendment #3

Collaborative Image Intensifier Research

Distance Estimation to Flashes in a Simulated NVG Environment

Principal Investigator (DRDC): Dr. Keith Niall; Co-investigator (RMC Student): Capt Garrett Morawiec

Purpose of Experiment:

To determine and/or train human observers to make estimates of distance under simulated night-vision goggle (NVG) conditions.

Participants Requested:

Eighteen (18) participants are required for this experiment. Participants should be of 18-60 years of age and can have either normal or corrected-to-normal vision. Men, women, military and civilians are all welcome.

Procedures:

This study is an amendment to the larger study which consists of six separate, simulation experiments. For this experiment, participants will be required to return after two (2) weeks for post-training testing.

Experiment: Distance Estimation with Simulated NVG in an Eye Lane

Participants will be presented with flashes of light on a computer screen and be asked to judge the distance from themselves to the flash while under simulated night-vision goggle conditions.

Duration of Subject Participation:

The experiment consists of 4 sessions (3 in one day, 1 two weeks later) taking a total of approximately 2 hours to complete

Location of Experiment:

All experimentation will be conducted at DRDC Toronto.

Risks to Participants:

Risks associated with this study are minimal. Participants may experience fatigue and eyestrain with the prolonged use of a computer.

Benefits:

These experiments will provide better understanding into NVG use and perceptual illusions that may be present during their use. The outputs of these reports will be incorporated into training procedures, operational procedures, design guidelines, and provide models used for perceptually accurate simulations.

Compensation:

Participants will be given basic stress allowance in accordance with DRDC Toronto guidelines.

Point of Contact:

For Denison Armouries participants: Capt Garrett Morawiec 416-633-6200 ext. 5312 Morawiec.gl@forces.gc.ca

For DRDC participants: Patti Odell 416-635-2000 ext. 3024 patti.odell@drdc-rddc.gc.ca

Dr. Keith Niall: 416-635-2002 Keith.Niall@drdc-rddc.gc.ca

Annex C Randomized order

Subject	Pre-Train	Train	Train - No Feedback	Post-train	2 Wk Post-Train
1	ba	ab		ab	ab
2	ab		ab	ba	ba
3	ab	ba		ab	ab
4	ba		ba	ab	ba
5	ab	ab		ba	ab
6	ab		ba	ab	ba
7	ba	ba		ba	ba
8	ba		ab	ba	ab
9	ab	ab		ba	ba
10	ba		ba	ab	ba
11	ab	ba		ba	ab
12	ba		ab	ab	ab
13	ab	ab		ab	ba
14	ba		ba	ba	ba
15	ba	ab		ab	ab
16	ab		ba	ba	ab
17	ba	ba		ba	ab
18	ab		ab	ab	ba

