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VIRTUAL ENVIRONMENTS AND WAYFINDING IN THE NATURAL ENVIRONMENT

by

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The results indicated that navigational ability had a more pronounced effect on performance then did treatment group. However, among the treatment groups, the intermediate ability group seemed to benefit the most from the VE. Within the VE treatment, the beginner ability group seemed to suffer from excess workload, while the advanced group found the VE treatment only useful for pinpointing the location of the marker. The results indicate that a properly designed VE can, through training, impart a familiarity with a selected natural environment area, better than map study for all except the most sophisticated land navigators. Further study is needed to examine aspects of the VE, how they need to be represented, and what other refinements or features could be included in such a VE in order to maximize training transfer,

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VIRTUAL ENVIRONMENTS AND WAYFINDING IN THE NATURAL ENVIRONMENT

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The results indicated that navigational ability had a more pronounced effect on performance then did treatment group. However, among the treatment groups, the intermediate ability group seemed to benefit the most from the VE. Within the VE treatment, the beginner ability group seemed to suffer from excess workload, while the advanced group found the VE treatment only useful for pinpointing the location of the marker.

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I. INTRODUCTION

A. PROBLEM STATEMENT: CAN VIRTUAL ENVIRONMENTS BE USED TO IMPROVE WAYFINDING PERFORMANCE FOR THE PERSON ON FOOT IN AN UNFAMILIAR NATURAL ENVIRONMENT?

The ability to use Virtual Environments (VE) as a training aid for improving combat performance by the individual foot soldier is predicated in great part on the level of fidelity between the VE and the environment being modeled. Just what that fidelity is, and how best to represent it, is still unknown. I infer that a significant part of that fidelity involves modeling the actual environment to the degree that the foot soldier, after having trained in the VE, feels as if he already *knows the place.* Knowing the place means in large part, being able to move about in that space with the same level of confidence which one has when you move through an oft frequented woodland, park, or forest. This place is known to the extent that even certain trees, rock clusters, minor trails, or other features are not only recognized on sight by this person but he could take you to these features by any number of routes without the aid of map, compass, or Geographic Positioning System (GPS).

Moreover, this person has the sense of well being that comes from knowing where he is and not fearing becoming lost. Knowing where you are allows you to reduce your dependency on navigational aids, thereby freeing time and concentration for other tasks. Knowing the environment as if you have already been there, allows you to rapidly exploit that knowledge for offensive and defensive actions without the apprehension which often accompanies moving through an unfamiliar environment never seen before but only roughly imagined by the low level of detail provided on a typical topographic map. This is one component of *situational awareness*:

" The most important thing learned from the Task Force XXI advanced warfighting experiment held at the National Training Center, Fort Irwin, Calif., last month is "that situational awareness is so powerful." Gen. William W. Hartzog, commander of Training and Doctrine Command.

According to the general, situational awareness consists of three things:

1. ***Knowing where you are.***
2. Knowing the location of friendly forces.
3. Knowing the location of the enemy.

"Now, when you know those three things you are given a startling tool on any battlefield anywhere," he said.

Unlike the combat vehicle crewman, who by virtue of his vehicle's speed, size, mobility characteristics, and function, is primarily concerned with representations of those features in a VE that impact on his vehicle's performance (manmade and natural features that facilitate or hinder vehicle movement and opportunities to fire or be fired upon), the foot soldier is concerned with a higher level of detail not represented by today's simulators. When operating on the mission objective area, this level of detail goes beyond the simple portrayals of vegetation and manmade features where a representative item is replicated in a uniform or pseudo random fashion. When viewed from the foot soldier's perspective, this type of modeling produces the "clean" or sterile VE which is often at significant variance to the actual terrain and thereby, at best, degrading the VE's utility or worse creating false knowledge. This type of modeling often omits depressions, minor roads or trails, clearings, and other conspicuous or important features to the foot soldier. Modeling these features and landmarks are essential if VEs are to create this level of spatial familiarity to the foot soldier about to conduct a mission on the modeled terrain.

To the non-military user, knowing what and when to model in a natural environment so that the user has a heightened sense of familiarity may not only pave the way for a more informed direct experience, but may permit decisions to be made without first hand experience of the actual environment if the user has confidence in the integrity of the model. Also by understanding what features are best modeled and how to present them in a VE meant to represent real space, VE designers may, in turn, learn how to create more navigable stand alone VEs thereby diminishing the common phenomena of "lost in cyberspace" (Darken and Sibert, 1996).

Can VEs be used to create the level of familiarity with the natural environment for the person on foot that up to this point has only been demonstrated for building walk-throughs or tested for aircraft flyovers? This study addresses that question.

II. BACKGROUND

A. SPACE, PERCEPTION, AND NAVIGATION

Landmark knowledge by itself is little more than a crude representation of the environment (Wickens, 1992). Navigational ability may reside in route or survey knowledge (see Glossary for explanation of landmark, route, and survey knowledge). Thorndyke's (1980) research has suggested that each of the respective knowledges is preferred for certain geographic tasks. Additionally each may be acquired independently of the other through different training techniques.

Route knowledge is derived from an egocentric point of view. This type of knowledge is illustrated by directions such as "right" at the road junction. This command will lead to different route choices based upon the perspective of the person at that moment, such as whether they are facing east or west at the time they encounter the road junction. In contrast to this is survey knowledge where the appropriate reaction upon encountering the same road junction would be to "take northerly road". In this instance, the needed direction would be taken regardless of which direction the road junction was approached from.

Thus, Thorndyke has proposed that the possession of route knowledge is best suited for decisions made from an egocentric frame of reference. This includes pointing out the direction of a landmark not currently visible or judging the distance that must be traveled between two points and actually navigating that route. Whereas survey knowledge, which provides a more exocentric viewpoint, would be good at estimating the relative direction between two different landmarks and estimating straight line distance as opposed to walking distance between them. Identifying the absolute location of a landmark on a map is also an instance of demonstrated survey knowledge.

Regarding Thorndyke training, argues that route knowledge is best obtained through direct navigation of an environment. Comparatively, survey knowledge is best initially obtained by map study. However, survey knowledge will also eventually be developed from direct navigation. Thorndyke and Hayes-Roth (1982) tested this assertion through two groups of subjects on orienting and distance estimation tasks. One group acquired knowledge of the topography of the Rand Corporation building through extensive navigation training (route knowledge). The other group acquired knowledge by map study (survey knowledge). The results confirmed predictions. At modest levels of training, the map learning group demonstrated better estimates of Euclidean distance and object localization than the route knowledge group did.

Additional training of both groups showed an asymmetry of results. Eventually the navigation trained group surpassed the map trained group in all tasks. The progression from route to survey knowledge suggests that our internally based egocentric frame of reference slowly progresses from an inside-out context dependent frame of reference to an outside-in context free representation (Wickens, 1996).

Wickens also asserts that these results have important training implications. He suggests that extensive map study may not be very effective in preparing someone to navigate in a strange environment. He claims that a more effective training procedure would be provided by an inside-out experience of an environment where "the operator actually navigates through videotapes, or even views a highly abstracted movie that indicates the twists, turns, and landmarks to be encountered in navigation".

III. VEs AND WAYFINDING

A. ABSTRACT LEVEL

Studies on the acquisition of spatial knowledge in VEs have been conducted on several levels. Fundamentally, they have dealt with simple geometric primitives such as cubes and rectangles confined within limiting walls (Peruch, Vercher, and Gauthier, 1995). Peruch et al have confirmed that spatial knowledge acquired through active exploration is superior to that of either dynamic passive or dynamic static exploration.

Their study consisted of a spatial layout of four target cubes hidden from each other by obstructing inner walls and all of these objects contained within a limiting wall with an entrance point on each of the four sides of this wall. In the active exploration condition, the participants freely explored the space, their view smoothly changing in response to their manipulation of a joystick. Their objective was to locate each of the four target cubes. In the two passive conditions, the objective was the same but in the case of the dynamic passive condition the participant had no control over route selection and viewed the smoothly changing scene from a programmed route designed to show the all four cubes twice the participant by touring the area in a clockwise and counterclockwise fashion. The programmed tour lasted four minutes. In the dynamic static condition, the participant viewed a series of static slide-like scenes selected along a continuous path. These scenes corresponded to one of every 72 frames of an 18 frame per second smooth changing scene rate. Each static scene was displayed for 4 seconds. All three exploration conditions were four minutes.

The participants (nine women and nine men ages 20 to 39) were allowed to practice working in the simulator in order to relate the motion of the joystick to the changing scene before the preview. After each group was given a preview of the simulated space (the exploration) under their respective condition, they were immediately subjected the target location test. The participant was required to do the target location test; where being placed near the center of the simulated space, they were directed to use the joystick to select the shortest path to reach a given target cube. Not one target cube was visible from the start point even if doing a 360 degree rotation. Eight test trials were performed for each of the experimental conditions. A large display screen was used that provided the perspective one would have of looking out the front windshield of a car with no side views.

The results showed that the active exploration condition systematically yielded the highest number of memorized spatial cues. Participants that acquired the highest spatial knowledge also had the highest performance score. Dynamic and static passive conditions of exploration yielded equivalent performance as determined by the same two dependent variables (score and completion time). This later point has interesting implications as to how two different viewing conditions, fixed frame and continuous sweeping may lead to an equivalent performance.

B. PROMOTING GEOGRAPHIC KNOWLEDGE IN SIMULATED AIRCRAFT NAVIGATION

Traditionally pilots have been trained to prepare for an upcoming flight by drawing and studying their routes on aeronautical charts. For flights conducted under visual flight rules pilots use the navigation method known as pilotage, a technique that is involved in nearly all low level rotorcraft operations (Williams, Hutchinson, & Wickens, 1996). In this method, pilots choose salient landmarks that will bracket their course.

Previous studies seem to indicate that active mode learning is superior to passive mode. However, this positive result may diminish as work load increases. Optimal scene detail is also in question, yet to be accurate, most of the studies involving scene detail have looked at landing, altitude maintenance, and bombing. Successful navigation is significantly dependent on the localization as well as positive identification of landmarks. This suggests that higher levels of scene detail may better support the identification component of the navigation.

In testing the effects of level of detail (LOD) and active vs. passive participation in a simulated rehearsal flight, active participation was once again demonstrably superior in promoting the acquisition of spatial knowledge (Williams, Hutchinson, & Wickens, 1996, experiment 1). A third group studied only a map and achieved of level of performance above the passive but below the active group. Two of three groups trained in low and high levels of scene detail respectively. When both groups transferred to a high image fidelity simulation to fly the same route the transfer results indicated no effect of scene detail on level of performance. However, it must be noted that all groups in this experiment still had access to their map and thus any influences from the various treatments could have been washed out by the fact that all the pilots still were able to refer to their maps during the test portion.

Survey knowledge was also tested among the three groups. Although the map study group was able to reconstruct the map to a higher level of detail then the other two groups, and they did well on the landmark recognition measure, they were no more successful than the other two groups in returning to the start point. The return to the start point task was given after the participant had arrived at the final checkpoint. The participant was not told that this would be a task on the test until arriving at the final checkpoint. Unlike preceding tasks, the participant was required to complete this final navigation task without reference to the map. The results of this survey knowledge test suggest that, though the map study group's reconstructed maps were superior and implied a superior survey knowledge than the other two groups, this ability did not translate into a capability to apply that knowledge. This result supports the presumed independence of reconstruction skills and the functional use of this survey knowledge proposed by Thorndyke and Hayes-Roth (1982).

This experiment was repeated, except that all participants were denied use of the map for the transfer test flight. The results from this second experiment imitated the first one except that the active group, with a fixed map orientation, experienced a significant drop in performance. Also during the rehearsal flight the active group was forced to fly 40% faster in the second experiment in order to reduce the study time for all groups to 20 minutes. The faster flight increased the bandwidth requirements for horizontal and vertical control and likely increased the overall flight control workload.

C. TRAINING DISMOUNTED SOLDIERS IN VIRTUAL ENVIRONMENTS: ROUTE LEARNING AND TRANSFER

The Army Research Institute (ARI) constructed a highly detailed model of an office building using Multigen and WorldToolKit (Witmer, Bailey, and Knerr, 1995). The building was rendered using a SGI Crimson Reality Engine and displayed via a Fakespace Lab two color Boom2 (a high-resolution binocular display at the end of an arm that allows six degrees of freedom movement and thumb buttons that control forward and backward movement).

The participants were sixty college students who had no previous exposure to the building. All participants first studied route directions and photographs of landmarks, either with or without a map, and then were assigned one of three rehearsal groups. The respective groups were the VE group that rehearsed in the building model, the building rehearsal group that rehearsed in the actual building, and a symbolic rehearsal group that relied on verbal rehearsal of the route directions. Having the participants estimate the distance and direction tested route knowledge to selected landmarks, while survey knowledge was tested by the capability of participants to exit the building using an unrehearsed route.

The research found that participants who rehearsed in the actual building made the fewest number of errors followed by the VE group, and then the symbolic group. Each of these differences was statistically significant. Knowledge accrued about the building layout or configuration (survey knowledge) was not significantly different among the various rehearsal conditions and no significant differences were found as from map use. Only a gender effect was noted with males performing better than females. There were no interactions among the various conditions.

The results indicate that spatial skills learned in a virtual environment can transfer to real-world settings if the virtual environment adequately represents important landmarks and stimulus cues. The VE group, though not performing as well as the building group, did much better than the symbolic group, even better than those who had previously studied a map.

D. WAYFINDING IN THE NATURAL ENVIRONMENT, MAPS, AND TERRAIN VISUALIZATION

The psychological aspects of wayfinding in the natural environment have been researched extensively by psychologist Rachel Kaplan. Included within her studies on the subject have been an examination on the fear of getting lost and on the building of confidence on the part of the navigator to mitigate or eliminate that same fear. Developing knowledge about future needs, learning techniques for dealing with new situations, and confidence in problem solving developed as a consequence of prior successful problem solving; all of these depend upon the adequacy of an individual's internal model of the environment, and this in turn depends upon experience (Kaplan, 1976).

The "future" environment must be modeled so that it facilitates envisioning it. Merely describing it makes it difficult for a number of people to arrive at the same spatial relationships and physical characteristics among objects. The scene needs to be taken in one sweep where the spatial characteristics are immediately comprehended in a uniform way by all who view them. This suggests that the best way to represent an environment is through a model or simulation. Though models are abstractions, they need not loose coherency because of a lack of detail. Object constancy is important in this sense so that houses are recognized as houses and so on.

Kaplan's study showed, among other things, that participant's required to draw a map of a natural environment after a brief walk through of that environment came up with radically different maps for depicting what they had seen in spite of the fact that they all had walked the same route. The majority of maps were linear (route maps) showing a sequence of landmarks connected by a line (the path walked). Two maps were pictorial, showing key features in elevation and obscuring geographical relationships, while two other maps were regional, showing areas defined by types of flora and topographic elevation. Kaplan concluded from this that the maps indicate that there is much more in a person's mind than what any single map conveys.

A later study by Kaplan involving 85 seventh graders indicated that prior experience (via abstract non-contour based maps) did make a difference in terms of reactions to the experience in the natural setting. Of more compelling interest was the conclusion that prior cognitive structuring of an unfamiliar outdoor setting must be done well or not done at all. The conclusion was drawn from the result that participants who had information that they knew to be irrelevant about the environment that they were about to enter had no difficulty ignoring it whereas another group which had been given relevant but misleading information experienced cognitive incongruity which detracted from their experience in the natural environment (their confidence about their knowledge of that environment).

A final study by Kaplan used contour maps and aerial photographs. The results of this study showed that the group who oriented themselves to the natural environment experience beforehand using an aerial photograph were more favorable to the experience and enthusiastic about the thought of future trips to the park than the contour map based group. In contrast to the contour map based group which had greater confidence in their wayfinding ability. Possible explanations could be the quick sense of space that the photograph provides to a participant base (106 seventh graders) not thoroughly schooled in contour map reading. The contour map group had received some instruction in reading contour maps prior to their use of a contour map during the test. Of particular note was the fact that the contour map based group had a higher degree of confidence in their wayfinding ability independent of their attitude regarding the experience. This implies that confidence and comfort in the natural environment contain a variety of informational inputs (Kaplan 1976).

On the basis of these studies Kaplan concluded that their is a need for a map that provides a more intuitive sense of height and depth than the contour map. The use of a "game" format to encourage active participation on the part of participants as opposed to passive learning was very well received on the part of participants. The fear of getting lost in the natural environment is not merely a function of a lack of prior experience with that particular environment, but of a lack of cognitive structure for such settings as a whole, or in other words the lack of a "sense of place". Concerning what is important to represent to the navigator on a map of a natural environment Kaplan is less sure. The only things that seem to stand out in the natural environment to her are the non-natural features of that environment. Of secondary importance are the characteristics of regions such as a forest, clearing, or tall grasses. Thus the problem of identifying landmarks in the natural environment becomes one of identifying unique features against background. Kaplan concludes that confident wayfinding and orientation in a natural environment can be enhanced, at least to a limited degree, by prior exposure to relevant information. Additionally, a critical component of this wayfinding skill will be the ability to identify what is "distinctive" after one has become sufficiently well acquainted with the setting to know what is distinctive. The importance of a sense of place and the preference for the familiar may relate to the ability to be comfortable with an environment so that distinctive elements can be differentiated (Kaplan, 1976).

Research on map reading and terrain visualization done by the Army Research Institute for the Behavioral and Social Sciences (Simutis and Barsam, 1983) has shown that their can be considerable individual differences when it come to map reading abilities. The ability to visualize three-dimensional terrain from a two-dimensional contour line representation represents the most complex skill required of a map reader. At the time of this study three solutions were proposed to help overcome the individual differences in map reading and terrain visualization skills demonstrated by soldiers:

1. Redesign the maps
2. Improve techniques to train map reading skills
3. Select individual with map reading abilities for this task

Redesigning of maps in accordance with user preference surveys has had little usefulness in facilitating better user performance with these maps (Wheaton, Zavala, & Van Cott, 1967). Different methods of portraying relief on a map have provided similar results in that performance gains in one area (time to extract relief data) were offset by performance losses in another area (terrain visualization). Only greater map reading experience positively correlated with increased map reading performance.

Research on individual map reading differences have confirmed that differences in spatial skill abilities exist. However, map readers will likely never be selected solely on their ability to read a map as many other skills are important in the performance of a military specialty. Consequently any improvements in map reading performance will have to come as a result of improvements in map reading training.

As with many other skills, trainers believe that the best way to improve terrain visualization performance is through experience. Thus techniques that broaden terrain visualization experience in short period of time are important to the Army. An experiment was conducted which studied the performance advantages among a three dimensional terrain board, stereoscopic slides, and two dimensional slides. Eight different groups were formed around combinations of the previously mentioned training aids. The group that trained with a combination of three-dimensional terrain boards and two dimensional slides performed the best in terrain visualization.