a = below the horizon

b = above the horizon

Annex D Data set

Trial	Subject	Train / No Train	Session	Horizon	Entry	Flash Type	Page #	Experi ment #	Actual distance	Entered distance	Distance difference	Dist Ratio	ln(ent/act)	Day	Time	FOV horizontal	FOV vertical	SR width	SR height	SR color depth	SR refresh rate
1	1	1	1	1	1	1	1	6	115	175	60	1.521739	0.419854	144	2007/05/24/09:27:36	100	100	1024	768	32	75
2	1	1	1	1	2	1	2	6	170	250	80	1.470588	0.385662	144	2007/05/24/09:26:03	100	100	1024	768	32	75
3	1	1	1	1	3	1	3	6	85.01	150	64.99	1.764498	0.567866	144	2007/05/24/09:26:35	100	100	1024	768	32	75
4	1	1	1	1	4	1	4	6	120	175	55	1.458333	0.377294	144	2007/05/24/09:26:48	100	100	1024	768	32	75
5	1	1	1	1	5	1	5	6	180	300	120	1.666667	0.510826	144	2007/05/24/09:25:49	100	100	1024	768	32	75
6	1	1	1	1	6	1	6	6	295	275	-20	0.932203	-0.070204	144	2007/05/24/09:26:17	100	100	1024	768	32	75
7	1	1	1	1	7	1	7	6	90.01	150	59.99	1.666482	0.510715	144	2007/05/24/09:27:50	100	100	1024	768	32	75
8	1	1	1	1	8	1	8	6	260	225	-35	0.865385	-0.144581	144	2007/05/24/09:27:02	100	100	1024	768	32	75
9	1	1	1	1	9	1	9	6	60.01	200	139.99	3.332778	1.203806	144	2007/05/24/09:25:35	100	100	1024	768	32	75
10	1	1	1	1	10	1	10	6	100	125	25	1.250000	0.223144	144	2007/05/24/09:27:18	100	100	1024	768	32	75
11	1	1	1	1	11	2	1	6	200	200	0	1.000000	0.000000	144	2007/05/24/09:29:35	100	100	1024	768	32	75
12	1	1	1	1	12	2	2	6	10.05	75	64.95	7.462687	2.009915	144	2007/05/24/09:28:34	100	100	1024	768	32	75
13	1	1	1	1	13	2	3	6	195	275	80	1.410256	0.343772	144	2007/05/24/09:29:08	100	100	1024	768	32	75
14	1	1	1	1	14	2	4	6	30.02	120	89.98	3.997335	1.385628	144	2007/05/24/09:28:15	100	100	1024	768	32	75
15	1	1	1	1	15	2	5	6	45.01	175	129.99	3.888025	1.357901	144	2007/05/24/09:29:23	100	100	1024	768	32	75
16	1	1	1	1	16	2	6	6	125	225	100	1.800000	0.587787	144	2007/05/24/09:28:57	100	100	1024	768	32	75
17	1	1	1	1	17	2	7	6	275	225	-50	0.818182	-0.200671	144	2007/05/24/09:29:52	100	100	1024	768	32	75
18	1	1	1	1	18	2	8	6	265	300	35	1.132075	0.124053	144	2007/05/24/09:28:45	100	100	1024	768	32	75
19	1	1	1	1	19	2	9	6	20.02	100	79.98	4.995005	1.608438	144	2007/05/24/09:28:03	100	100	1024	768	32	75
20	1	1	1	1	20	2	10	6	25.02	125	99.98	4.996003	1.608638	144	2007/05/24/09:30:12	100	100	1024	768	32	75

Trial	Subject	Observer X	Observer Y	Observer Z	Object 2 X	Object 2 Y	Object 2 Z	Object 2 scale	Age	Gender	Status	Corrective Lenses	Previous use with NV
1	1	6300	6020	1.5	6331.7	6130.6	0.5	0.25	30	2	1	2	1
2	1	6300	6020	1.5	6253.1	6183.4	0.5	0.25	30	2	1	2	1
3	1	6300	6020	1.5	6297	6105	0.5	0.25	30	2	1	2	1
4	1	6300	6020	1.5	6316.7	6138.8	0.5	0.25	30	2	1	2	1
5	1	6300	6020	1.5	6306.3	6199.9	0.5	0.25	30	2	1	2	1
6	1	6300	6020	1.5	6381.3	6303.6	0.5	0.25	30	2	1	2	1
7	1	6300	6020	1.5	6327.8	6105.6	0.5	0.25	30	2	1	2	1
8	1	6300	6020	1.5	6371.7	6269.9	0.5	0.25	30	2	1	2	1
9	1	6300	6020	1.5	6300	6080	0.5	0.25	30	2	1	2	1
10	1	6300	6020	1.5	6279.2	6117.8	0.5	0.25	30	2	1	2	1
11	1	6300	6020	1.5	6258.4	6215.6	0.5	0.25	30	2	1	2	1
12	1	6300	6020	1.5	6297.9	6029.8	0.5	0.25	30	2	1	2	1
13	1	6300	6020	1.5	6252.8	6209.2	0.5	0.25	30	2	1	2	1
14	1	6300	6020	1.5	6306.2	6049.3	0.5	0.25	30	2	1	2	1
15	1	6300	6020	1.5	6313.9	6062.8	0.5	0.25	30	2	1	2	1
16	1	6300	6020	1.5	6295.6	6144.9	0.5	0.25	30	2	1	2	1
17	1	6300	6020	1.5	6261.7	6292.3	0.5	0.25	30	2	1	2	1
18	1	6300	6020	1.5	6263.1	6282.4	0.5	0.25	30	2	1	2	1
19	1	6300	6020	1.5	6301.4	6040	0.5	0.25	30	2	1	2	1
20	1	6300	6020	1.5	6304.3	6044.6	0.5	0.25	30	2	1	2	1