Under the same study, Army researchers experimented with computer graphics as a means of training terrain visualization. A low resolution computer graphics application was used where the participant could place himself on a specific site within the map and then could rotate an arrow from 0 to 360 degrees to indicate the direction of view. Once the site was selected the participant could then view the terrain as if they were standing on the chosen site and looking in the chosen direction. The terrain could be plotted on the screen in two or three dimensions. No mention is made in the study as to the portrayal of map features other than relief. From figures included in the study it would seem that only relief was modeled and all other types of features, both manmade and natural were not part of the terrain modeling.

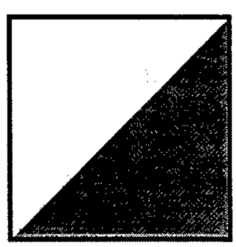
Participants were classified as to spatial ability through three subtest scores from the kit of Factors Referenced Cognitive Tests. Participants were classified as having either above, average, or below average spatial ability. These three groups were then further divided between two test conditions: interactive and non-interactive.

The tests indicated that for participants of above average spatial ability interactive graphics training was more effective than non-interactive training. There was no effect of training condition for participants of average or below average spatial ability (Simutis and Barsam, 1983).

E. ORIENTEERING

By virtue of the added detail in an orienteering map, which makes it a more suitable template for deriving a high fidelity VE than any other topographic map, and the presence of two orienteering clubs in the area, I decided to use orienteering as the basis for my experiment on wayfinding in the natural environment and VEs. Orienteering provided me with a detailed conceptual framework for map and corresponding VE construction, a method for evaluating the effectiveness of navigating an orienteering course (Lowry and Sidney, 1989), and a pool of skilled map readers with which to draw upon for participants. This last point has significance since from a logistics relevancy, the research is within a military applications context and I restricted participation to only those individuals who were familiar with map and compass use. Prior exposure to sport orienteering was required. Finally, since orienteering has a history as an organized sport reaching back over 100 years in Sweden, it also has a correspondingly extensive taxonomy, methods for training, and most importantly within the context of this study, a system for identifying and classifying common navigation errors.

Orienteering is a sport where participants use specialized maps, clue sheet, and a compass to locate orange and white three side flags known as "controls" (see Figure 1) in a race against the clock. It is wayfinding in the natural environment with a competitive angle. Courses vary in difficulty and are rated with color codes to reflect their relative difficulty to each other. The easiest course (white) normally contains from seven to twelve controls set alongside roads and/or trails for a cumulative control to control distance of approximately three to five kilometers.



Dimensions:
12" x 12"

Colors:
White
International Orange

Figure 1. One Side of Three Sided Orienteering Control Marker

Like all courses, regardless of difficulty level, these controls must be found in sequence. Upon finding a control marker, the participant will take out his scorecard and "punch" their card with the punch that hangs from the control. The punch is approximately the size of a small pocket paper stapler and contains a letter or symbol pattern in small spikes which when applied to the scorecard, perforates it leaving a hole pattern in the scorecard that matches the punch's pattern. This verifies to the scoring official back at the finish that this participant did indeed find a given control. Participants must find all the controls on their course in order to be considered as finishing. At that point, all finishing competitor's times for a given course are compared and sorted, with the fastest time winning, etc.

The orienteering map is a highly detailed specialized map reflecting the orienteering participants need to know fine details about the environment which in they are competing. These details include but are not limited to all roads, trails, and classifications of vegetation based upon a competitor's ability to run through it. Other features as small as isolated boulders, individual trees, fences, and other features not normally represented on a USGS topographic map, are often part of an orienteering map. The idea being, if the map contains such detail, then the orienteering course designer can use that detail in the creation of a course. Orienteering maps are normally produced at a scale of 1:15,000 or 1:10,000 whereas most USGS and military maps start at scales of 1:24,000/1:25,000 and go up. So not only do the purposes of orienteering and normal topographic maps differ, but their respective scales denote corresponding levels of detail. More information on orienteering map specifications can be found in International Specifications for Orienteering Maps in Appendix A.

The clue sheet is the one other aid that the competitor uses to pinpoint the location of the control. It is normally a small sheet of paper which contains orienteering symbols (and corresponding textual explanations for beginners) as to the precise location of the control within the circle drawn on the map. It will include a description of the feature the control is placed on, such as hilltop, fence corner, or individual tree. It will also state on what side of this feature the control is located, such as on the north side of a tree, or southwestern corner of a building. The intention here is to provide all the information necessary to the competitor so that a deliberate course can be set for the control, as opposed to luck being the deciding factor influencing the finding of the control as the competitor enters the marked circle. See Figure 2 for the clue sheet used in this study.

Orange			2070 meters			11 m		Course Orange Length 2070 meters Climb 11 m
Start								Start
1								Building Northwest side
2					1x1			Pit Shallow Size 1x1 m
3								
4					3x3			Small depression Shallow Size 3x3 m
5					4			Single tree Deciduous Height 4 m Northwest side
6					3x7			Ruin Size 3x7 m On top
7								Dry ditch Ruined East end
8								Clearing
9								Clearing Northeast edge

Figure 2. Clue Sheet Used in this Study

Finally my role as cofounder and president of the Monterey Bay Orienteering Club (MBOC) placed me in the position where I gained first hand experience in orienteering map making and course setting. It further gave me the opportunity to recruit participants for the experiment from the MBOC membership. Pivotal to my role as cofounder and president was the acquisition of digital mapping data for Ft. Ord which was produced in 1993 in conjunction with its closing. This data, produced at 100ft and 300ft per elevation data point, was crucial in providing the necessary high fidelity input for producing an orienteering map and the VE that would later be derived from it.

F. GIS AND RAPID DEVELOPMENT OF VEs

The rapid development of VEs from existing Geographic Information Systems (GIS) databases is key to VEs becoming viable training mediums for the military or those wishing a high fidelity computer representation terrain found in the physical world. Rapid development of a model should stem from taking existing GIS data, I assume the GIS data is over 90% accurate and at the scale needed by the VE builder, with 96 hours or less spent converting, inputting, and refining the raw GIS data into the final VE. High fidelity means the ability to model features as small as a pit 1 meter deep by 1 meter in diameter, and to be able to place that pit in its appropriate location within the VE.

This state presumes that there are VE file formats, modeling tools, and when necessary conversion utilities for GIS data that taken together give the VE builder the necessary tools to methodically create the VE without having to resort to rewriting code within a modeling tool, or developing custom import or export filters for porting the GIS data to the VE modeler. And of course all data that is ported to the VE maintains its GIS spatial integrity.

Though several vendors claim that their products are capable of meeting some of the above criteria, my experience over the course of 3 months proved that most of those claims were without merit. What follows is a brief synopsis of my attempts to port the Ft. Ord GIS data into a VE and why I eventually had to settle for an unorthodox solution to the problem.

The implication is that anyone desiring to create a VE rapidly must depend upon base topographic data to already exist as conventional aerial or satellite survey can be both costly and untimely. Thus, using existing GIS data from the most popular GIS formats is the most efficient first step in creating a high fidelity VE of an actual piece of terrain.

The data produced as a result of the 1993 Ft. Ord closure was done in both AutoCAD r12, ESRI's ArcINFO coverage and ArcView shapefile formats. Since ArcView represented the most cost effective solution for creating maps for the MBOC, it was this application that became the software of choice for producing orienteering maps. With the exception of the USGS's DEM format and the DOD's DTED format, the GIS file formats represented by AutoCAD, ArcINFO, and ArcView constitute the most prevalent GIS data formats is use today. Many state and local government agencies, as well as private civil engineering firms use at least one of these applications for GIS. These applications also enjoy widespread use outside of the United States as well.

Recent developments in VRML 2.0 and the announcement by Intel on August 25 of several new motherboards featuring Advanced Graphics Port technology for the Pentium II processor promise to move sophisticated graphics development from the realm of the high priced SGI workstation to the modestly priced PC. Additionally, a conversion filter for DEM (USGS elevation data) to VRML 2.0 and ESRI's pending release of a plugin for ArcView that can export shapefiles into VRML 2.0 as well as create 3D models directly from the same shapefiles, also bodes well for the widespread distribution of terrain modeling tools and their subsequent support and enhancement by the greater software developing community.

IV. APPROACH

To determine if prior exposure to a high fidelity non-immersive VE improves navigation in the natural environment I had to first define what constituted good navigation. At this point land navigation for the dismounted soldier is still a function of training, experience, and the reliance on tools such as map, compass, and recently Global Positioning Devices (GPS). In a perfect scenario, there wouldn't be a need to rely on these tools to assist you in going from point to point. Obviously, this situation is only applicable to navigation over ground that you are already very familiar with.

This represents the ideal, though it is difficult to achieve in real terms when the section of terrain in question is large and/or complex, thus posing a significant memorization problem. Also, how much time is available to familiarize (to physically walk the ground) has a direct influence on one's ability to assimilate the features of the terrain and create route or survey knowledge. However, for the purposes of testing training transfer from a VE, this concept of navigation without reference to map or compass, while simultaneously maintaining a disciplined route from point to point to preclude chance from factoring into discovering a point, is just the approach I decided upon. The argument is restated as a premise:

> Familiarity with an environment produces fewer navigational errors than unfamiliarity (in this context deviation from a self prescribed route) and familiarity with an environment leads to less dependency on aids such as map and compass. This is evidenced by fewer references to both.

Orienteering through its specialized maps and requirement for fine navigation skills, is a good medium for testing natural environment familiarity through a navigation problem. A sequential progression from point to point, as done on an orienteering course, facilitates the creation and testing of route knowledge. An orienteering map, produced at a very small scale would allow almost direct extrapolation of the map to the VE. The map would act as a feature template upon which the VE can be built. Not only does this simplify construction of the VE by having it follow construction of the map, but it would also insure feature congruence between the two abstractions of the environment. Finally, the map would serve as an audit trail by providing the medium upon which the participant can plan his route and later have that same participant's actual route overlaid on the same map.

Not all natural environments are equally suited for an experiment involving route planning and memorization. The same could be said for survey knowledge within the natural environment. Environments which lack landmarks, where the flora and topography is generally uniform, presents a formidable navigation obstacle without use of map and compass. Such environments are best navigated through a method known as "dead reckoning". Here the navigator determines his initial location, plots a magnetic bearing to his destination, and then walks that bearing while logging distance traveled by means of a pace count (the method for determining distance walked by pacing off 100 meters, remembering that count, and adding 100 meters to your distance walked at every interval you walk that pace) . This method requires continual reference to the compass and diligent pace counting. It is also the principle mean of navigating at night when landmarks are concealed by darkness.

Ft. Ord's former training area is dominated by three types of habitat. Perennial grasslands cover about one third of the former training area and are characterized by knee high grasses and in some places widely scattered oak trees. These areas have excellent visibility and pose no real traversing problem. The second type of habitat is the oak forest. A woodland dominated by Inland or Coast Live Oak which vary in height from 25 to 45 ft. The former tree will often have canopies that reach all the way to the ground. This woodland varies in density and amount of undergrowth with some areas easily traversed, while others may be quite thick or contain large quantities of poison oak where traversal becomes more difficult. The final habitat is maritime chaparral. Chaparral by its abrasive qualities and tendency to grow in dense uniform thickets is a considerable obstacle to the walker. Even on the edge of chaparral communities where the plants break up their otherwise unbroken thickets, chaparral is best walked around as opposed to attempting to fight your way through it. As a consequence of its use as an active duty Army installation for much of this century all of the former training area is a lattice work of paths, jeep trails, and minor roads. Finally, there are some small wood buildings, concrete tent pads or foundations to ruined buildings, and power lines in the former training area.

Thus, much of Ft. Ord is ideally suited for this test. A mixture of meadow, traversable woodland, impassable thickets, occasional building, and latticework of trails allows for the creation of a course rich in landmarks, but also posing many opportunities for parallel error to the navigator. Since many of the participants for the experiment are drawn from the MBOC and its San Francisco based predecessor, the Bay Area Orienteering Club (BAOC), an was selected which had not been used previously for an orienteering event. This precluded participants from having a significant prior exposure to the course area and thereby skewing the results of the study. Additionally the area chosen should not be either too hilly (turning the navigation problem into an athletic test) nor flat (avoiding the featureless landscape referred to above). It also has to offer clear reception of the differential GPS (DGPS) signal being broadcast from nearby Toro Mountain.

V. IMPLEMENTATION

A. TREATMENTS AND ABILITY CLASSIFICATION

Three groups comprise the treatments within the study. As a benchmark against which all performance is compared, one group would get to walk the actual course immediately prior to being tested on that course. During the training phase this "Real World" (RW) group would have unlimited access to map and compass as they walk the actual course locating each control and marking on their map the route they intend to follow during the immediately following test phase where they don't have access to map and compass without penalty. It was expected that this group would perform the best as they would experience the test environment in first person as opposed to an abstraction.

The second group, the Control Group (CG), previews the map only. This represents the existing method of planning and terrain visualization. A participant in the CG has to plot his route based only on map study. Like the other two groups (RW and VE), the plotted route is on the same map that the participant would later be able to refer to (under penalty) during the test phase.

Finally, the VE group would preview the course via a non-immersive VE and map. The map was still necessary from the standpoint of plotting the participant's route through the course. Also, the VE as constructed did not have an audit capability with which to either track the participants movements through it, or record a path at the participant's discretion.

15 participants volunteered for the study, all were males between the ages of 28 and 68. Participant's ability was assessed through a questionnaire on previous orienteering experience (see Appendix B) and they were then evenly divided among the three treatment groups. The ability classification of the participants was as follows:

1. Three Advanced
2. Nine Intermediates
3. Three Beginners

All advanced participants were from the BAOC and were actively competing in orienteering events at the rate of one or more events per month. Additionally, advanced participants had competed in more than 24 orienteering or military land navigation exercises in their lifetime. This frequency of recent competition, over 24 events participated in to date, and a self assessed advanced ability level led to a participant being classified as advanced.

Intermediates may not have participated in any more navigation events in their lives then beginners, but assessed themselves as intermediates based upon question three. The significance of this needs to be clear. By stating that they (intermediates) navigate in a more aggressive fashion (see Appendix B, question 3, answer b) it denotes a level of experience, and therefore confidence, not shared with beginners who still navigate by the safest route possible (see Appendix B, question 3, answer a). Participants who self assessed themselves as advanced but lacked the previously noted competitive history and frequency level of advanced participants were classified as intermediates.

Beginners had participated in fewer than 12 orienteering or military land navigation exercises in their lives. Beginners also self assessed themselves as beginners based on question three. The correlation between fewer then 12 events over a lifetime, and a self assessed beginner's ability level, led to a participant being classified as a beginner.

B. COURSE AREA AND MAP

An area immediately to the southwest of the junction of Gigling and Watkin's Gate road was selected for the course. The selected area was bounded by Gigling Road on its north, and dirt roads on its remaining three sides. It comprised an area of approximately 1200 x 700 meters in size of gently rolling forest, meadow, and thicket. Several buildings, to include ruins and concrete foundations, and two sets of single wire power lines added to the feature list. The area was crisscrossed with an extensive path and jeep trail network. See course map in Appendix C, and an explanation of the map's legend in Appendix D.

An initial survey was conducted to determine the area's suitability to task based upon natural and manmade feature distribution. When the area was considered adequate, an orienteering course was laid out. The map of this area was produced after approximately 25 hours of survey and 25 hours of computer work. A digital aerial photograph (created 1993) produced at the one meter per pixel level was used as the template for the survey and subsequent computer map production (see Appendix E).

IOF Map conventions were followed most the time, the exceptions being telephone poles/wire, and concrete pads both of which were symbolized in ways not covered by the IOF map handbook. This was necessary because the symbol palette in ArcView does not contain full support for all IOF map symbols. The map was produced at a scale of 1:5,000. This very small scale was chosen to make it easy for participants to accurately trace their planned route through the course. A larger more conventional scale of 1:15,000 would have made such fine route tracing impractical. Also, the smaller scale allowed the portrayal of small breaks in the vegetation (2 meters or less in width) which would be significant to the participant trying to thread his way between thickets of fight. The 1:5,000 map scale was the appropriate scale for direct translation to the VE.

C. THE COURSE

The course decided upon was the technical equivalent of an orange course (intermediate skill range in sport orienteering). The orange course meant that the controls were located off of paths and roads. Controls were placed so that catching features were at times be along the route to, or at least in the immediate vicinity of, a control.

Control placement would provide route choice to the participant. This meant that the participant normally perceived at least two principle routes to a given control from his current location (normally the preceding control). Route choice was strictly up to the participant. The participant was informed prior to beginning his training that there was no bonus for choosing a more aggressive route. Rather he chose a route that he was able to stay on without deviation. Choices between an indirect yet conservative route where the prospect of route deviation was minimized, and an ambitious more direct route which normally meant primarily cross country without benefit or roads or trails with which to guide the navigator (handrail) was available at each control. An analysis of each control and the probable routes to them can be found in Appendix F.

I decided to place nine controls on the course for several reasons. One was to provide a large enough number of controls so that early errors on the first two or three controls would not dominate the overall results of a course run. Experienced and inexperienced navigators alike will affirm the importance of being right while searching for the first few controls. Finding the first few control in accordance with expectations has the effect of building confidence in the navigators analysis and execution of the navigation problem. Conversely, early errors that lead to not finding the first or second control can severely shake the navigators confidence, leading to self doubt, and further errors in judgment.

Also, by having nine controls I had the opportunity to vary the difficulty level of a given control so that there was a balance of fairly easy confidence builders and difficult parallel error laden controls. Nine controls were the approximate number I could fit into the course area without resorting to undesirable backtracking where the participant would be crossing a piece of ground already seen when searching for a previous control. And finally nine controls laid out to comprise a cumulative course distance of under 3,000 meters was a course capable of being completed without running in less than an hour.

D. THE VE

Jack Nicklaus Golf 4.0's Course Designer was the software used to create and later preview the course. Some of the limitations inherent with the Course Designer was the "hole" convention. This limited modeling of the environment to 640 x 215 yard views, or what would normally be considered the maximum length and width of a golf course hole. Within the context of the course area previously described this limitation was not significant. Due to the topography and vegetation, a participant would never have an unrestricted field of view stretching out more than 150 meters. Careful alignment of these holes within the constraints imposed by the terrain, control placement, and the likely routes taken by participants meant that the most likely approaches into a control could be previewed from within the confines of one 640 x 215 yard "hole".