Annex E Participant package

Collaborative Image Intensifier Research

Distance Estimation to Flashes in a Simulated NVG Environment

Participant Package

Collaborative Image Intensifier Research

Protocol #L-491, Amendment #3

Project: ADDNS-TD (Advanced Deployable Day/Night Simulation)

DRDC (Defence Research & Development Canada)

Principal Investigator: Dr. Keith Niall

Co-investigator: Captain Garrett Morawiec

Executive summary

Night operations are of increasing importance to the Canadian Forces. Night operations are often conducted with the aid of image-intensification devices. These are electro-optic devices that amplify ambient light hundreds or thousands of times in an image. Such indirect-view devices allow night scenes to be viewed at a level of clarity that approaches that of their daylight counterparts. The primary differences between vision with image intensifiers and daylight vision are: 1) image intensifiers are sensitive to a portion of the near infrared spectrum to which human eyes are normally insensitive; 2) the resolution of image intensifiers is not as high as that of human vision, and 3) the amplification of light, which is achieved through a cascade of electrons within the device, introduces artifacts such as 'blooming' or 'halo formation'. These features of the device may be mistaken for properties of the environment. Image intensifiers are also known as night-vision devices (NVDs) or night-vision goggles (NVGs). Currently there is little capability for training or simulating image-intensification devices in the Canadian Forces; as these devices are expensive, and in demand. This means that there is little opportunity to practise extreme, dangerous, or rare scenarios with the devices.

The Advanced Deployable Day/Night Simulation (ADDNS) Technical Demonstration project seeks to redress this gap in capability, among its other contributions. ADDNS is a DRDC Technical Demonstration project that is intended to run until 2008. The ADDNS project seeks to advance knowledge of image-intensification devices, and to establish and improve a display capability for the simulation of image-intensifiers. The goal of the project is to demonstrate transportable visual simulations that provide night-vision and high-resolution daylight capability. The project is sponsored by the Director of Air Requirements Five (DAR5), and by the Director of Land Synthetic Environments (DLSE).

In this experiment, I intend to build upon previous research to better understand human ability to judge distances in a simulated environment using NVGs. I intend to introduce additional variables and determine whether training remains effective under these new conditions. These variables include the distance estimation from the subject to a single flash of light, five flashes of light, and one flash of light for an extended duration.

Background

Welcome to the DRDC-Toronto study on night-vision-goggle (NVG) use and the perception of distance. The purpose of this study is to investigate the effects of the use of simulated night-vision-goggles on your perception of distance to different light sources. These studies will aid in the development of better training measures and more accurate simulations for users training to use NVGs, without the dangers associated with real-world training missions.

The development of certain electro-optic devices has changed the domain of night operations for the Canadian Forces. These devices are known as image intensifiers or night vision devices. Night vision devices can be said to amplify moonlight or starlight, but this amplification is the result of a cascade of electrons within the device: the devices do not provide a direct view of the world. The ADDNS project is intended to provide a new simulation capability for night vision devices. A new simulation is needed, for several reasons. One is that artifacts of these electro-optic devices introduce unusual properties to a scene: it is not clear to an observer which properties are artifacts, and which are features of the landscape. Another reason is that night vision devices are sensitive to the near-infrared region of the spectrum, which lends odd characteristics to familiar objects. Trees may glow slightly, for example.

Distortions of the visual scene and its degradation with night vision devices may not be immediately apparent to an observer. Distortions may arise either in the optics of the devices (some of these are known as barrel, pincushion, or shear distortions of the image) or in the electronics of the devices (two examples are electronic scintillation at low ambient light levels, and the formation of bright halos around light sources at high ambient light levels).

Such properties of night vision devices have been linked to distortions in perception, and a number of accidents and incidents have been blamed on illusions caused by such distortions (see Moore, 1990 and Crowley, 1990). In addition to these factors, differences between the two tubes can affect performance. Though most night vision devices are bi-ocular, presenting one image to two eyes (with a fixed disparity for all objects), binocular devices presenting different images to each eye can cause further distortion. Some of these effects are magnification differences, differences in image rotation (leading to shear), luminance differences (suspected of leading to the Pulfrich effect), and differences in tube alignment (leading to dip and divergence in the image). Night vision devices have been implicated as a causal factor in military helicopter incidents and accidents in a number of countries. Some reports have identified the risk of disorientation with night vision goggles as ten to fifteen times greater than for ordinary daytime flight (Durnford et al., 1995). Given such evidence of illusion and image distortion, it can be supposed that more complex aspects of vision could be affected, including object detection, object recognition, texture perception and motion perception. Brickner (1989) identifies a number of illusions and failures of judgment that accompany the use of night vision devices. These include errors in distance estimation, in which objects are perceived as further than they are; errors in slant estimation; and errors in estimation of speed. These errors and illusions are not well understood. These effects on visual perception will compound patent shortcomings of the devices: decreased visual acuity, and reduced field-of-view.

The present series of experiments seeks to distinguish between illusion and unfamiliarity. There may be effects of the devices that arise deep in the physics of the devices, which are not easily changed. On the other hand, there may be some errors in judgment that are more superficial and corrigible. These experiments examine the judgment of several operationally relevant properties as observers use simulations of night vision devices on a desktop computer screen.

Procedure

The present study poses questions about egocentric distance estimation, that is the distance from the observer to the stimuli, in a simulated environment. Specifically, it examines a soldier’s ability to judge distances to an enemy’s muzzle flash, which is characterized by a bright visible light emanating from the muzzle of a discharged firearm. The simulated environment will be an open field at night, viewed on a desktop computer in a dark room. The room number is 1007, located at DRDC Toronto. The screen will simulate the visual characteristics expected when wearing night vision goggles (NVGs). Observers will be required to judge the distance from themselves to flashes of light of varying speed and quantity.

In each session, a light will either flash once, simulating a muzzle flash, flash five times, simulating a machine gun burst, or flash once for 8 seconds giving the observer more time to estimate. These flashes will occur at different positions ranging from 5m to 300m away, at, above and below the horizon and in the left, centre, and right fields of view. The observer will make an estimate of the distances to the light.

Methods/design

The subjects will be divided into two groups undergoing a repeated measures design. There are four sessions of testing in the experiment: pre-training, training, post-training, and two-week post-training. The first three sessions are run in one day and should take approximately one hour and fifteen minutes to complete. The fourth session will take place two-weeks later and should take forty-five minutes to complete; total experiment time is therefore two hours. Each session will consist of 20 exposures to each of the three flash variables; a single flash of light, five flashes of light, and one flash of light for an 8 second duration. Observers are given no training or feedback in the pre-test, post-test, and two-week post-test conditions. In the training session, the experimental group will be given feedback on their estimates while the control group will not. Feedback will consist of the simulation software providing the actual distance to the flashes of light immediately after the observer makes his or her estimate. The computer software will record distance estimations.

Eighteen observers will be tested. All observers will receive instructions on how to use the simulation software for the experiment. The observer's age, gender, and previous experience with NV devices will be recorded. All observers will read and sign the attached consent form.