Another constraint on the model's construction was the fact that the program was never designed with GIS data import capability. Though the program had been used to model many actual golf courses, these models were constructed strictly with the eye of the modeler as the measuring tool for ensuring spatial fidelity. By moving the tees around, in the "under construction hole", one could come to some rough measurements as to horizontal distance. Vertical distance or elevation is similarly approximated by alternately raising and lowering a section of ground and then placing an object of known height such as a tree of building next to the modified ground in order to determine it height or depth. This resulted in a very tedious and time consuming approach to model construction.

As previously indicated the map was created prior to the VE. So the map acted as a template for VE construction. This was particularly important in defining boundaries, especially those separating rough open ground from forest or other conspicuous demarcation between two very different map features. Spatial fidelity was created by first bringing up a view within ArcView at a scale that would closely match the size of the hole in JNG as it appeared on the screen. A transparent overlay was printed out from ArcView that contained contour lines, vegetation distribution, road and trail network, and other manmade objects. This overlay was spatially accurate. The overlay was then taped onto the screen and the hole from JNG would then be positioned so that the boundaries of the hole lined up with the boundaries of the overlay. Then contour lines, vegetation, and other objects were all traced and filled in on the hole underneath the template. The total time spent to construct a hole was between 20 and 30 hours. This variance was due primarily to the amount of elevation that had to be modeled on a particular hole. The more relief that had to be created the greater the amount of time spent, as rendering elevation changes with the modeler was an extremely slow process.

The application of vegetation was a mixed blessing. The Course designer contained a rich palette of trees and bushes, which though they did not match the Ft. Ord flora exactly, provided an adequate facsimile of Ord's vegetation. Although, all flora had to be placed into the hole on a plant by plant basis, there was no defining an area with a given plant type and then allowing the computer to randomly or uniformly distribute the plants over that area. The resulting method involved hundreds of mouse clicks as trees and bushes had to be individually placed into the environment.

The Hawthorne Tree from the Course Designer palette closely approximated the look of a Live Oak. This became the tree of choice for woodland representation within the VE. I attempted to replicate the height of tree groves in the test area to reflect the differing characteristics of tree groves throughout the course. Oak trees on more exposed ground have a tendency to be shorter (25 ft) with canopies that stretch all the way to the ground. On the other hand, their counterparts on ground sheltered from the prevailing west wind, may grow to a height of 45 ft with lower limbs well above the forest floor allowing for running through them.

Other minor flora, such as undergrowth, young bush-like oak trees, and chaparral were simulated with objects from the shrub palette. Density levels of vegetation were approximated so that they appeared to correlate with the vegetation classifications on the map, which again, were meant to portray a participants ability to run through a given section of vegetation, and not his ability to see through it.

Road and trail application was easier. A simple tracing of the outline and its selection as "rough", "topsoil", "sand", or "cart path", and the path was given its appropriate representation in the VE. Buildings were restricted to one type modeled in the course designer, a latrine, which could be varied in size. Telephone wire poles were approximated by enlarged saguaro cacti. Wire was not capable of being strung between these cacti, but this was not a detraction from participants correlating the cacti with poles on the map and considering the cacti as poles. All objects in this environment were billboards and not true 3D. That is, they had the same appearance regardless of direction they were approached from. Plates provided to the VE participants (during their training phase) with representative correlation's between the actual and virtual environments can be found in Appendix G.

E. DATA CAPTURE

Capture of the participant's planned route was easily accomplished by providing each participant with their own laminated map upon which they directly drew on their chosen route through the course. During the Inbrief, the participant was given an outline of his objectives (see Appendix H) and the parameters which he would have to adhere to in marking his map and doing the course (see Appendix I). RW Group participants drew on their planned route as they walked the actual course during their training phase. The CG and VE Groups drew their planned routes onto the map while they respectively planned with map and map/VE.

Data capture of the participant's actual track through the course was accomplished by three means. The principle capture system was a backpack worn by the participant that contained a DGPS with 5 meter positional accuracy coupled with an Apple Message Pad 130 (see Figure 3). The 130 served as a capture platform for the transmitted DGPS coordinates. The 130 was programmed to accept a coordinate when 5 meters or more away from the previously plotted coordinate. This kept the output clean by eliminating redundant positional plots from the participant not moving. For this study it was not of much concern with how long a participant stood in one sport, but rather the path they took from one point to another. DGPS coordinates were transmitted to the 130 every two seconds, insuring that there was going be a plot every five meters. The 130 also served as a recording platform for a participant's map and/or compass checks. Participants were told that each request to look at the map and/or compass during the test phase would restrict them to discrete 30 second chunks. This did not mean that participants could only see the map and/or compass for 30 seconds before it was taken away from them, rather for every interval of 30 seconds that the participant had the requested object in his hand, an entry was made into the 130 correlating a DGPS reading with the possession of said object.

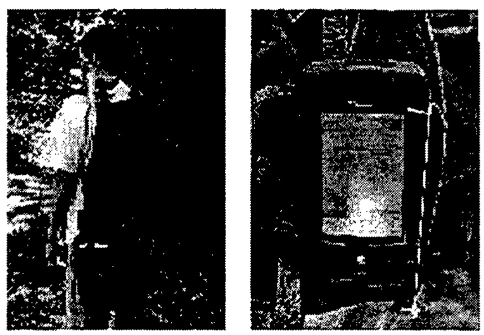


Figure 3. DGPS Backpack and Message Pad 130

The second means of data capture during the testing phase was with the HelmetCAM. The HelmetCAM was a Hi8 camcorder bolted to the top of a standard US Army Kevlar Helmet. A parachutists shock pad served as a vibration dampener between the helmet and the camcorder. A sighting apparatus was fashioned to the camera so that the boundaries of the camcorders view field could be determined by the camera operator who was not be able to look through the cameras viewfinder. The camera was sighted to capture the participant while the camera operator stood at a distance of about 2 meters from the participant. The focus level was set on infinity to be able to capture distance and panorama shots. The principle purpose of the HelmetCAM was to record instances of map/compass check thereby validating the 130 entries, and to provide data for behavioral analysis, see figure 4.

The final means of data capture was by manually recording route traveled and instances of map/compass check on the participants map in the event of DGPS failure. My intimate knowledge of the test area, due to my direct experience in creating the orienteering map for the area, would allow me to reliably record the participants route manually within most of the test area in the event of DGPS failure.

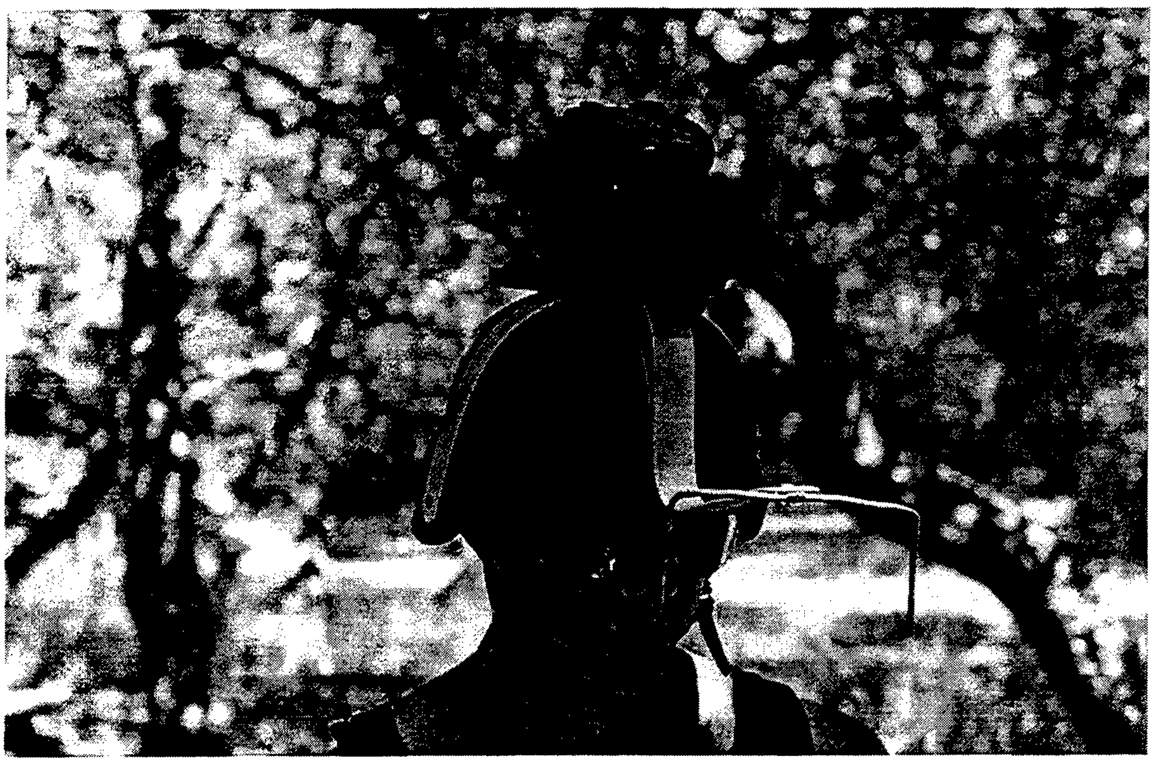


Figure 4. HelmetCAM

VI. METHODS

A. PROTOCOLS

Participants from all three groups were directed to meet at my office at NPS. Participants had been advised that they would be doing the equivalent of an orange level orienteering course and that they should dress appropriately. It was further specified that the course length would be under three kilometers, and that provided that they made few mistakes, running would not be necessary to complete the course. Participants were not informed as to the location of the course until their Inbrief, which immediately preceded the training and testing phases of the experiment.

Soon after arriving, participants were verbally informed as to the task that lay before them and the constraints they would operate under in the performance of that task. They were also informed as to what treatment they would be part of. They were provided the same information in writing via the Participant Task List (see Appendix H), Important Information on Marking Your Map (see Appendix I), and About the Orienteering Map (see Appendix D). Participants also filled out the Orienteering Ability Questionnaire (see Appendix B), again in order to have a written copy for archival. Participants had previously filled out an email version of the same questionnaire which had allowed me to classify them into ability and treatment groups (while ensuring proportional representation of ability within each treatment, participant's orienteering ability was assessed and they were randomly assigned a treatment group prior to the beginning of the experiment). Participants also filled out a consent form (see Appendix J) prior to the beginning of the experiment.

Once these formalities were accomplished, participants began the task appropriate for their treatment. In addition to the map, which was common to all three treatments, a clue sheet was given to all participants (see Figure 2). Participants were informed as to the function of the clue sheet (if they did not already understand it) and told that unlike the map and compass, they would be allowed to keep the clue sheet for the duration of the experiment. In addition to its normal function within orienteering, the clue sheet in this context would serve as a reminder as to the type of feature located at each control. The exception to this was control three which had no clue and would be the focus of a test of survey knowledge.

The CG participants were placed in a room where they could not be interrupted and given one hour to plan their route through the course, mark it on the map, and commit it to memory. At the end of the hour, or earlier if a participant decided he needed less time, the map and compass was taken away from the participant and he was immediately driven out to the course area.

VE participants were given the same map with similar instructions. However, they were to plan their route with the aid of the VE. Prior to being given the map and official time started, VE participants were allowed to familiarize themselves with the navigation techniques and convention of the VE by practicing them on one of the golf courses which came with JNG. This allowed them to become familiar with the mechanics of movement through the VE and thereby reduce the added workload inherent in using this additional tool. At the end of the hour, the map and compass were taken from the participant and he was immediately driven out to the course area.

After the initial Inbrief and formalities, a RW participant was immediately driven out to the course area. As with all participants, he was blindfolded for the final drive into the course area to preclude him from surveying a portion of the course prior to beginning official time. Once at the start point for the course the RW participant was given the DGPS to wear (to allow for a comparison between routes taken on training and testing phases) and given one hour to preview the course. The participant was escorted for the duration of the preview. In the event time expired while the participant was still out in the course area, he was then escorted out of the course area via a route that would not assist him in gathering anymore helpful information about the course, and taken back to the start point. During this training phase, the RW participant was also expected to have marked his planned route on the map.

At this point, the treatment for all three groups is identical with the exception of the debrief questionnaire, which was more extensive for the VE group. For the testing phase, a participant would wear the DGPS and position himself at the start point. Prior to beginning the course all participants were tested on survey knowledge by asking them to imagine they were standing at control three and to shoot azimuths to the finish, control six, and control eight. These answers were recorded on the back of their map. Once this task was complete, the map and compass were given to the participant, they were told they were at the start point for the course, and they were allowed one minute orientation period. It was expected that during this time they would orient the map and confirm their location at the marked start, as well as get a little time to reconcile the map with his surroundings.

Once the minute was over, the map and compass were taken back from the participant and he was asked if he had any questions. There were no questions asked. The HelmetCAM was turned on, the DGPS activated, and official time was begun. A small chime emanated from the 130 every time a data point was logged. This feedback helped to determine if the DGPS was working. If it failed, official time was suspended followed by an attempt to re-establish its reception, and if failing that, manually recording the participant's route through the course became necessary.

Verbal interaction with the participant was minimal. When he arrived at a control he would be informed what control number it was. If he strayed outside of the boundaries of the course he was informed that he was out of bounds. He was also given periodic time hacks informing him how much time he had remaining in the hour.

Participants progressed from control to control in sequence. On a few occasions participants accidentally found a control out of sequence. They were reminded that finding this control out of sequence did not count and that they would have to return to this same control in the proper sequence later in the course. Instances of map and/or compass checks were logged into the 130 where they occurred.

The test phase concluded when the participant found the "finish control" or the allotted hour expired. At that point, a direct route was taken back to the start point and we immediately returned to NPS for debrief. Commute time to and from NPS was approximately 10 minutes each way.

While the data was downloaded trom the 130, the participant filled out a debrief questionnaire (see Appendix K). VE participants filled out an additional questionnaire (see Appendix L). Once the DGPS data had been overlaid on the aerial photo within the computer, the participant was debriefed on their course run. Unless the participant did something unusual, the focus of the debrief was on deviations from planned route and frequency and location of map and/or compass checks. The entire debrief was recorded on a micro cassette. A complete list of the equipment used in this study can be found in Appendix M.

B. MEASURING WIDELY VARYING PERFORMANCE

As previously alluded to, performance measurement would be a function of three items. In order for a participant to be awarded a perfect result, he would have to perform to the following standards during the test phase:

1. Find all nine controls in sequence within one hour or less.
2. Stay on his marked route within the route tolerances outlined in the Inbrief
3. Perform items one and two without need of map or compass.

With this as the benchmark for perfect performance, measuring that performance was accomplished by direct observation and through using the tools previously described in the Implementation Chapter. However, it became apparent that in the case of a participant not finishing the course, a numerical penalty proportional to what the participant did not succeed in finding, and taking into consideration the relative performance of other participants, would have to be developed. Otherwise much statistical comparison across the duration of the course was not possible.

In developing the penalty scheme, it was decided to insure that the penalties that a participant received for failing to find a control(s) by running out of time (I called this a *default error*) was not in excess of those penalties that the participant had acquired while actively looking for controls while still within the allotted hour (I called these *active errors*). This scheme was meant to be on the conservative side, by not speculating that the participant would do much worse than the average of the worst performing treatment group for that control on which he would be awarded default error. On the other hand, the failure to find a control could not be ignored, and the penalty should be at least in part, quantifiable by what the participant had planned to do but failed to accomplish. With this in mind, the following scheme was developed with *default errors* to account for when a participant had failed to finish the course for lack of time:

1. Control on which the participant was on, but failed to find before time expired

a) Default Map and Map/Compass Checks

1. Use only those map and map/compass checks that the participant actually made.
2. Do not assign any more to the participant as a consequence of their default.

The rationale here was that it is difficult to speculate on when and where a participant will ask to see the map and/or compass. This fact, in conjunction with the possibility that the participant could well be on their route and know exactly where they are going (the errors that put them in this predicament are from previous controls), makes assigning additional map and compass check penalties harsher then what is needed to at least put this participants performance on this control into relation with other participants (this is accomplished with the distance off route measure).

On the other hand, the participant could see time expire while still looking for this control which they have committed the bulk of their map and compass checks errors on (they are lost). In this situation additional penalty map and compass checks will not be needed for statistical impact, as the participant has likely already done that actively.

b) Default Distance Off Route

When time expired, the participant was either on or off their planned route. In the former case the Default Distance Off Route penalty will be simply measuring the rest of their planned route into the control which they did not actually walk and assigning that as their distance off route. In the later case, the participant is already off their route. Depending on whether that person was on road or off road when time expired dictated the path that was drawn to link their ending location with their original planned route. Normally, this was the most direct route from their ending location to put them back on their original route. The cumulative distance of the inferred route and their remaining planned route became the distance off route penalty for that control.

c) Default Error

An error under normal conditions (actively committed), is nothing more than a deviation from the planned route. Data analysis revealed that their were no instances where a participant deviated from their route, returned to it, and stayed on it a while, and then deviated once more. Once a participant deviated from their original route, they did not ever return to it and deviate once more. Thus, there are only instances of one recorded error per control. So if a person had deviated from their route and then time expired they were assigned the one error as they would have been otherwise. If the participant had not deviated from their route, they were still assigned an error since they had failed to complete their planned route before time expired.

2. Controls that the participant was not allowed to attempt because time had expired

a) Default Map and Map/Compass Checks

In this instance, the participant is not allowed to proceed onto this control(s) since time expired. In order to insure that this participant's group was not rewarded for his failure to make it to this control(s) map/compass checks were assigned that were equal to the average of the treatment group(s) with the highest average map and map/compass checks. If this average was not a whole number, then it was rounded up to the nearest whole number and that number was assigned to the participant. As an example: If participant A had failed to get to controls eight and nine for lack of time then the *highest treatment group(s)* averages for map and map/compass checks for those controls (lets say for control eight; .6 map checks, 0 map/compass checks and control nine; 1.3 map checks, .4 map/compass checks). After rounding, the numbers assigned to this participant would be 1 and 0 for control eight's checks, and 2 and 1 for control nine's checks.

b) Default Distance Off Route

This was fairly straightforward as the participant had never even begun this control(s). Their planned route for the missed control was carefully measured, and since they had failed to walk any of it, they had obviously been off route here. Their planned route distance was assigned as their distance off route.

c) Default Error

This also was a straightforward assignment. Since this was also a deviation (the participant had not even begun to walk his planned route for this control) and all other observed deviations had amounted to one per control, it was easy to justify assigning the participant an error for his failure to reach this control.

3. Summary

The validity of the preceding penalizing method for participants that fail to find and/or begin to look for controls is bore out by the numbers contained in the raw data for Checks (see Table 1) and Total Distance Off Route (see Table 2).