The primary aim of the study is to consider differences in the dependent measure due to feedback. The main dependent measure of the analyses will be the estimated distance minus the perceived distance, in meters. This measure is signed as a difference measure; it takes on both positive and negative values.

Significance to the Canadian Forces

In combat, infantry soldiers must judge distances from themselves to the enemy in order to accurately return fire and pass the enemy's location onto the rest of the section. Muzzle flashes from the enemy are one of the major ways of doing this. This research will add to our knowledge of NVGs, ultimately increasing the combat effectiveness of the Canadian Forces.

Subjects

There are no special characteristics of potential participants. Potential participants will be recruited from DND employees in and around the DRDC building and Denison Armouries. Denison Armouries consists of the Joint Task Force Central Area (JTFC) and Land Force Central Area (LFCA) HQs, 32 Canadian Brigade Group HQ and various organizations within 32 CBG and JTFC/LFCA HQ. Recruitment will occur primarily through the use of word of mouth and e-mails. A more active campaign consisting of call-for-subjects flyers will be sought if recruitment numbers are low. An example of a flyer can be seen on page 33.

Medical

This study poses minimal physical and psychological risks, as such, no physician coverage will be required. Medical screening will involve the RA asking the subjects whether they have changed their sleeping behaviour, consumption of prescription or over-the counter drugs, alcohol or caffeine within the past 36hrs. The RA will also confirm that the subject has not consumed gravol in the past 48hrs. Additional medical screening will simply involve the RA asking the subject whether they feel well enough to proceed before the start of each day. In the event that a subject experiences fatigue or eyestrain, they will notify the RA who will end the session. This session will be made up at another date.

Conflict of interests

If at any time the subject or experimenter feels that there is a conflict of interest, either one can stop the experiment at any time. Depending on the nature of the conflict, the session may be postponed or cancelled indefinitely.

Risks and benefits

Observers will be provided with and required to have read the participant package outlining the details of the experiment prior to providing informed consent. Observers may choose to withdraw from the experiment at any time. They may also be removed from the experiment by the Principal Investigator or his designate if it is so decided.

Possible side effects and hazards

Observers may experience fatigue and eyestrain or neck strain with prolonged use of the computer.

Benefits

The experiments conducted on behalf of this project will provide better understanding of NVG use and perceptual illusions that may be present during their use. The experiments will also provide valuable training information that will address the following: Can observers be trained to use NVGs? Is this training sustainable? Do flashes of light affect a person’s judgment in a static position? The results obtained in these reports will be incorporated into training procedures, operational procedures, and design guidelines; in the sense that they will provide models usable for perceptually accurate simulations.

Time commitment and compensation

Subjects will be asked to participate in 4 sessions (3 in one day, 1 two weeks later) taking a total of approximately 2 hours to complete. A basic stress allowance has been established for all experiments conducted at DRDC Toronto. Stress allowance is provided at the rate of $11.69

(CDN) per diem. Observers who choose to withdraw from the experiment (or are removed by the Principal Investigator) will be compensated in proportion to the number of days and hours of participation. Compensation is based on the following:

(# of hours x $2.50) + ($11.69 x days)

Any observer that completes all phases of this experiment is entitled to $28.38. This amount is subject to tax.

Volunteer consent form

Protocol #L-491, Amendment #3

Collaborative Image Intensifier Research

Distance Estimation to Flashes in a Simulated NVG Environment

Principal Investigator: Dr. Keith Niall (DRDC)

Co-investigator: Captain Garrett Morawiec (RMC)

I, ______________________ (name) of ____ (address and phone number) hereby volunteer to participate as an observer in the study, "Collaborative image intensifier research" (Protocol # L – 491, Amendment #3). I have read the research protocol in the participant package, and have had the opportunity to ask questions of the Investigators. All of my questions concerning this study have been answered to my satisfaction. However, I may obtain additional information about the research project and have any questions about this study answered by contacting Keith Niall at 416-635-2002 or Capt Garrett Morawiec at 416-633-6200 ext. 5312.