Participant #	Study Group	Ability	Controls Attempted	Controls Found	% Controls Found	Active Map Checks	Default Map Checks	Total Map Checks	Active Map w/Compass Checks	Default Map w/Compass Checks	Total Map w/ Compass Checks	Total Active Checks	Total Default Checks	Total Checks	Active % of Total Checks
4	Control	Advanced	9	9	100%	1	0	1	0	0	0	1	0	1	100%
5	RW	Advanced	9	9	100%	2	0	2	0	0	0	2	0	2	100%
10	VE	Advanced	9	9	100%	8	0	8	0	0	0	8	0	8	100%
8	Control	Beginner	9	9	100%	1	0	1	0	0	0	1	0	1	100%
1	RW	Beginner	2	1	11%	8	12	20	0	8	8	8	20	28	29%
6	VE	Beginner	6	5	55%	9	4	13	0	2	2	9	6	15	60%
3	Control	Intermediate	7	6	66%	10	3	13	1	1	2	11	4	15	73%
12	Control	Intermediate	8	7	77%	5	3	8	10	1	11	15	4	19	79%
13	Control	Intermediate	4	3	33%	6	6	12	18	3	21	24	9	33	73%
2	RW	Intermediate	9	9	100%	8	0	8	0	0	0	8	0	8	100%
11	RW	Intermediate	9	9	100%	0	0	0	0	0	0	0	0	0	100%
15	RW	Intermediate	9	9	100%	3	0	3	0	0	0	3	0	3	100%
7	VE	Intermediate	9	8	89%	12	0	12	0	0	0	12	0	12	100%
9	VE	Intermediate	9	9	100%	7	0	7	0	0	0	7	0	7	100%
14	VE	Intermediate	9	9	100%	1	0	1	0	0	0	1	0	1	100%
Avg Control			7.4	6.8	75%	6	2	7	6.8	1	6.8	10.4	3.4	13.8	85%
Avg VE			8.4	8	89%	7	1	8.2	0	0.4	0.4	7.4	1.2	8.6	92%
Avg RW			7.6	7.4	82%	4	2	6.6	0	1.6	1.6	4.2	4	8.2	86%

Table 1. Controls Found vs Active and Default Checks

Participant #	Study Group	Ability	Controls Attempted	Controls Found	% Controls Found	Active Errors	Default Errors	Total Errors	Active Distance off Route	Default Distance off Route	Total Distance Off-Route	Active % of Total Distance off Route
4	Control	Advanced	9	9	100%	1	0	1	234	0	234	100%
5	RW	Advanced	9	9	100%	2	0	2	480	0	480	100%
10	VE	Advanced	9	9	100%	5	0	5	1127	0	1127	100%
8	Control	Beginner	9	9	100%	4	0	4	2129	0	2129	100%
1	RW	Beginner	2	1	11%	2	7	9	2800	1426	4226	66%
6	VE	Beginner	6	5	55%	2	3	5	1364	1896	3260	42%
3	Control	Intermediate	7	6	66%	6	2	8	1397	1358	2755	51%
12	Control	Intermediate	8	7	77%	5	1	6	2483	757	3240	77%
13	Control	Intermediate	4	3	33%	3	5	8	2037	2141	4178	49%
2	RW	Intermediate	9	9	100%	7	0	7	1688	0	1688	100%
11	RW	Intermediate	9	9	100%	1	0	1	282	0	282	100%
15	RW	Intermediate	9	9	100%	2	0	2	1318	0	1318	100%
7	VE	Intermediate	9	8	89%	5	1	6	1642	105	1747	94%
9	VE	Intermediate	9	9	100%	4	0	4	1491	0	1491	100%
14	VE	Intermediate	9	9	100%	3	0	3	962	0	962	100%
Avg Control			7.4	6.8	75%	3.8	1.8	5.4	1858	651.2	2507	76%
Avg VE			8.4	8	89%	3.8	0.8	4.6	1317.2	400.2	1717	87%
Avg RW			7.6	7.4	82%	2.8	1.4	4.2	1313.6	285.2	1599	93%

Table 2. Controls Found vs. Active and Default Distance Off Route

VII. RESULTS

The results described here are a two-way MANOVA of ability and study group on individual dependent variables. The graphs in this section indicate the CG as Control, and the RW and VE groups as they have been previously labeled. Error bars indicate the standard deviation for each group. Successful training transfer is best illustrated by superior performance in the testing phase of the experiment. The three training conditions are compared across multiple factors to determine if the VE condition was effective as compared to the alternative training methods.

A. TOTAL CHECKS

Study group had little effect on Total Checks (P=.7928, F=.241, df=2). The relationship between ability and Total Checks (P=.1836, F=2.278, df=2) is unclear (see Figure 5).

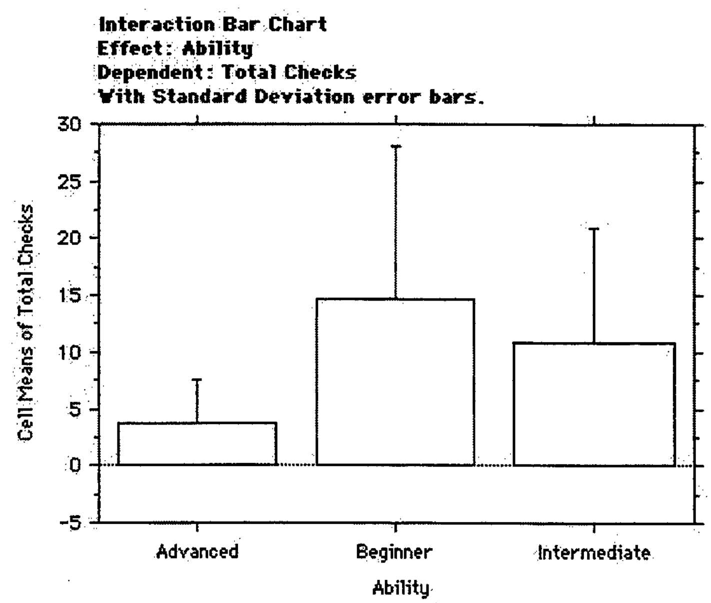


Figure 5. Ability Group and Total Checks (Active and Default)

However, there was an interaction between study group and ability on Total Checks (P=.0363, F=5.270, df=4, see Figure 6). Increased confidence for the RW, through training in the actual environment, leads to fewer map checks. As expected the CG seems the least confident. What is interesting though is the proximity of the VE to the RW group within the larger sample size of the intermediate ability group.

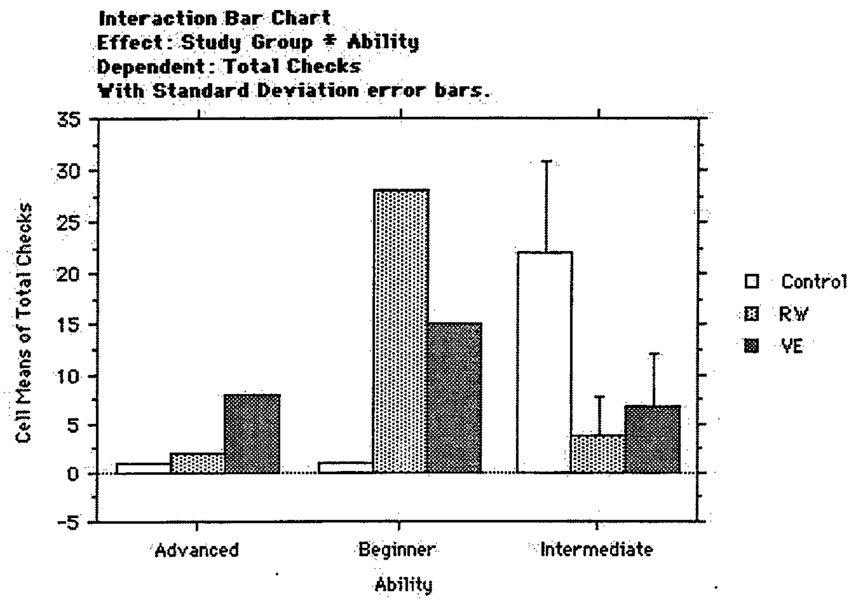


Figure 6. Total Map/Compass Checks over Entire Course

B. TOTAL DISTANCE OFF ROUTE

Similarly, the results for study group and Total Distance Off Route shows little effect (P=.9994, F=.001, df=2). However, this time there is a pronounced effect for Ability on Total Distance Off Route (P=.0073, F=12.450, df=2, see Figure 7).

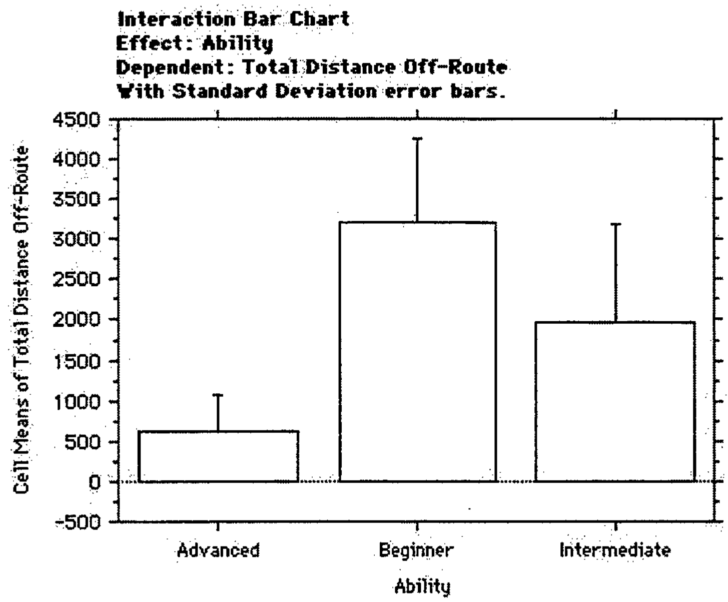


Figure 7. Total Distance Off Route by Ability Group

As in Total Checks, there is a pronounced interaction between ability and study group on Total Distance Off Route (P=.0285, F=5.874, df=2, see Figure 8).

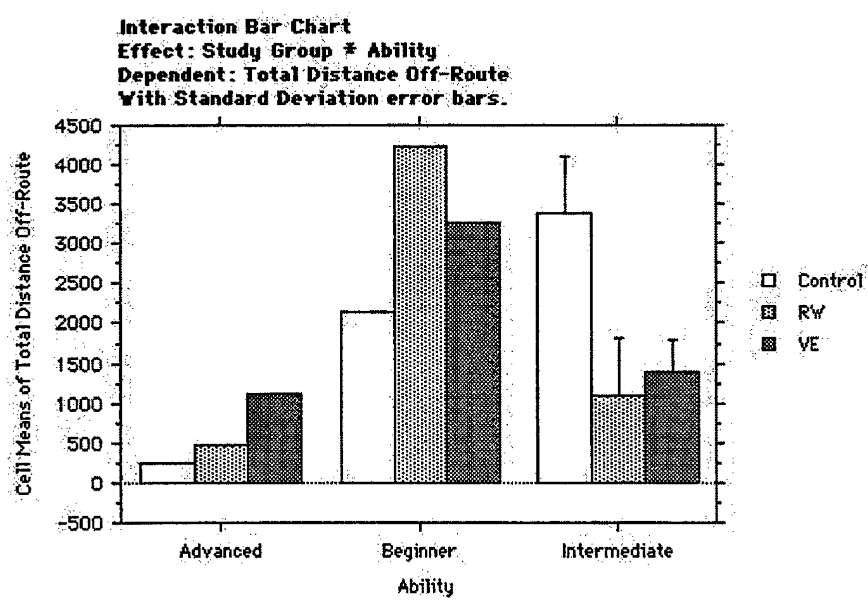


Figure 8. Total Distance Off Route Over Entire Course by Study and Ability Groups

There was no unusual behavior regarding the number of checks a participant made in relation to the distance they were off their route. As one would expect, the farther a participant perceived he was off his route, the more likely he was going to make a check (P=.0001, F=70.033, df=1, see Figure 9).

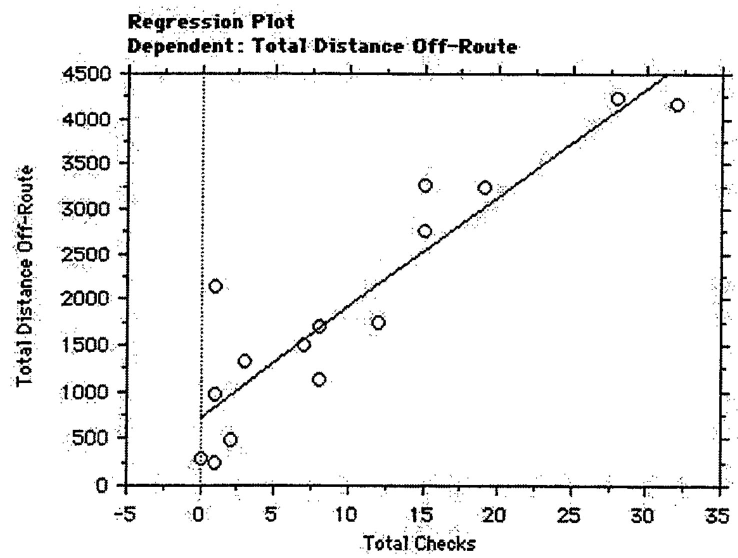


Figure 9. Number of Checks as Related to Distance Off Route

Preliminary indications are that the real world condition may exhibit high performance across ability levels through most of the testing phase (see Figure 10). But performance may

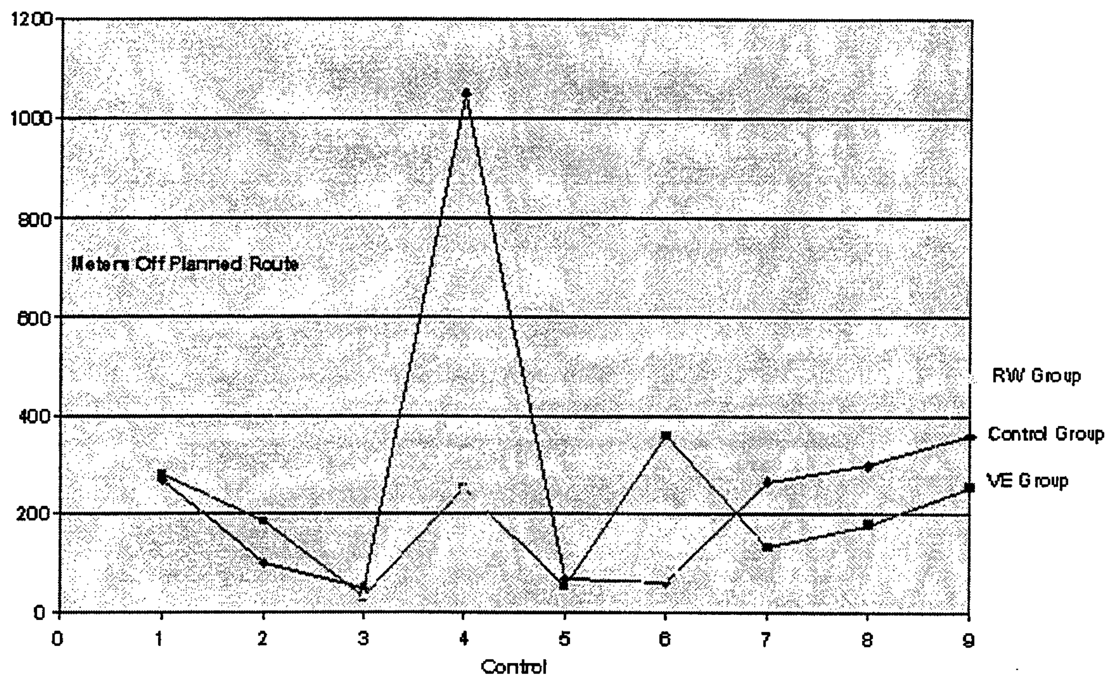


Figure 10. Treatment Group Distance Off Route by Control

drop off dramatically over time because these participants may have had more difficulties during the training phase in covering the entire course. The tendency of the more skilled participant to catch his error earlier is confirmed (P=.0854, F=3.812, df=2) by the Total Distance Off Route divided by the number of instances of deviation off that route (see Figure 11). Advanced participants caught their errors faster then all other ability groups and corrected them resulting in less deviation off of planned route. Beginners were the slowest to catch and correct their route deviations.

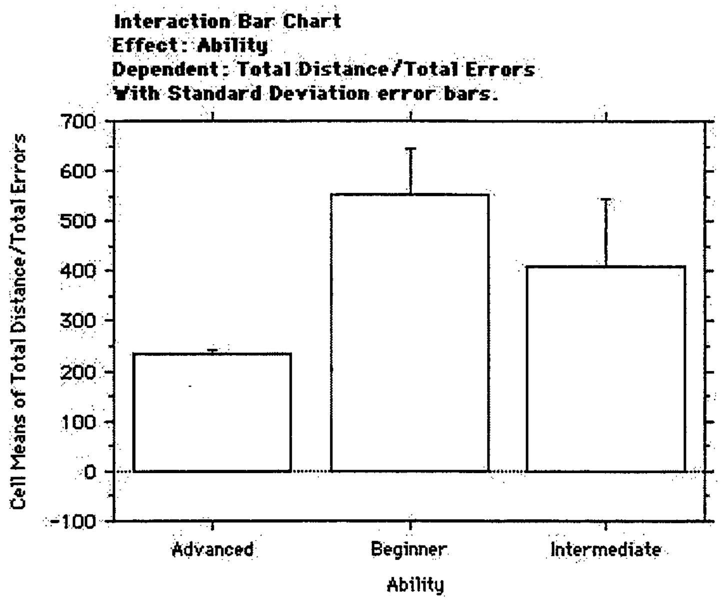


Figure 11. Ability's Influence on Error Detection and Correction

C. TOTAL ERRORS

Study group's effect on Total Errors, which again were a measurement of discrete instances of deviation from planned route, was not significant (P=.8508, F= .166, df=2). There was a weak effect for ability on Total Errors (P=.2019, F=2.114, df=2) and a modest interaction between ability and study group on Total Errors (P=.1421, F=2.6, df=4, see Figure 12).