The primary aim of the study is to determine if subjects can be trained, through the use of immediate feedback, to accurately give egocentric distance estimations to flashes of light. Another goal of this study is to determine if this training persists for up to two weeks. I have been told that I will be judging distances to flashes of light in a simulated NVG environment and that this environment will be presented on a desktop computer.

I have been told that I will be asked to participate in 4 sessions (3 in one day, 1 two weeks later) taking a total of approximately 2 hours to complete. I am aware that I will receive remuneration in the amount of $11.69 for each completed day for a total amount of $28.38 if I complete the entire research project.

As with many forms of judgment, observer performance may be affected by many factors: the amount of sleep from the previous night, the side effects of prescription medication, non-prescription medication, and over-the-counter drugs, excessive alcohol consumption, and the level of caffeine. We ask that observers do not change their habits in these respects within 36 hrs prior to their participation or during the course of the experiments; if they are changed the experimenter should be made aware. Over-the-counter medications like Gravol have been shown to change eye movements and vestibular responses (sense of balance and motion) and therefore it is recommended that any observers not take this medication 48 hrs prior to participating in the study.

I have been told that the principal risks of the research experiment are experiences of fatigue and eyestrain associated with prolonged use of a computer monitor. The risk to the observer is minimal. I have been given examples of potential minor and remote risks associated with the experiment and consider these risks acceptable as well. Also, I acknowledge that my participation in this study, or indeed any research, may involve risks that are currently unforeseen by DRDC

Toronto. Should I experience any symptoms after completing the experiment, I will call the principal investigator or his designate.

For Canadian Forces (CF) members only: I understand that I am considered to be on duty for disciplinary, administrative and Pension Act purposes during my participation in this experiment and I understand that in the unlikely event that my participation in this study results in a medical condition rendering me unfit for service, I may be released from the CF and my military benefits apply. This duty status has no effect on my right to withdraw from the experiment at any time I wish and I understand that no action will be taken against me for exercising this right.

In the highly unlikely event that I become incapacitated during my participation, I understand that every necessary medical treatment will be instituted even though I am unable to give my consent at that time. I will go with the Investigator(s) to seek immediate medical attention if either the Investigator(s) or I consider that it is required. Every effort will be made to contact a family member or the designated person indicated below should that be necessary.

I understand that I am free to refuse to participate and may withdraw my consent without prejudice or hard feelings at any time. Should I withdraw my consent, my participation as an observer will cease immediately, unless the Investigator(s) determine that such action would be dangerous or impossible (in which case my participation will cease as soon as it is safe to do so). I also understand that the Investigator(s), or their designate may terminate my participation at any time, regardless of my wishes.

I have been informed that the research findings resulting from my participation in this research project may be used for commercialization purposes. Data from the research will be held confidentially, without personal identifiers. I understand that I will be given a copy of this consent form so that I may contact any of the above-mentioned individuals at some time in the future should that be required. The principal investigator (Keith Niall) can be contacted at 416-635-2002 or Capt Garrett Morawiec at 416-633-6200 ext. 5312.

I have informed the Principal Investigator that I am currently a subject in the following other DRDC Toronto research project(s): ____ (cite Protocol Number(s) and associated Principal Investigator(s)), and that I am participating as a subject in the following research project(s) at institutions other than DRDC Toronto: ____ (cite name(s) of institution(s))

I understand that by signing this consent form I have not waived any legal rights I may have as a result of any harm to me occasioned by my participation in this research project beyond all risks I have assumed.

Volunteer’s Name ______________________

Signature: ______________________________________ Date: ________________

Name of Witness to Signature: ______________________

Signature: ______________________________________ Date: ________________

Family Member or Contact Person (name, address, daytime phone number & relationship)

____

____

____

Section Head/Commanding Officer’s Signature (see Notes below)____________________

Section/Unit: ____________________________

Principal Investigator: ________________________

Signature: ______________________________________Date: ________________

Notes:

For civilian personnel at DRDC Toronto: Signature of Section Head is required designating that volunteer observer is considered to be at work and that approval has been given to participate in this research project.

For military personnel on permanent strength at CFEME: Approval in principle by Commanding Officer is given in Memorandum 3700-1 (CO CFEME), 18 Aug 94; however, members must still obtain their Section Head’s signature designating approval to participate in this particular research project.

For other military personnel: All other military personnel must obtain their Commanding Officer’s signature designating approval to participate in this research project.

FOR OBSERVER ENQUIRY IF REQUIRED:

Should I experience any symptoms after completing the experiment, I will call the principal investigator or his designate. Should I have any questions or concern regarding this project before, during, or after participation, I understand that I am encouraged to contact Defence R&D Canada – Toronto (DRDC Toronto), P.O. Box 2000, 1133 Sheppard Avenue West, Toronto, Ontario M3M 3B9. This contact can be made by surface mail at this address or in person, by phone or e-mail, to any of the DRDC Toronto numbers and addresses listed below:

Principal DRDC Toronto Investigator:

Keith Niall, 416-635-2002, Keith.Niall@drdc-rddc.gc.ca

Co-Investigator (RMC student):

Captain Garrett Morawiec, 416-633-6200 ext. 5312, Morawiec.gl@forces.gc.ca

Chair, DRDC Human Research Ethics Committee (HREC):

Jack Landolt, 416-635-2120, jack.landolt@drdc-rddc.gc.ca

I understand that I will be given a copy of this consent form so that I may contact any of the above-mentioned individuals at some time in the future should that be required.

Annex F Research Assistant's checklist

PRIOR TO TEST DAY

1. Coordinate the subject's test time with Garrett.

2. Inform guardhouse of subject arrival date.

3. Information required from Garrett prior to the subject's testing;

    a. whether subject is in the experimental group (will give them train_a and train_b session) or control group (will give them train_no feedback_a and train_no feedback_b session).

    b. The order within each session. The order in which the subjects will be exposed to the below the horizon (a) and above the horizon (b) variable will be varied. Therefore, a subject will not get an ab (pre-train), ab (train or train no feedback), ab (post-train), and ab (2 week post-train).

TEST DAY

1. Greet subject at the front gate if coming in from outside DRDC. Otherwise, greet subjects at room 1007 in DRDC.

2. Collect the subject's Volunteer Consent Form. Ensure it is properly filled out, most importantly, the subject's CO (or designate) has given permission.

3. Confirm that they have not changed their habits wrt prescription drugs, excessive alcohol consumption, and caffeine consumption within the past 36hrs. As well, as consuming gravol within the past 48hrs.

4. Confirm they understand the principal risks of the research experiment (that being eyestrain and fatigue) and that they can withdraw from the experiment without prejudice or hard feelings at any time.

5. Give subject the instruction sheet to read. After they have read the instructions and have been allowed to ask questions, inform the subjects of the following;

    a. The subject is standing in a field (eye height 1.5m). The flashes of light below the horizon are simulating muzzle flashes from small arms. The flashes above the horizon is a variable introduced to compare the sky texture with the ground texture, it is not meant as a realistic engagement from small arms fire.

    b. The distance from themselves to the flashes of light are anywhere from 10-300m, in 5m increments.

c. There was no perspective (size differences) of the halos. Although most objects appear smaller as they move farther away, halo size remains constant whether the flash is viewed from a distant or in close proximity. This is the result of true halo characteristics

d. If the subjects find that they are getting tired/bored/frustrated, they must understand that they can pause the experiment to take a break at any time. It is undesirable for subjects to just enter numbers without trying to accurately gauge the distance in order to “get it over with”.