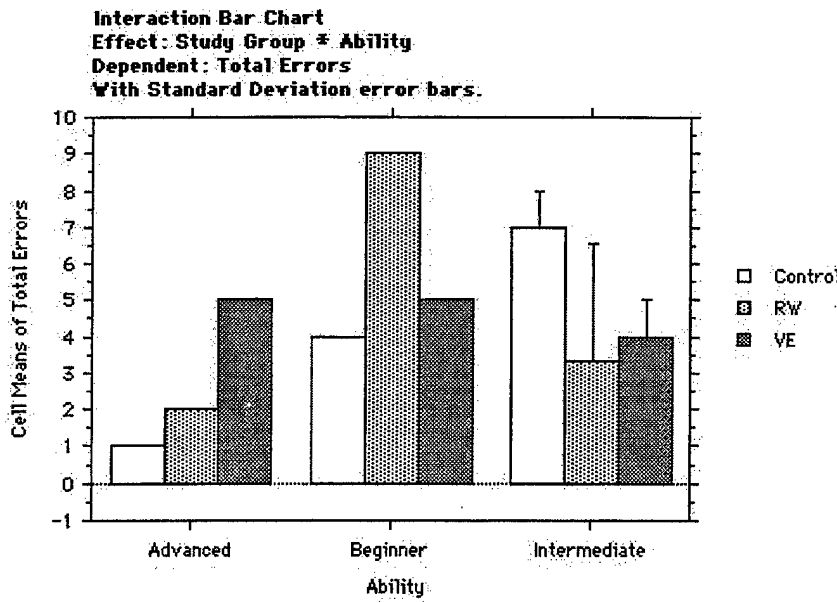


Figure 12. Total Errors and Interaction between Ability and Study Groups

D. CONFIDENCE

Confidence may be inferred by an examination of Planned Routes and their relative difficulty. Under most circumstances the most direct route to a control was the most aggressive. There was little effect between ability and aggressiveness of Planned Route (P=0.9241, F=0.080, df=2, see Figure 13).

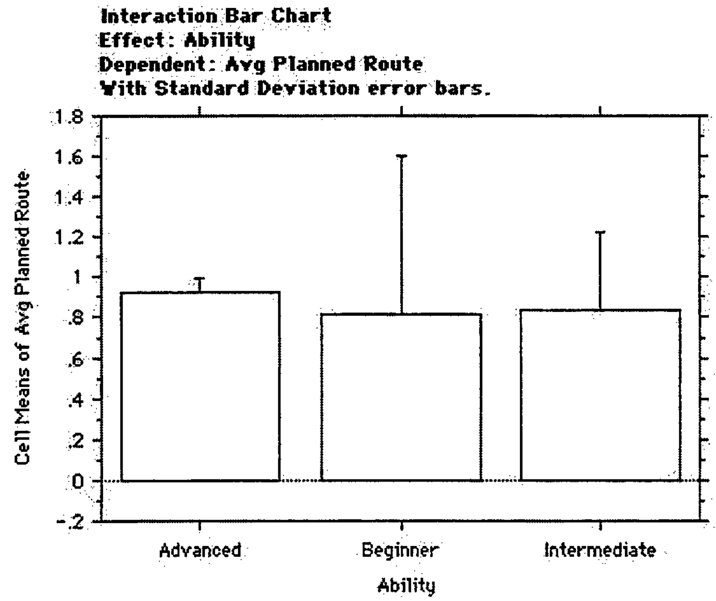


Figure 13. Aggressiveness of Planned Route by Ability Group

Training condition modestly effected Planned Route was by (P=0.136 F=2.834, df=2, see Figure 14) and showed that the real world participants felt more confident than others and consequently planned more aggressive routes.

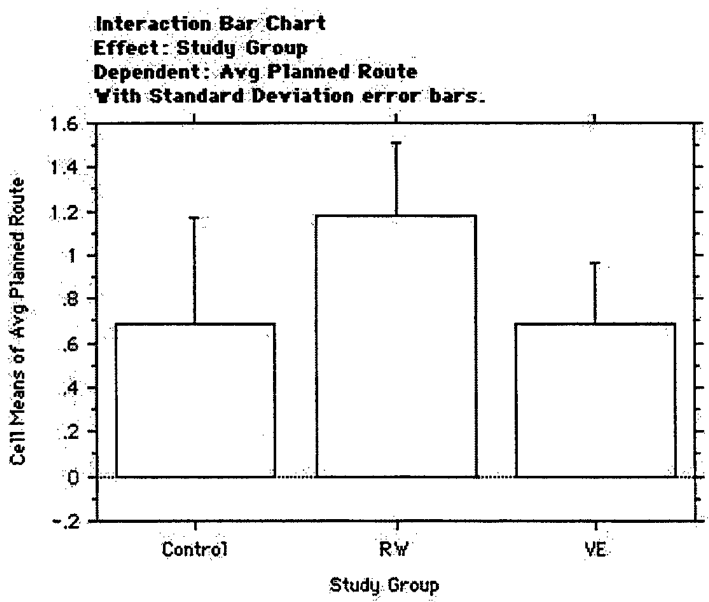


Figure 14. Aggressiveness of Planned Route by Study Group

On the other hand over confidence created by having seen and planned most of the course at a manageable pace with direct aggressive routes, leads to an overly aggressive route being selected for a control(s) when there is not enough time to familiarize oneself with the route(s) to the same degree that was done earlier in the course. So for those participants who hastily completed the end of the course during training in the real world condition, the latter part of the testing phase was even more difficult than the map only treatment group who would have carefully planned a more conservative route consistent with earlier routes (see Figure 15 for aggressiveness of route and Figure 10 for distance off route).

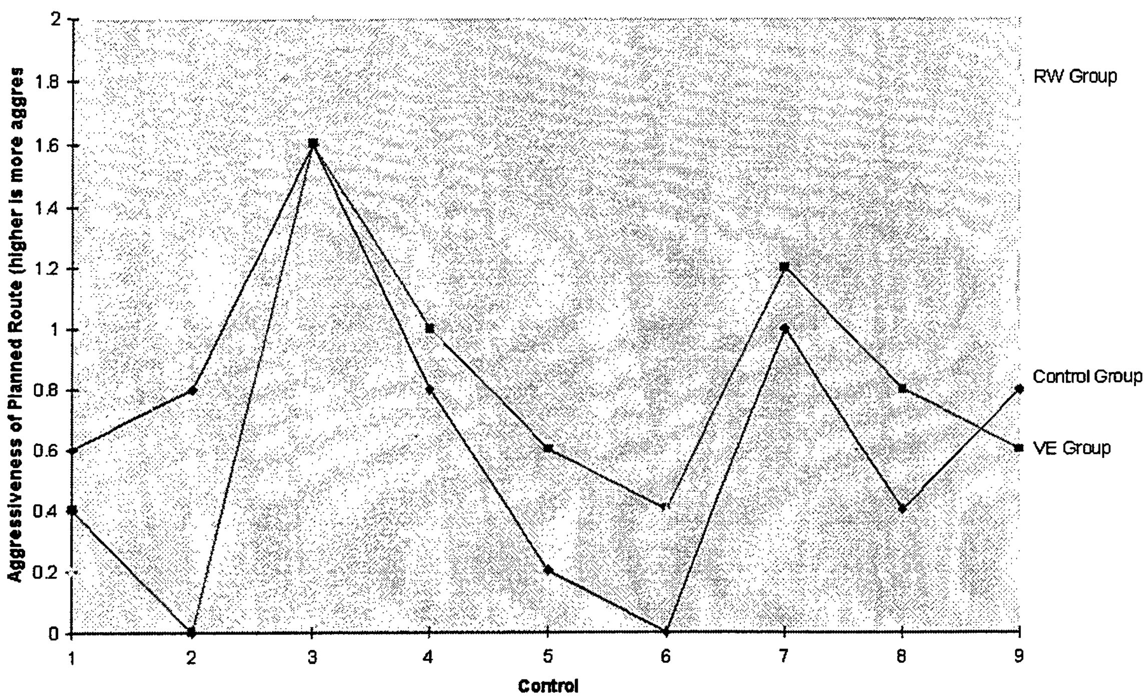


Figure 15. Aggressiveness of Planned Route by Control

Anecdotal comments by participants while doing the course and in the later debrief show route choice is a complex function of confidence, experience, and perceived difficulty. Its influence on performance is not clear here, with participant comments shedding some light (see Discussion), but it is an area that requires further study.

VIII. DISCUSSION

The fact that ability level had a greater effect on performance than training method is no surprise. Previous studies by the Army Research Institute have documented this fact. The criteria used to qualify an advanced participant effectively restricts this classification to people who for sake of their highly specialized skills, experience, and recent continual practice could be considered "professionals". These criteria restrict the advanced ability group to a very small subset within the set of people who can use map and compass to navigate. This includes all military personnel who though they may have received extensive training and later practice, are not trained to do the type of fine detailed map reading and precise navigation required in this study.

This is not alarming as it is assumed that the target audience for this work (even highly trained special operations personnel) would be considered intermediates and beginners by this classification scheme. However, it facilitated comparison to have a high bench mark to show what was possible among a group of highly trained and experienced people. The ability of participant four to have navigated the course with such skill after studying the map for less than an hour was amazing. This skill, it was later found out through conversation with another member of participant four's Orienteering Club, is regarded as exceptional within his club. The ability to take a two dimensional representation, identify the relevant cues in which to plan a precise route, and then walk that route within the previously described tolerances while having to make only one map check and only one error over 2,000 meters is extraordinary. No other participant in the Control Group approached this performance, and with one exception, the same could be said for the well trained Real World Group. This skill level represents an unusual ability and not likely a skill level that could be duplicated with training (since equally well trained and experienced participants from that participant's Orienteering Club do not match this his map assimilation skill).

Advanced participants make fewer errors and are better able to recover from them once made. This is likely due to their ability to use redundancy in navigational cues. While beginners might use one cue to distinguish a route change point, an expert will likely have a hierarchy of cues with which he checks at every route change point. There will be the primary cue that confirms vicinity, closely followed by supporting cues that confirm that the primary cue truly indicates that this is the desired point. This redundancy allows for greater error checking and by continual checking while on the new route, quick identification of errors are made once they occur. This reduces the most common error, the parallel error, which beginners are apt to make repeatedly.

The course was set such that there were numerous opportunities to make parallel errors. As expected, many of the errors observed were of this type. It is not clear whether or not the VE helped prevent this type of error. It is suspected that that this VE was of marginal utility in preventing parallel errors. In part this is due to the "hole" view aspect limitation of the VE, which precluded seamless and rapid reorientation to many viewpoints surrounding the likely parallel errors on a given control, and the fact that most intermediate participants were not sophisticated enough to consciously plan routes to avoid making a parallel error.

The VE clearly precluded misinterpretation of map symbols. This was determined in the debrief and is most evident on control four (see participant's 3 and 12's maps in Appendix N). Since the VE portrays the terrain in three dimensions, no VE participant made the same error made by at least two Control Group participants. This error was a misreading of the contour lines (the depression containing control 4 was read as a hilltop). It could be argued that this depression is poorly represented by lack of prominent tick marks on the lowest contour line. However, this error was not made by the advanced or the beginner participants. This underscores the fact that maps by their higher level of abstraction and reliance on symbols, are much easier to misinterpret than a three dimensional representation, especially when there is a time constraint, and the work load is non-trivial.

The RW condition did not do as well as anticipated. I suspect this to be a function of two things:

1. That by having to walk the course and plan for the subsequent test, time compression occurred on the last two controls. As previously mentioned this led to planning judgment errors where an overly aggressive route was planned in context with the amount of time remaining to commit that route to memory.

2. By having to actually "Orienteer" the course during the training phase (given the map immediately preceding the start of that phase) less experienced participants may not have taken the time to carefully study the map and choose a deliberate, carefully executed route in context with the unique information provided on the orienteering map.

This last condition was most manifest on participant one. Who though a beginner in orienteering, choose aggressive advanced level initial routes. This was due is in large measure to his preferred technique of using map and compass for dead reckoning routes to large easily identifiable features while hiking in the mountains. As previously discussed, this method is suitable for covering great distances where route precision and knowing exactly where you are at all the time is not required. However, when this method is employed against small features (like a 1x1 meter pit) on an unfamiliar finely detailed map, it is easy to walk right by the feature you are looking for or repeatedly misjudge distance. This is exactly what happened to participant one who never was able to find control 2. His usual method of moving around more in the hope of bumping into the control (feature) did not work.

Participant one also illustrates the connection between early failure in navigation, its influence on confidence, and in turn probability of later success. By failing to find control two within the first 15 minutes, participant one's confidence was shaken. Continued failure resulted in diminishing confidence where he began to question his analysis and ability to visualize the terrain. He was quite experienced in non-orienteering form of navigation described in the last paragraph, but early failure made him question his fundamental abilities in the test's context. His inability to recover from the early error and attempt a new method or gather a new appreciation for the map, was in many ways related to his diminishing confidence.

This is not an unusual phenomena, even advanced orienteers expect to go through an initial familiarization phase in which the information provided by the map is "fit" by direct experience to the actual environment. Early success creates confidence, which in turn positively influences the chance for future success. Conversely, early and protracted failure, can diminish confidence and lead to doubting map, and/or abilities in this new environment. Perhaps the VE by giving a 3D representation, used in conjunction with a map for training, can help reduce the learning curve in that initial map/environment correlation phase. Thus reducing the chance of early error and as important, increasing confidence before going into an unfamiliar environment where the fear of getting lost (especially upon first entering the environment) is very real for all ability levels.

The utilization of a VE with a map used to familiarize a navigator prior to going into the actual environment may actually improve performance since they require the development of a method or discipline in planning. In the case of the Real World Group, their opportunity to experience the environment directly while planning could foster a "I'll run there and see what I see enroute" plan which could be very inefficient and lead to many time wasting errors. As already indicated, their early success with aggressive direct routes later shaped their route choice for the final control, which for many of them due to a lack of time, was not experienced in the training phase to the same extant as earlier controls.

Habit is another potential vice that could be recognized and consciously accepted or rejected through training in a VE. One participant, a helicopter pilot, chose many direct routes in spite of the fact that he was part of the Control Group. What had worked for him as a pilot, where point to point navigation without much regard for minor ground features is normal, would not work on this course. Direct azimuths with pace, as participant one, and perhaps one or two features along the way for route confirmation, was not successful in a test such as this where an abundance of opportunities for parallel error would play havoc with anyone who did not foresee potential errors and sought to eliminate them through using multiple features for route confirmation. The VE could be provided with an intelligent tutor, which could appraise the environment within the context of what the user sought to do, and suggest various courses of action by displaying them and spotlighting the cues and those that have the potential to be mistaken for the correct cue.

IX. CONCLUSIONS

A sport orienteering study was presented that investigates the utility of VEs as a training tool for natural environment familiarization beyond what is possible with a map alone. In conclusion:

1. Ability level is more important to navigation performance than training method.
2. Intermediate users benefit more from the VE training method than either advanced or beginner users.
3. The VE allows for time compression in training, allowing more area to be traversed in a shorter amount of time than would be possible in physical reality.

It's believed that the VE allows intermediate users to develop more redundancy in the cues they use while navigating. Anecdotally, this was confirmed by some intermediate participants who remembered using the small grove of large oak trees immediately beyond control 4 as their reference point for finding that control. Their less developed ability to visualize the terrain directly from a map is where the VE has its greatest impact in making vivid what otherwise might be overlooked or even omitted on a map.

Advanced orienteers have such highly developed abilities in terrain visualization from maps that the VE does not seem to offer them much that they do not already possess. However, the increased workload on such a participant by having to navigate through a VE and refer back to a much more familiar map, may impair their performance. The one advanced participant, who did the VE, remarked that is was helpful for visualizing the control within the context of its immediate surroundings, but not very helpful beyond that. Orienteering maps are very precise and allow experts to navigate by many cues simultaneously.

A. FUTURE WORK

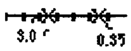
This study was not designed to answer all questions about the utility of VEs to navigation training in the natural environment. Having established that their is some utility to the properly scaled and configured natural environment VE, future work should look at how VEs can be optimized for training navigation and creating user familiarity, and where certain cases demand it, an almost complete user knowledge of the represented environment. This experiment should be extended by adding new conditions altering the fidelity of the interface as well as the environment itself. Also method of information presentation such as sequence, toggling features on and off, a built in compass that presents the user with the bearing where his view is currently directed, a measuring tool and virtual pedometer for facilitating distance to and traveled while in the VE are some of the technical improvements that could be made to improve training transfer.

The objective is to determine if the use of VEs is a practical augmentation to conventional map study techniques used by today's military. These early results encourage further investigation of VEs for navigation training towards the the development of usable systems that can be deployed in a variety of settings and application areas.

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

607 Out-of-bounds area
An out-of-bounds area, see also symbol 529, is drawn with vertical stipes.
Colour: purple.

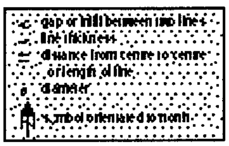
608 Dangerous area
An area presenting danger to a competitor
Colour: purple.



609 Forbidden route
A route which is out-of-bounds.
Colour: purple.

610 First aid post
The location of a first aid point.
Colour: purple.

611 Refreshment point
The location of a refreshment point which is not at a control.
Colour: purple.



International Specification for Orienteering Maps

1 INTRODUCTION

Orienteering is now a worldwide sport. A common approach to the interpretation and drawin
orienteering maps is essential for fair competition and for the future expansion of the sport. It is
aim of the International Specification for Orienteering Maps to provide a map specification which
accommodate the widely varying situations in different countries. These specifications should be r
in conjunction with the basic rules for orienteering competitions. Deviations are permissable only
the sanction of the national map committee. For international events and World Cup races s
sanction must be given by the IOF after consultation with the IOF Map Committee. There is a separ
specification for ski-orienteering maps.

2 GENERAL REQUIREMENTS

2.1 Orienteering and the map

Orienteering is a sport in which the runner completes a course of control points in the shortest poss
time, aided only by map and compass. As in all forms of sport, it is necessary to ensure that
conditions of competition are the same for all competitors. The more accurate the map, the better
can be done, and the greater the opportunity for the course planner to set a good and fair cours

From the competitors' point of view, a detailed and legible map is a reliable guide for choice of ro
and it enables him to navigate along a route chosen as suiting his navigational skill and running ab
However, skill in route choice loses all meaning if the map is not a true picture of the ground - if
inaccurate, out-of-date or of poor legibility.

Anything which bars progress is essential information - cliffs, water, dense thicket. The path and t
network shows where the going and navigation is easiest. A detailed classification of the degree
hindrance or good going helps the competitor to make the right decisions. Orienteering is first of a
navigate by map reading. An accurate map is therefore necessary for a good and effective route cho
No competitor should gain an advantage or suffer a disadvantage because of faults on the map

The aim of the course planner is a course where the deciding factor in the results will be navigat
skill. This can be achieved only if the map is sufficiently accurate, complete and reliable, and is
clear and legible under competition conditions. The better the map the course planner has, the gre
the chance he has of setting good, fair courses, whether for the elite or for the novice.

Great detail on the map offers the planner many features for controls, and hence enables him to cho
good legs, vary control sites and check that the controls are correctly placed on the map.