6. Ask if they have any questions.

7. Turn off lights and pull blinds.

8. Remember, for each session, explain what it is (especially the train session, remind them where to look for the feedback).

9. Begin experiment

10. After experiment, ensure you have subject contact info and have subject sign pay sheet.

Annex G Subject instructions

In this experiment, you will be asked to estimate distances to flashes of light in a simulated NVG environment.

1. Once the experimenter has loaded the file onto the screen, the programme will ask you to input your NAME, AGE, CONTACT INFO, GENDER, STATUS (civilian or military), if you wear CORRECTIVE LENS, and whether you have PREVIOUS USE OF NVGs.

2. The session will begin when the experimenter presses the “play” button.

3. You will then see an open field at night. A moment later, 5 flashes will appear on the screen. You will be prompted to input a distance into a window that will appear at the top right corner of the screen. Enter your estimated distance using the keyboard and then press “enter” in the window using the mouse. To move to the next trial, use the mouse and press “next”.

4. After 10 exposures to the 5 flashes, you will be presented with 10 exposures of the single flash. Finally, you will be exposed to 10 exposures of an extended 8-second flash.

5. Once the session is complete, the computer will automatically bring you back to the main page.

6. The experimenter will then load the next session onto the screen and steps 1-5 will be repeated. A total of 6 sessions will be conducted on the first day, some will have the flashes appear below the horizon and some above. If you are in the experimental group, during the training session, the correct distance will appear in the “feedback” box located in the window after you have pressed the “entered”.

7. Once all sessions are complete, the experimenter will ensure they have your contact and that a pay sheet has been filled out.

8. If possible, the 2 week-post train session will then be scheduled. If not, Capt Garrett Morawiec will contact you to find a suitable time.

Please remember that you are free to refuse to participate and may withdraw your consent without prejudice or hard feelings at any time.

Thanks for participating!

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The Canadian Forces have recognized the importance of simulator training as a cost-effective alternative to real training; yet the effect of display simulation on visual perception is not fully understood. Eighteen subjects participated in an experiment to determine if training, in the form of immediate feedback, improved distance estimation to muzzle flashes in a simulated NVG environment. Testing was performed on a PC desktop computer using software that simulated a large open grassy field. Subjects were exposed to three flash types; five flashes, single flash, and a prolonged flash. Flashes were presented to the subjects both above and below the horizon. Significant improvement was shown in the experimental group's accuracy; this accuracy persisted over two weeks but with notable deterioration. Contrary to expectation the perception of a single flash resulted in significantly greater accuracy than the prolonged flash. This experiment reinforces the effectiveness of simulation as a tool in preparing soldiers. A bibliography of the topic is included.

Les Forces canadiennes reconnaissent l'importance de la formation sur simulateur à titre de substitut économique à la formation réelle; cependant, les effets de la simulation de l'affichage sur la perception visuelle demeurent mal compris. Dix-huit personnes ont participé à une expérience visant à déterminer si la formation avec rétroaction immédiate améliorait l'appréciation des distances de lueurs de départ dans un milieu de simulation observé avec des LVN (lunettes de vision de nuit). Les essais ont été réalisés sur un ordinateur de bureau à l'aide d'un logiciel qui simule une vaste étendue (champ). Les participants ont été exposés à trois types d'éclairs : une série de cinq éclairs, un éclair unique et un éclair prolongé. Les éclairs étaient générés au-dessus et en-dessous de l'horizon. Des améliorations importantes ($p \leq 0,05$) ont été observées dans la précision de l'information fournie par le groupe étudié; la précision a été maintenue pendant deux semaines, mais s'est tout de même détériorée considérablement au cours de cette période. Contrairement aux attentes, la distance de l'éclair unique a été perçue avec une précision beaucoup plus grande ($p \leq 0,05$) que celle de l'éclair prolongé. Cette expérience est venue confirmer l'efficacité de la simulation comme outil de préparation des soldats.

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night vision; distance estimation; training; simulation

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