Controls are the most important building blocks of a course. Choice of sites, placing of the mark
checking their positions, and locating controls in competition, all put definite demands on the map.
map must give a complete, accurate and detailed picture of the terrain. For an international ever
must be up-to-date in all parts which could affect the end result of the competition. If it is not up-to-
it must be improved.

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

528 Settlement
Houses and gardens and other built up areas. Roads, buildings and other significant features within a settlement must be shown. If all buildings cannot be shown an alternative symbol (black line screen 33%, 25 l/cm) may be used.
Colour: green 50% and yellow 100%.

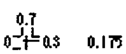
529 Permanently out of bounds
Areas which are permanently forbidden to the runner are shown as out of bounds. The screen is superimposed on the normal map detail. A bounding line may be drawn if there is no natural boundary.
Colour: black or purple.

530 Parking area
A paved, asphalt or other surfaced area for parking or other purposes.
Colour: black and brown 50 - 100% (40 lines/cm).

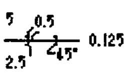
531 Ruin
The ground plan of a ruin is shown to scale, down to the minimum size shown opposite. Very small ruins may be drawn with a solid line.
Colour: black.

532 Sports track
The plan of a sports track is shown to scale with yellow superimposed.
Colour: black with yellow and/or brown.

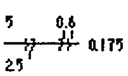
533 Firing range
A firing range is shown with a special symbol to indicate the need for caution. Associated buildings are individually marked.
Colour: black.



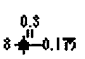
534 Grave
A distinct grave marked by a stone or shrine. Location is at the centre of gravity of the symbol, which is orientated to north. A cemetery is shown by using grave symbols as space permits.
Colour: black.



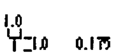
535 Crossable pipeline
A pipeline (gas, water, oil, etc.) above ground level which can be crossed over or under.
Colour: black.



536 Uncrossable pipeline
A pipeline which cannot be crossed.
Colour: black.



537 High tower
A high tower standing above the level of the surrounding forest. Location is at the centre of gravity of the symbol.
Colour: black.



538 Small tower
An obvious shooting platform or seat, or small tower (or a trig. point in some countries). Location is at the centre of gravity of the symbol.
Colour: black.

Absolute height accuracy is of little significance on an orienteering map. On the other hand, important that the map shows as correctly as possible the relative height difference between ne bouring features.

Accurate representation of shape is of great importance for the runner, because a correct, detailed sometimes exaggerated picture of the landform is an essential precondition for map reading. Howe the inclusion of a lot of small detail must not disguise the overall shapes. Drawing accuracy is of prim importance to any map user because it is closely connected with the reliability of the final map.

As a general rule, these specifications should be followed closely. However, when drawing a surve feature, consideration must be given to its immediate surroundings, and in order to improve legit deviations from the specified line widths can be tolerated - see section 3.2.

2.4 Generalisation and legibility

Good orienteering terrain contains a large number and a great variety of features. Those which most essential for the runner in competition must be selected and presented on the orienteering m To achieve this, in such a way that the map is legible and easy to interpret, cartographic generalise must be employed. There are two phases of generalisation - selective generalisation and gra generalisation.

Selective generalisation is the decision as to which details and features should be presented on map. Two important considerations contribute to this decision - the importance of the feature from runners' point of view and its influence on the legibility of the map. These two considerations sometimes be incompatible, but the demand for legibility must never be relaxed in order to preser excess of small details and features on the map. Therefore it will be necessary at the survey stag adopt minimum sizes for many types of detail. These minimum sizes may vary somewhat from one t to another according to the amount of detail in question. However, consistency is one of the r important qualities of the orienteering map, and therefore the same selective criteria must be u throughout the map.

Graphic generalisation can greatly affect the clarity of the map. Simplification, displacement exaggeration are used to this end.

Legibility requires that the size of symbols, line thicknesses and spacing between lines be base the perception of normal sight in daylight. In devising symbols, all factors except the distance betw neighbouring symbols are considered.

The size of the smallest feature which will appear on the map depends partly on the graphic qual of the symbol (shape, format and colour) and partly on the position of neighbouring symbols. Immediately neighbouring features, which take up more space on the map than on the ground, essential that the correct relationships between these and other nearby features are also maintai

3 MAP SPECIFICATION

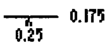
3.1 Scale and vertical interval

The scale for an orienteering map is 1:15,000 with a 5m contour interval. In flat terrain a contour inte of 2.5m may be used.

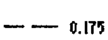
APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

505 Vehicle track
A track or poorly maintained road suitable for vehicles only when travelling slowly. Width less than ca 3 m.
Colour: black.

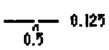
506 Footpath
A large path, or old vehicle track, which is distinct on the ground.
Colour: black.



507 Small path
A small path or (temporary) forest extraction track which can be followed at competition speed.
Colour: black.



508 Less distinct small path
A less distinct small path or forestry extraction track.
Colour: black.



509 Narrow ride
A distinct ride, less than ca. 5 m wide. A ride is a linear break in the forest (usually plantation) which does not have a distinct path along it. Where there is a path along a ride, symbols 507 or 508 should be used in place of symbol 509.
Colour: black.

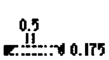
510 Visible path junction
When a path junction or intersection of paths or tracks is visible, the dashes of the symbols are joined at the junction.
Colour: black.

511 Footbridge
A footbridge with no path leading to it.
Colour: black.

512 Crossing point with bridge
A path or track crossing a river, stream or ditch by a bridge.
Colour: black.

513 Crossing point without bridge
A path or track crossing a river, stream or ditch without a bridge; a ford.
Colour: black.

514 Indistinct junction
When a junction of paths or tracks is not clear, the dashes of the symbols are not joined.
Colour: black.



515 Wide ride
A ride or firebreak, wider than 5 m. The edges are shown with the symbol for a vegetation boundary (416). The appropriate yellow or green screen should be used to fill in between the dotted lines for open or overgrown rides respectively.
Colour: black and yellow or green.

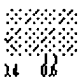
SYMBOL				1:15,000		1:7,500		
no.		Colour	%	Lines		LT	NT	Dimensions
116	Broken ground	brown	-	-	∗	88	270	ø0.35-0.1, r
210	Stony ground	black	-	-	∗	n.a.	251	ø0.25-0.35, r
211	Sandy ground	black	10	24/cm	s	8	27-10	ø0.35, s0.9, a
		yellow	50	40/cm	s	33	50-50	
212	Bare rock	black	30	54/cm	s	32	65-30	
301	Lake in fill	blue	50-100	40/cm	s	33	50-50	
309	Uncrossable marsh	blue	50	20/cm	∗	213	1010-50	t0.9, s1.0
310	Marsh	blue	33	27/cm	∗	69	326	t0.25, s0.75
311	Indistinct marsh	blue	-		∗	121	272	t0.25, s0.85
								d1.8, g0.5
401	Open land	yellow	100					
402	Open with scattered trees	yellow	50	16/cm	∗	n.a.	1160	ø0.8, s1.2, a4
403	Rough open	yellow	50	40/cm	s	33	50-50	
404	Rough open scattered trees	yellow	50	40/cm	s	33	50-50	
		+white	50	16/cm	∗	n.a.	n.a.	ø0.8, s1.2, a4
406	Forest: slow run	green	20	40/cm	s	30	50-20	
407	Undergrowth: slow run	green	17	13/cm	∗	67	334	t0.25, s1.5
408	Forest: difficult to run	green	50	40/cm	s	33	50-50	
409	Undergrowth: difficult to run	green	33	27/cm	∗	69	954	t0.25, s0.75
410	Vegetation: impassable	green	100					
412	Orchard	green	25	12/cm	·	911	315	ø0.9, s1.6
		yellow	100					
413	Vineyard	yellow	100					
		green	-		∗		315	t0.4, s1.7
								d2.5, g1.2
415	Cultivated land	yellow	100					
		+black	5		∗	919	205	ø0.3, s1.8
501	Road infill	brown	50	40/cm	s	33	50-50	t2.25, t1.75
502	"	"	"	"	s	"	"	t1.5, t1.0
503	"	"	"	"	s	"	"	t1.5, t0.6
528	Settlement	yellow	100					
		+green	50	40/cm	s	33	50-50	
	alternative	black	33	27/cm	s	69	326	t0.25, s0.75
529	Out of bounds	black	33	13/cm	s	324	326	t0.5, s1.5
530	Parking area	brown	50	40/cm	s	33	50-50	

\+ standard commercial photographic screen
∗ special o-screen - available from IOF Map Committee through Harvey's

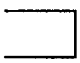
LT indicates a Letratone screen
NT indicates a Normatone screen

t = line thickness
ø = diameter
s = space between centres
d = dash length
g = gap
r = random dots

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS



404 Rough open land with scattered trees
Where there are scattered trees in rough open land, areas of white (or green) should appear in the tone. Such an area may be generalised by using a regular pattern of large white dots in the yellow screen.
Colour: yellow 50% (40 lines/cm), white 50% (16.75 lines/cm).

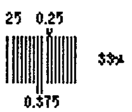


405 Forest: easy running
Open forest where there is no hindrance to the runner
Colour: white.

406 Forest: slow running
An area with dense trees (low visibility) which reduces running to ca. 50 - 80% of normal speed.
Colour: green 20% (40 lines/cm).

407 Undergrowth: slow running
An area of dense undergrowth but otherwise good visibility (brambles, heather, low bushes, and including cut branches) which reduces running to ca. 50 - 80% of normal speed. This symbol may not be combined with 406 or 408.
Colour: green 17% (13 lines/cm).

408 Forest: difficult to run
An area with dense trees or thicket (low visibility) which reduce running to ca. 10 - 50% of normal speed.
Colour: green 50% (40 lines/cm).



409 Undergrowth: difficult to run
An area of dense undergrowth but otherwise good visibility (brambles, heather, low bushes, and including cut branches) which reduces running to ca. 10 - 50% of normal speed. This symbol may not be combined with 406 or 408.
Colour: green 33% (27 lines/cm).

410 Vegetation: very difficult to run, impassable
An area of dense vegetation (trees or undergrowth) which is barely passable. Running reduced to ca. 0 - 10% of normal speed.
Colour: green 100%.

411 Forest runnable in one direction
When an area of forest provides good running in one direction but less good in others, white stripes are left in the screen symbol to show the direction of good running.
Colour: green.

412 Orchard
Land planted with fruit trees, bushes.
Colour: yellow 100% and green 25% (12 lines/cm).

413 Vineyard
The lines may be orientated to show the direction of planting.
Colour: yellow 100% and green.

4 EXPLANATION OF SYMBOLS

Definitions of map features and specifications for the drawing of symbols are given in the follo sections. Symbols are classified into 6 categories -

Land forms	(brown)
Rock and boulders	(black)
Water and marsh	(blue)
Vegetation	(green + yellow)
Man-made features	(black)
Course symbols	(purple)

NOTE: dimensions are specified in mm at the scale of 1:15,000. All drawings are at 1:7,500 for clarity only.

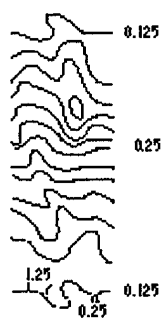
gap or limit between two lin
line thickness
distance from centre to cen
of length of line
diameter
symbol orientated to north

4.1 Land forms

The shape of land is shown by means of very detailed contours, aided by the special symbols for s knolls, depressions, etc. This is complemented in black by the symbols for rock and cliffs. Orientee terrain is normally best represented with a 5m contour interval. An interval of 2.5m may be necess in certain types of terrain. It is not permissible to use different intervals on the same map.

Excessive use of form lines should be avoided as this will complicate the map and give a w impression of height differences. If the representation of an area needs a large number of form li a smaller contour interval provides a more legible alternative.

The relative height difference between neighbouring features must be represented on the ma accurately as possible. Absolute height accuracy is of less importance. It is permissible to alter height of a contour slightly if this will improve the representation of a feature. This deviation should normally exceed 25% of the contour interval and attention must be paid to neighbouring feature



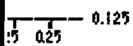
101 Contour
A line joining points of equal height. The standard vertical interval betw contours is 5 metres.
Colour: brown.

102 Index contour
Every fifth contour should be drawn with a thicker line. This is an aid to quick assessment of height difference and the overall shape of the gro Where one of these contours coincides with an area of small knolls or dep sions, it may be shown with a normal contour line.
Colour: brown.

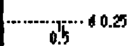
103 Form line
An intermediate contour line. Form lines are used where more information be given about the shape of the ground. They are used only where repres tation is not possible with ordinary contours. Only one form line may be u between neighbouring contours.
Colour: brown.

104 Slope line
Slope lines may be drawn on the lower side of a contour line, eg along the of a re-entrant or in a depression. They are used only where it is neces to clarify the fall of the ground.
Colour: brown.

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

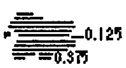


307 Minor water channel
A natural or man-made minor water channel which may contain water only intermittently.
Colour: blue.

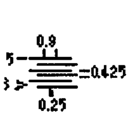


308 Narrow marsh
A marsh or trickle of water which is too narrow to be shown with symbol 310 (less than ca. 5m wide).
Colour: blue.

309 Uncrossable marsh
A marsh which is uncrossable or dangerous for the runner. A black line surrounds the symbol.
Colour: blue, black.



310 Marsh
A crossable marsh with a distinct edge. Symbol 310 may be combined with symbol 403 for clearly open marshes. For densely wooded marshes symbol 310 may be combined with symbols 406-410. The smallest marsh should be shown by at least two lines on the map.
Colour: blue (with yellow/green).



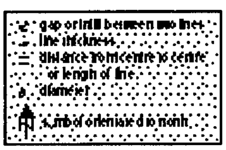
311 Indistinct marsh
An indistinct or seasonal marsh or area of gradual transition from marsh to firm ground, which is crossable. The edge is generally indistinct and the vegetation similar to that of the surrounding ground. Symbol 311 may be combined with symbol 403 for clearly open but indistinct marshes. There may be occasions where it is appropriate to use symbol 311 with symbol 401. For densely wooded marshes symbol 311 may be combined with the symbols 406-410.
Colour: blue (with yellow/green).

312 Well
Wells and captive springs, which are clearly visible on the ground.
Colour: blue.

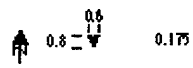
313 Spring
The source of a stream with a distinct outflow. The symbol is orientated to open downstream.
Colour: blue.

314 Special water feature
A special small water feature. The definition of the symbol must always be given in the map legend.
Colour: blue.

...TE: dimensions are specified in mm at the scale of 1:15,000. All drawings are at 1:7,500 for clarity only.

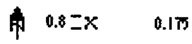


114 Small depression
Small shallow natural depressions and hollows (minimum diameter 2m) w... cannot be shown to scale by contours are represented by a semicircle. M... mum depth from the surrounding ground should be 1m. Location is the ce... of gravity of the symbol, which is orientated to north. Symbol 115 is use... man-made pits.
Colour: brown.

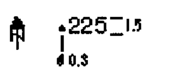


115 Pit
Pits and holes with distinct steep sides which cannot be shown to scal... symbol 106 (minimum diameter 2m). Pits with any other shape than r... should be shown by contours. Minimum depth from the surrounding gr... should be 1m. Location is the centre of gravity of the symbol which is or... tated to north.
Colour: brown.

116 Broken ground
An area of pits or knolls which is too intricate to be shown in detail. The den... of dots may vary according to the detail on the ground.
Colour: brown.



117 Special landform feature
This symbol can be used for a special small landform feature. The defin... of the symbol must be given in the map legend.
Colour: brown.



118 Spot height
Spot heights are used for the rough assessment of height differences. ... height is given to the nearest metre. The figures are orientated to the n... Water levels are given without the dot.
Colour: black.

4.2 Rock and boulders

NOTE: dimensions are specified in mm at the scale of 1:15,000. All drawings are at 1:7,500 for clarity only.

Rock is a special category of land form. The inclusion of rock gives us information about danger and runnability, as well as providing features for map reading and control points. Rock is shown in black to distinguish it from landforms features. The outline of the symbol should accurately represent the shape of the rock face projected on a horizontal plane. Care must be take... make sure that rock features such as cliffs agree with the shape and fall o... ground shown by contours or form lines.

201 Impassable cliff
An impassable cliff, quarry or earth bank (see 106) is shown with a 0.3... line and downward tags showing its full extent from the top line to the foot... tags may be omitted if space is short, eg. narrow passages between cliffs (... passage should be drawn with a width of at least 0.3 mm). The tags ... extend over an area symbol representing detail immediately below the ... face. When a rock face drops straight into water making it impossible to ... under the cliff along the water's edge, the bank line is omitted or the ... should clearly extend over the bank line.
Colour: black.

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

202 Rock pillars/cliffs
In the case of unusual features such as rock pillars or massive cliffs or gigantic boulders, the rocks may be shown in plan shape without tags. Actual size may vary according to the height of the rock.
Colour: black.

203 Passable rock face
A small vertical rock face (minimum height 1m) is shown without tags. If the direction of fall of the rock face is not apparent from the contours, short tags should be drawn in the direction of the fall.
Colour: black.

204 Rocky pit
Rocky pits, holes or mineshafts which may constitute a danger to the runner. Location is the centre of gravity of the symbol, which is orientated to north.
Colour: black.

205 Cave
A cave is represented by the same symbol as a rocky pit. In this case the symbol should be orientated to the slope as indicated opposite. The centre of gravity of the symbol marks the opening.
Colour: black.

206 Boulder
A small distinct boulder (minimum height 1m). Every boulder marked on the map should be immediately identifiable on the ground.
Colour: black.

207 Large boulder
A particularly large and distinct boulder.
Colour: black.

208 Boulder field
An area which is covered with so many blocks of stone that they cannot be marked individually is shown with solid non-equilateral triangles. A minimum of two triangles should be used (one only if used with other rock features). The going is indicated by the density of the triangles.
Colour: black.

209 Boulder cluster
A small distinct group of boulders so closely clustered together that they cannot be marked individually. The symbol is an equilateral triangle orientated to the north.
Colour: black.

210 Stony ground
Stony or rocky ground which affects going should be shown on the map. The dots should be randomly distributed with density according to the amount of rock. For large areas a screen may be used (see table p.7)
Colour: black.

211 Open sandy ground
An area of soft sandy ground or gravel with no vegetation and where runn is slow. Where an area of sandy ground is open but running is good, it is sh as open land (401/402).
Colour: black 10% (24 lines/cm) and yellow 50% (40 lines/cm).

212 Bare rock
A flat area of rock without earth or vegetation is shown as bare rock. An a of rock covered with grass, moss or other low vegetation is shown as c land (401/402).
Colour: black 30% (54 lines/cm) or grey.

4.3 Water and marsh

NOTE: dimensions are specified in mm at the scale of 1:15,000. All drawings are at 1:7,500 for clarity only.

This group includes both open water and special types of vegetation cau by the presence of water (marsh). The classification is important becau indicates the degree of hindrance to the runner and provide features for reading and control points. A black line round a water feature indicates th cannot be crossed under normal weather conditions. In dry countries features listed in this section may only contain water in some seasons.

301 Lake
Large areas of water are shown with full colour or a dot screen of at least 5 Small areas of water should be shown with full colour. A black bank indicates that the feature cannot be crossed.
Colour: blue, black.

302 Pond
Where the lake or pond is smaller than 1mm² on the printed map, the bank is omitted.
Colour: blue.

303 Waterhole
A water-filled pit or an area of water which is too small to be shown to sc Location is the centre of gravity of the symbol, which is orientated to no
Colour: blue.

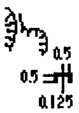
304 Uncrossable river
An uncrossable river or canal is drawn with black bank lines. The bank l are broken at a ford.
Colour: blue, black.

305 Crossable watercourse
A crossable watercourse, minimum 2m wide. The width of watercourses c 5m wide should be shown to scale.
Colour: blue.

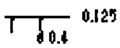
306 Crossable small watercourse
A crossable watercourse (including a major drainage ditch) less than wide.
Colour: blue.

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

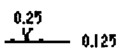
105 Contour value
Contour values are often included to aid assessment of large height differences. They are inserted in the index contours in positions where other detail is not obscured. The figures should be orientated so that the top of the figure is on the higher side of the contour.
Colour: brown.



106 Earth bank
A steep earth bank is an abrupt change in ground level which can be clearly distinguished from its surroundings, e.g. gravel or sand pits, road and railway cuttings or embankments. The tags should show the full extent of the slope, but may be omitted if two banks are close together. Impassable banks should be drawn with symbol 201 (impassable cliff).
Colour: brown.

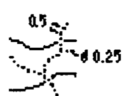


107 Earth wall
Distinct earth wall.
Colour: brown.

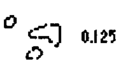


108 Small earth wall
A partly ruined earth wall may be shown with a dashed line.
Colour: brown.

109 Erosion gully
An erosion gully or trench which is too small to be shown by symbol 106 is shown by a single line. The line width reflects the size of the gully. Minimum depth 1m. The end of the line is pointed.
Colour: brown.

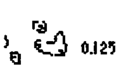


110 Small erosion gully
A small erosion gully or trench. Minimum depth 0.5m.
Colour: brown.



111 Knoll
Knolls are shown with contour lines. A prominent knoll falling between contour lines may still be represented by a contour line if the deviation from the actual contour level is less than 25%. Smaller or flatter knolls should be shown with form lines.
Colour: brown.

112 Small knoll
A small obvious mound or rocky knoll which cannot be drawn to scale with a contour (diameter of mound less than ca. 5m). Knolls of any other shape than round should be shown by contours. The height of the knoll should be a minimum of 1m from the surrounding ground.
Colour: brown.



113 Depression
Depressions are shown with contours or form lines and slope lines. Prominent depressions falling between contour lines may be represented by a contour line if the deviation from the actual contour level is less than 25%. Smaller or shallower depressions should be shown by form lines.
Colour: brown.

4.4 Vegetation

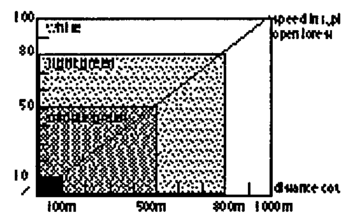
The representation of vegetation is important to the orienteer because it affects runnability and it provides features for map reading.

COLOUR
The basic principle is as follows:
- white represents runnable forest
- yellow represents open areas divided into several categories.
- green represents the density of the forest according to its runnability and is divided into sev categories.

RUNNABILITY
White represents typically open runnable forest for the particular type of terrain. If no part of the fo is runnable then no white should appear on the map.
The runnability depends on the nature of the forest (density of trees/brush wood and undergrou bracken, brambles, nettles, etc.) but does not take account of marshes, stony ground etc. which shown by separate symbols.

Runnability in forest is divided into 4 categories according to running speed. If speed through typically open runnable forest is, for example, 5 min/km, the following ratios apply:

open forest	80-100%	5 - 6m 15s/km
slow run	50-80%	6m 15s - 10m/km
difficult to run	10-50%	10 - 50 min/km
fight	0-10%	>50 min/km



NOTE: dimensions are specified in mm at the scale of 1:15,000. All drawings are at 1:7,500 for clarity only.

401 Open land
Cultivated land, fields, meadows, grassland, etc. without trees, offering g running.
Colour: yellow.

402 Open land with scattered trees
Meadows with scattered trees or bushes, with grass or similar ground c offering easy running. Very small areas are shown as open land (401).
Colour: yellow 50% (16.75 lines/cm).

403 Rough open land
Heath, moorland, felled areas, newly planted areas (trees lower than ca. or other generally open land with rough ground vegetation, heather or grass. Symbol 403 may be combined with symbols 407 and 409 to sh reduced runnability.
Colour: yellow 50% (40 lines/cm).

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

Printing

…enteering map must be printed on good, possibly water resistant, paper (weigh 180 - 120 gsm). …e in up to 6 colours depending on the cartography and the nature of the terrain it covers.

…l care must be taken to ensure an exact register of colours. On a map printed in several colours …urse planner must have the opportunity to check the register via superimposed crosses in the …nt colours. The maximum acceptable error is 0.2 mm.

…ity depends on the correct choice of colours. The following recommendations are intended to …rdize maps as much as possible. The alternative colour given can be used in preference to the …mended colours, since the ultimate choice of colour also depends on the structure of the terrain. …commendations are given in the PMS system (Pantone Matching System).

Colour	PMS number	Alternative
Black	Process black	
Brown	471	
Yellow	136	122, 129
Blue	299	
Green	361	
Grey	428	427
Violet	Purple	

…arger scale maps

…at 1:10,000 may be produced for two reasons, (a) for greater legibility or (b) for special types …ain.

Maps where greater legibility is required

…may be maps of small areas to be used for training, for introductory and school events. They …competition maps for older and younger age groups where reading the lines and small symbols …es a problem.

…maps must be drawn with lines, line screens and symbol dimensions 50% greater than those …r 1:15,000 maps. Where practical the same dot screens as used at 1:15,000 will give the most …map and are therefore to be preferred. In practice drawing the artwork at 1:7,500 for reduction …,000 will give the correct dimensions if the same artwork is reduced to 1:10,000. It may be more …al and cheaper to produce a 1:10,000 version by enlarging the 1:15,000 film negatives/positives.

…10,000 maps the spacing of grid lines should be 25mm which represents 250m on the ground.

…ation there is usually a progression of scales from 1:2,500 to 1:5,000 to 1:10,000. Maps at very …cales such as 1:2,500 will clearly contain more detail such as playground equipment. Line …sions for 1:10,000 maps should also be used for these maps.

Special terrain

…eptional cases, where terrain is extremely complex and it is not possible to draw the essential …at 1:15,000, a 1:10,000 map drawn with 1:15,000 dimensions is permissible. For international …the use of larger scales must be approved by the IOF.

0.125

414 Distinct cultivation boundary
The boundary of cultivated land when not shown with other symbols (le… wall, path, etc.) is shown with a black line. A permanent boundary betw… different types of cultivated land is also shown with this symbol.
Colour: black.

0.25 0.8 100% YELLOW BLACK

415 Cultivated land
Cultivated land which is seasonally out-of-bounds due to growing crops … be shown with a black dot screen.
Colour: yellow 100%, black 5%.

0.175 0.5

416 Distinct vegetation boundary
A distinct forest edge or very distinct vegetation boundary within the for…
Colour: black.

417 Indistinct vegetation boundary
Indistinct boundaries between areas of green, yellow or white are sh… without a line. The edge of the area is shown only by the change in colo… dot screen.

0.8 0.8 0.175

418, 419 Special vegetation features
Symbols 418 and 419 can be used for special small vegetation features. … definition of the symbol must be given in the map legend.
Colour: green.

4.5 Man-made features

NOTE: dimensions are specified in mm at the scale of 1:15,000. All drawings are at 1:7,500 for clarity.

The track network provides important information for the runner and the c… sification must be clearly recognisable on the map. Particularly importan… the competitor is the classification of smaller paths. Account must be taker… only of the width, but also of how obvious the path is to the runner. Other man-made features are also important both for map reading anc… control points.

0.175 0.37

501 Motorway
A road with two high ways for the use of motor traffic only. The space betw… the black lines must be filled with brown (50-100%).
Colour: black and brown 50-100% (40 lines/cm).

0.175 0.57

502 Major road
Road wider than 5 m. The space between the black lines must be filled … brown (50-100%). A road under construction (symbols 501, 502 and … may be shown with broken lines.
Colour: black and brown 50-100% (40 lines/cm).

0.175 0.37

503 Minor road
Road 3 - 5m wide. The space between the black lines must be filled … brown (50-100%).
Colour: black and brown 50-100% (40 lines/cm).

0.35

504 Road
A maintained road suitable for motor vehicles in all weather less than 3m …
Colour: black.

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

imensions of map symbols

ommended that an orienteering map is surveyed and drawn at 1:7,500 - twice the printing scale.
reduction ratios may be used. When scribing, a 1:1 ratio is normal.
isions in this book are given at the printed scale of 1:15,000.

e widths are based on the micronorm pen sizes. All line widths and symbol dimensions must
d within 20% of their specified value. Deviations from the nominal value must only be used to
e legibility. Certain minimum dimensions must also be observed. These are based on both
g technology and the need for legibility.

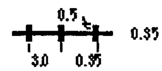
IUM DIMENSIONS
gap between two fine lines of the same colour, in brown or black: 0.15 mm.
smallest gap between two blue lines: 0.25 mm.
test rock face symbol: 0.6 mm
test stream or ditch symbol: 0.6 mm.
test bend in contour (spur or reentrant): 0.25 mm (from centre to centre of the lines).
test area of marsh: at least two lines with a length of 0.5 mm.
test dotted line: at least two dots.
test dashed line: at least two dashes.
test area enclosed by a dotted line: 1.5 mm (diameter) with 5 dots.
test area of colour
Blue, green, grey or yellow full colour: 0.5 mm^2
Black dot screen: 0.5 mm^2
Blue, green or yellow dot screen: 1.0 mm^2

tures smaller than the dimensions above must be either exaggerated or omitted, depending on
er or not they are of significance to the orienteer. When a feature is enlarged, neighbouring
es must be displaced so that the correct relative positions are maintained.

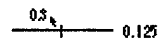
ENS
ation, open areas, marshes, etc. are shown with dot or line screens. The following two tables list
rmissible combinations of screens and the commercial availability of screens to meet the
cations. Some countries have produced special orienteering screens.

O Permitted combinations

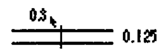
	116 Broken ground	210 Ston., ground	309 Uncrossable marsh	310 Marsh	311 Indistinct marsh	401 Open land	402 Open land, scattered trees	403 Rough open land	404 ... with scattered trees	406 Forest, slow run	407 Undergrowth, slow run	408 Forest, difficult to run	409 Undergrowth, difficult	410 Vegetation, light
roken ground														
ton, ground														
ncrossable marsh														
larsh														
idistinct marsh		O												
pen land					O									
pen land, scattered trees		O			O									
ough open land	O	O		O	O									
... with scattered trees	O	O		O	O									
orest, slow run	O	O		O	O									
ndergrowth, slow run	O	O		O	O			O	O					
orest, difficult to run	O	O		O	O									
ndergrowth, difficult to run	O	O		O	O			O	O					
egetation, light	O	O		O	O									



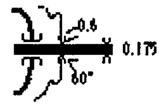
516 Railway
A railway or other kind of railed track (tram way, truck way, etc.).
Colour: black.



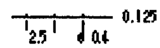
517 Power line
Power line, cable way or skilift. The bars indicate the exact location of pylons.
Colour: black.



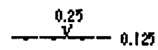
518 Major power line
Major power lines should be drawn with a double line.
Colour: black.



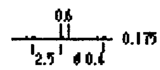
519 Tunnel
A way under roads, railways, etc. which may be used by the runner. ' symbol is used whether or not the tunnel has a track leading to it.
Colour: black.



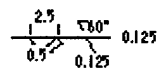
520 Stone wall
A stone wall or stone-faced bank.
Colour: black.



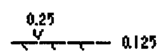
521 Ruined stone wall
A ruined stone wall may be shown by a dashed line.
Colour: black.



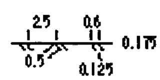
522 High stone wall
A stone wall higher than ca 1.5m, not crossable to the average orientee
Colour: black.



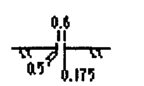
523 Fence
A wooden or wire fence less than ca. 1.5 m high.
Colour: black.



524 Ruined fence
A ruined fence may be shown with a dashed line.
Colour: black.



525 High fence
A boarded or wire fence higher than ca 1.5m, not crossable to the aver orienteer, eg. deer fence.
Colour: black.



526 Crossing point
All ways through or over high fences or walls must be indicated. The syn may also be used for a gate through or stile over a stone wall (520) or a fe (523).
Colour: black.

527 Building
A building is shown with its ground plan so far as the scale permits.
Colour: black.

APPENDIX A.
INTERNATIONAL SPECIFICATIONS FOR ORIENTEERING MAPS

e mapper, the task is knowing which features to map and how to represent them. A continuing ement in the sport is important for a basic understanding of the requirements for the orienteering its content, the need for accuracy, the level of detail and above all need for legibility.

Content

enteering map is a detailed topographic map. The map must contain the features which are s on the ground to a competitor at running speed. It must show every feature which could ce map reading or route choice - land forms, rock features, ground surface, runnability, main ses, hydrography, settlement and individual buildings, the path and track network, other lines of unication and features useful from the point of view of navigation.

ape of the ground is one of the most important aspects of an orienteering map. The correct use tours to show a three dimensional picture of the ground - shape and height difference - cannot eremphasised.

egree to which a feature is recognisable, the openness of the forest and runnability of the terrain l be taken into consideration at the survey stage.

laries between different types of ground surface provide valuable reference points for the map . It is important that the map shows the edges of areas of marsh, solid ground, boulder field, and it lines of rocky terrain.

bility and the openness of the terrain affect route choice and the running speed. Information on factors must therefore be shown on the map by classifying paths and tracks, by indicating er marshes, water features, rock faces and thick forest are passable, and by showing the bility on the ground surface and the presence of open areas. Clearly visible vegetation boundaries l also appear since they are useful for map reading.

ap must contain the features which are obvious on the ground and which are of value from the of view of map reading. An attempt must be made when surveying to maintain the clarity and ty of the map, i.e. the minimum dimensions designed for normal sight must not be forgotten when ng the degree of generalisation.

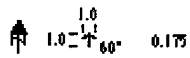
ap should contain some place names to help the competitor to orientate his map to north. Names l be written from west to east and placed to avoid obscuring important features. The style of ng should be simple.

h lines are black 0.125-0.175 mm lines pointing to magnetic north. Their spacing on the map should 33 mm which represents 500 m on the ground at the scale of 1:15 000. North lines may be broken obscure small features such as boulders, knolls, cliffs, stream junctions, path ends, etc. In ional cases blue 0.175 lines may be used. The sides of the map (paper) should be parallel to agnetic north lines. Arrowheads may be used to show magnetic north.

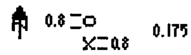
Accuracy

eneral rule should be that competitors shall not perceive any inaccuracy in the map. The acy of the map as a whole depends upon the accuracy of measurement (position, height and) and the accuracy of drawing. Accuracy of position on an orienteering map must be consistent at obtained by compass and pacing. A feature must be positioned with sufficient accuracy to e that a competitor using compass and pacing will perceive no discrepancy between map and l. In general a 5% accuracy in distance between neighbouring features will satisfy these require-

539 Cairn
Cairn, memorial stone or boundary stone (or a trig point in some count more than 0.5 m high.
Colour: black.



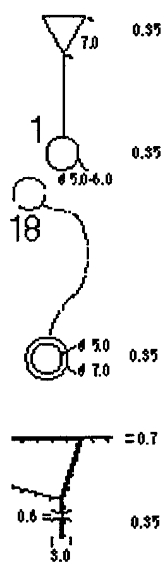
540 Fodder rack
A fodder rack which is free standing or built on to a tree. Location is a centre of gravity of the symbol. For land access reasons these may omitted.
Colour: black.



541,542 Special man-made features
Special man-made features are shown with these symbols. The definitio the symbols must be given in each case in the map legend.
Colour: black.

4.6 Overprinting symbols

Notes: all specified dimensions are in mm at the printed scale of 1:15,000. Drawing dimensions are at 1:15,000 also.



Courses should be overprinted at least for elite classes. For other clas they can be drawn by hand.

601 Start
The start or map issue point (if not at the start) is shown by an equila triangle which points in the direction of the first control. The centre of a tria or circle shows the precise position of the feature but it is not actually mar
Colour: purple.

602 Control point
The control points are shown with circles. The size of the circles shoul chosen to minimise interference with map detail around the controls. controls are numbered in order, with the figures orientated to the north. start, controls and finish are joined with lines in numerical order. Section the lines or circles should be omitted to leave important detail showing.
Colour: purple.

603 Marked route
A marked route is shown on the map with a dashed line.
Colour: purple.

604 Finish
The finish is shown by two concentric circles.
Colour: purple.

605 Uncrossable boundary
A boundary which it is not permitted to cross.
Colour: purple.

606 Crossing point
A crossing point through or over a wall or fence, or across a street or rail or a tunnel is drawn on the map with two lines curving outwards.
Colour: purple.

APPENDIX B.

ABILITY ASSESSMENT QUESTIONNAIRE

Virtual Environments and Navigation in Natural Environments Questionnaire

Name______________________

Age_______

Sex M / F

1. How many Orienteering Events have you participated in during your life (include military land navigation events)

    a. Less than 12
    b. Between 13 and 24
    c. Greater than 24

2. How many events have you participated in within the last year?

    a. Less than 12
    b. Between 13 and 24
    c. Greater than 24

3. What skill level would you consider yourself?

    a. Beginner - You navigate to a control mainly on well-traveled trails and fields. You go out of your way to be safe.

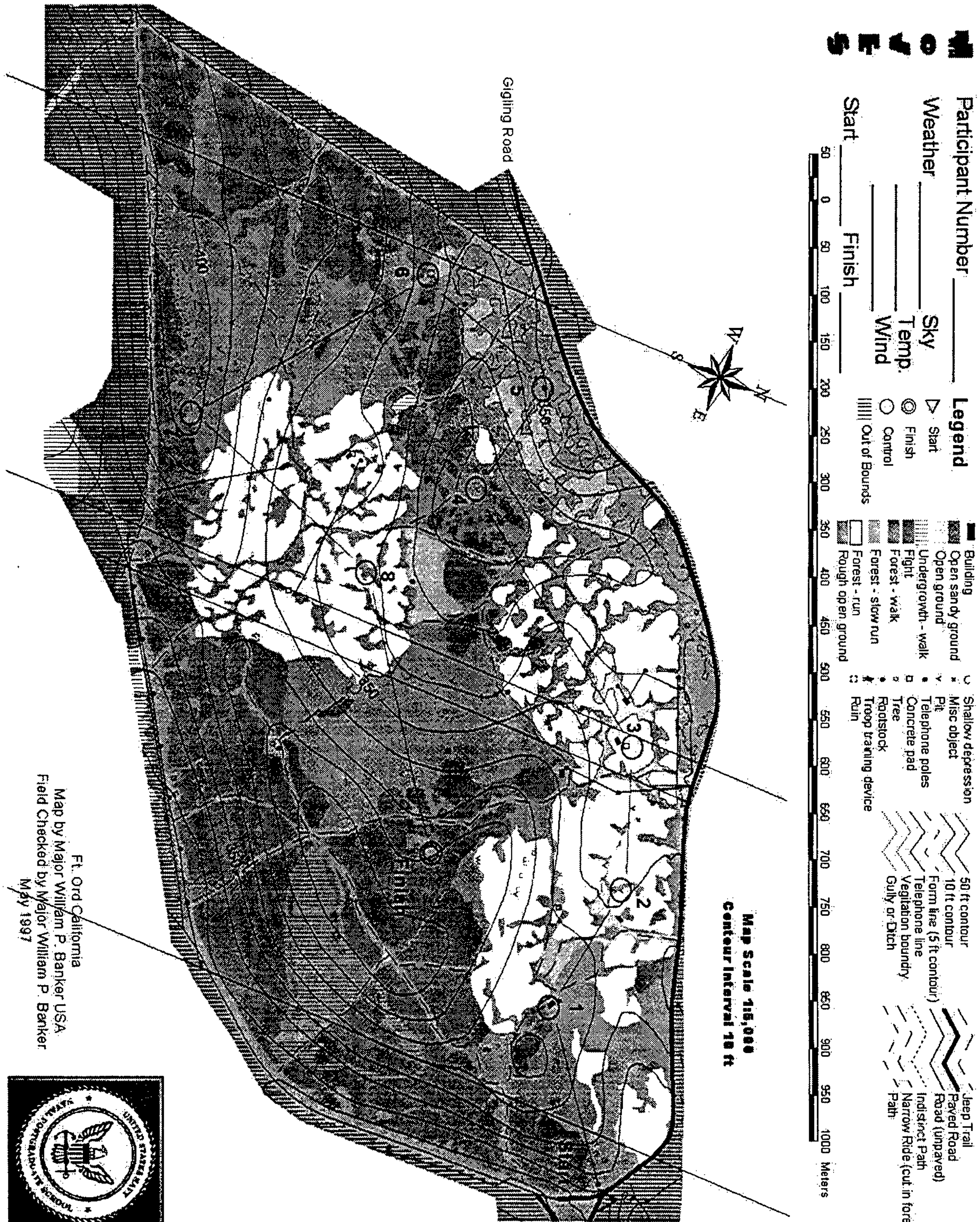
    b. Intermediate - Distinct handrails and catching features. You rely on very distinctive handrails (roads, trails, streams, ridges, etc.) to get you into the vicinity of the control and then rely on catching features (a prominent feature that alerts you as to where you are on your intended route). OR in the absence of handrails you rely on large catching features to get you into the control.
    c. Advanced - Catching features. You use handrails if available but more often you will use catching features of all types and size to guide you into the control.

4. If you are part of an official ranking system, how are you ranked?

5. Are you currently experiencing any health problems that may impair your performance today?

APPENDIX C.

PARTICIPANT MAP



APPENDIX D.

ORIENTEERING MAP LEGEND EXPLANATION

About the Orienteering Map

All maps are generalizations. They use symbols to portray actual features on the earth's surface. Not all features are represented with the same precision. Discrete non-vegetation items are plotted on the map in the exact location they are in the actual environment, whereas vegetation boundaries (unless indicated with a distinctive dotted line) are not meant to represent a clean break from one type of vegetation to another. Rather this line separating one vegetation area from another is a generalization of where one type more or less ends and another more or less begins. The line separating the two can best be thought of as a blurry line where the two types of vegetation intermingle. The below guide will help you determine the specific limitations of each symbol on the orienteering map.

Building - Buildings in the area are of several types:

a. Latrines - most common building, tan in color, approx. size 3 x 8 meters
b. Shelters - second most common building, green wood, roofed, no walls, approx. size 3 x 8 meters
c. Admin. - field office and shack, black with gold trim, 8 x 8 meters and 2 x 2 meters respectively

Open Sandy Ground - a significant patch of sand that will slow running

Open ground - dirt, hard pack, free of grass and other vegetation.

Undergrowth walk - immature chaparral or oak, dense stands of bushes, incomplete overlap of two distinct areas of fight which allow restricted passage along that overlap, other plants that prevent running.

Fight - mature chaparral or immature oak in such density that passage through is very difficult, running impossible

Forest walk - oak forest with patchy undergrowth, low lying tree limbs or tree density that prevents running from being sustained

Forest slow run - oak forest fairly free of undergrowth, but with low lying limbs or tree density that makes sustained running difficult.

Rough open ground - grass covered ground, possibly with scattered (avoidable) undergrowth. **Note that there are a few locations that have what appears to be old jeep trails but are portrayed as rough open ground. Sometimes the distinction between one or the other blurs. If in doubt refer to other more distinctive features (contour lines, etc.) to determine your location.**

Shallow depression - most likely an old decaying foxhole position or other man made excavation where the banks have eroded to create a bowl-like depression of 1 - 3 feet below surrounding ground.

Misc. object - a manmade feature, rubble, derelict military equipment, or other item whose exact description is only provided if it is the location of a control

Pit - an old foxhole or likely other man made pit that has steep vertical walls and may be reinforced with wood, depth from 2 - 5 ft. **Note that there will be many pits in the area that are not depicted on the map. The pits that are depicted are accurate.**

Telephone poles - wood poles (if bearing wire it will be noted on map) approx. 25 - 30 ft in height

Concrete pad - old concrete tent pad extending from 2 - 5 inches above ground level

Tree - a tree or large bush (could be two or more trees growing close together – forming an unbroken single canopy -- if the trees are small)

Rootstock - a dead or overturned tree

Troop training device - a bunker or other man made item built for training soldiers

Vegetation boundary - the edge of a vegetation type

Gully or Ditch - ranging from a shallow 1 ft deep gully to 5 ft deep military trench

Jeep Trail - a road more suitable for 4 x 4 vehicles due to width restriction and/or ruts. May be distinctive and worn or in some places overgrown with grass but still containing ruts.

Paved Road - a surfaced all weather road

Road - a sandy or dirt road wide and level enough for 2 wheel drive vehicles

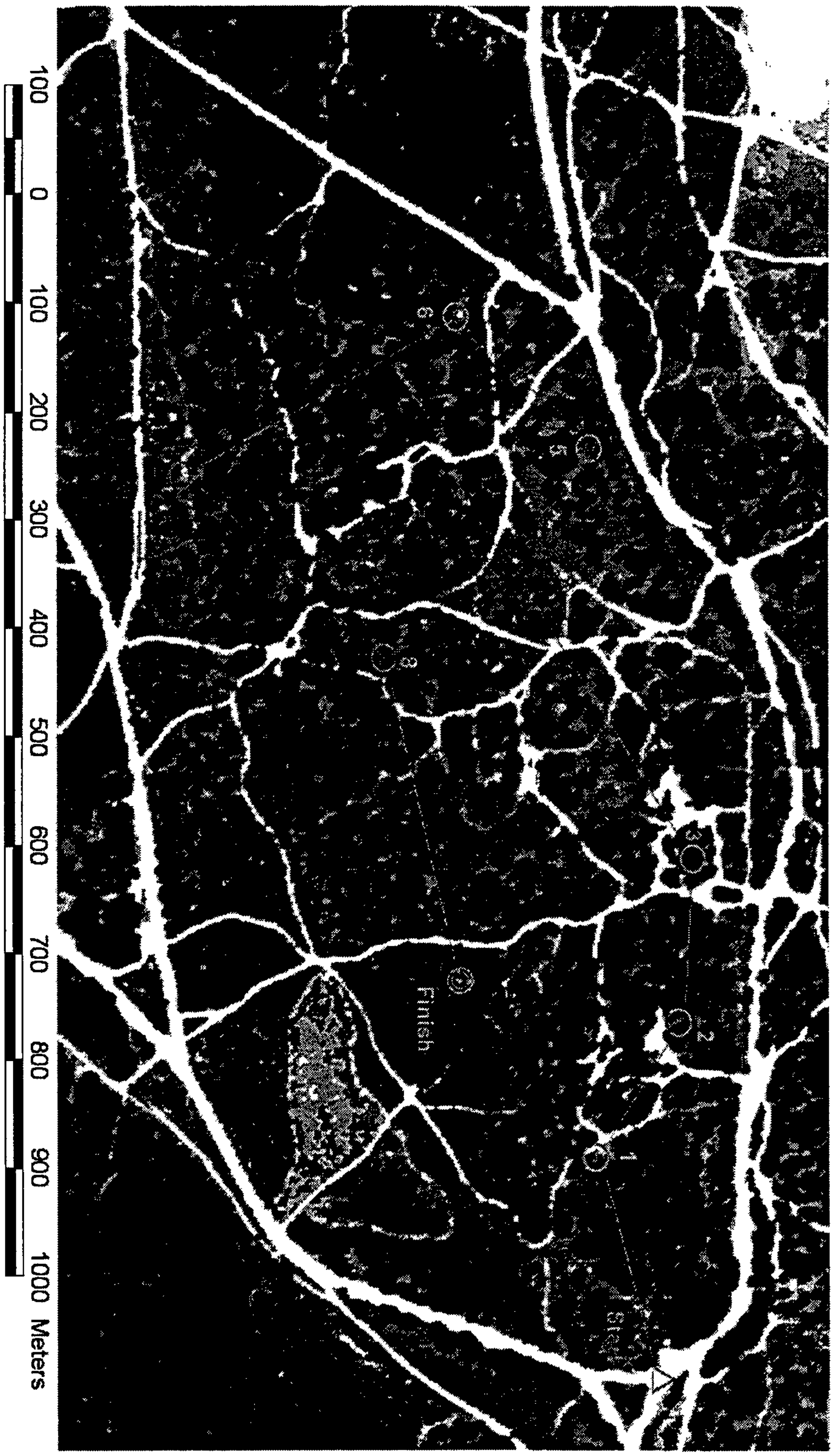
Indistinct Path - a path that is in the process of being overgrown with only intermittent marks on the ground that indicate that it was once a well traveled path

Narrow Ride - a linear break in the forest that may have once been a jeep trail but now is overgrown with grass and lacks telltale wheel ruts

Path - a foot or bike path.

APPENDIX E.

AERIAL PHOTOGRAPH OF COURSE AREA



APPENDIX F.

THE COURSE'S MOST PROBABLE ROUTES.

What follows below is an analysis of the some of the most probable routes to a given control. They do not represent the only ways of getting to a control but the most likely routes chosen by participants based upon my orienteering experience and knowledge of the terrain. They are listed to better illustrate Orienteering conventions such as handrails and catching features by putting them into the context of the course. They will also serve as a basis for comparison and discussion of the actual routes planned and later run by participants. As can be seen by the breakdown of routes, all controls possess at least one beginner's route. Intermediate and advanced routes are delineated from each other by the proportion of handrails to catching features. If there are more handrails as compared to catching features than the route is intermediate. The opposite is true if there are more catching features to handrails. When classifying routes taken by participants in the study, if an exact match for a participant's route could not be found from the below list then the route was examined within the context of its use of handrails (including what type) and catching features and assigned a route designation that correlated with the same level of difficulty for the routes on that control (beginner, intermediate, advanced).

A. Control 1.
   1. Beginner
      a) Gigling Road west to jeep trail
      b) Jeep Trail south by east by south to building
      c) Control on NW corner of building
   2. Beginner
      a) Watkin's Gate Cutoff to indistinct path.
      b) Indistinct path southwest up hill to jeep trail
      c) Jeep Trail west to building
      d) Control on NW corner of building
   3. Intermediate
      a) West through plotted individual trees (catching features)
      b) Handrail rough open ground south to junction indistinct path and jeep trail
      c) Jeep Trail west to building (catching feature)
      d) Control on NW corner of building
   4. Advanced
      a) West through plotted individual trees
      b) Follow runnable forest southwest
      c) Try to hit small rough open gap by keeping walkable forest to left shoulder
      d) use forest fight to west as catching feature if needed
      e) Control on NW corner of building
      f) Use jeep trail for catching feature if control is missed
   5. Advanced
      a) Go straight at control from start

B. Control 2.
   1. Beginner
      a) Jeep trail northwest to building
      b) Follow open ground to west and look for rough open clearing going northwest (handrail)
      c) Follow rough open clearing northwest looking for pit
      d) Control in pit

2. Intermediate
   a) Jeep trail northwest to building
   b) Go straight at control (WSW) from building

3. Advanced
   a) Set out on straight line directly for control
   b) Hit open ground and look for building on the right and rough open break on the left. (Catching feature)
   c) Follow rough open clearing northwest looking for pit
   d) Control in pit

C. Control 3.
1. Beginner
   a) Head northwest and get out onto Gigling Road
   b) Take Gigling Road west to jeep trail junction with telephone pole
   c) Take jeep trail southeast to convergence of two jeep trails
   d) Head southwest into tree grove looking for control
      (1) Use building as catching feature
      (2) Use open ground to west as backup catching feature
   e) Control hanging from tree limb
2. Advanced
   a) Head straight at control; use jeep trail prior to control as catching feature
   b) Head southwest into tree grove looking for control
      (1) Use building as catching feature
      (2) Use open ground to west as backup catching feature
   c) Control hanging from tree limb

D. Control 4.
1. Beginner
   a) Head southwesterly and try to get on jeep trail headed in same direction
   b) Take jeep trail to junction
   c) Take jeep trail southeast to junction
   d) Take southerly fork to next junction
   e) Take fork to northwest
   f) Once beyond patches of fight leave trail and start looking for control
   g) Control is in pit
2. Beginner
   a) Turn around and go back to jeep trail to the east
   b) Take jeep trail southwest to junction
   c) Take fork to the south to another junction
   d) Take fork to the west to next junction
   e) Take southerly fork to next junction
   f) Take fork to northwest
   g) Once beyond patches of fight leave trail and start looking for control
   h) Control is in pit
3. Intermediate
   a) Go south towards road junction
   b) Get on road and take to junction
   c) Take road west to other road junction
   d) Handrail around fight to west coming down through small patch of fight into control
4. Advanced
   a) Head straight at control expect to hit jeep trail that runs NW to SE (catching feature)
   b) Hit trail and then thread way through scattered fight

c) Emerge into center of depression and rough open ground, (catching feature) look for pit
d) Control is in pit

E. Control 5.

1. Beginner
   a) Move back out onto jeep trail
   b) Take trail west to trail junction
   c) Take trail WNW up to misc object
   d) From misc. object go straight at control
2. Intermediate
   a) Move directly at control
   b) Use Gigling Road as catching feature if miss on control
   c) Control is in center of clearing
3. Advanced
   a) Move directly at control
   b) Use southwesterly linear clearing as catching feature
   c) Follow clearing NW right into control
   d) Use Runnable forest along Gigling as catching feature in case of miss

F. Control 6.

1. Beginner
   a) Move out onto Gigling Road and take it westerly to junction with dirt road
   b) Move down dirt road (south) to junction with jeep trail
   c) Take jeep trail to east look for concrete rubble
   d) Move southeast through runnable forest
   e) Look for control on concrete pad
2. Beginner
   a) Move straight at control and hit jeep trail
   b) Go southwest on Jeep trail to junction with another jeep trail
   c) Take jeep trail westerly and look for concrete rubble
   d) Move southeast through runnable forest
   e) Look for control on concrete pad
3. Intermediate
   a) Move south to junction of two jeep trails (catching feature)
   b) Handrail jeep trail southeasterly to clearing (catching feature)
   c) Handrail clearing to the west
   d) Hit fight going west (catching feature) and move south
   e) Handrail fight (keeping it on right shoulder) into control
   f) Look for control on concrete pad

4. Advanced
   a) Move straight at concrete rubble (aiming off technique) use jeep trail as catching feature and handrail
   b) Move southeast through runnable forest
   c) Look for control on concrete pad

G. Control 7.

1. Beginner
   a) Move back out onto east west jeep trail
   b) Go west to junction of jeep trail and dirt road
   c) Take dirt road south to junction with four jeep trails
   d) Take jeep trail east by northeast
   e) Look for second linear break in vegetation (indistinct path)
   f) Take indistinct path (handrail) to ditch
   g) Follow ditch to its end
   h) Control at east end of ditch
2. Intermediate
   a) Move through rough open ground easterly to jeep trail (catching

feature)
b) Follow jeep trail (handrail) to junction with other jeep trail by building
c) Locate telephone poles and follow wire (handrail) south easterly
d) Hit fight and turn west and follow fight boundary into ditch (handrail)
e) Control at east end of ditch

3. Advanced
a) Move through rough open ground easterly to jeep trail (catching feature)
b) Take jeep trail to curve where it turns east (hand rail)
c) Leave jeep trail and head straight for control use east west jeep trail as checkpoint (catching feature)
d) Aim off to east side of ditch and go southeast (telephone wires to east as catching feature to prevent drifting too far east)
e) Use fight as catching feature
f) Hit fight and turn west and follow fight boundary into ditch
g) Control at east end of ditch

4. Advanced
a) Move straight at control
b) Use jeep trail junction as attack point
c) From attack point take offset route to west part of ditch
d) Follow ditch to east and find control at end of ditch

H. Control 8.

1. Beginner
a) Handrail fight to the east till hitting the jeep trail
b) Follow jeep trail northerly through intersection to sharp curve to the east
c) Once at sharp curve to east turn off trail to west and look for control in clearing
d) Control located in clearing

2. Intermediate
a) Handrail fight to telephone poles
b) Take telephone poles NW back to jeep trail junction
c) Follow jeep trails east to next junction
d) Take jeep trail north
e) Leave jeep trail and move directly at control

3. Advanced
a) Move directly at control (avoiding forest walk) use jeep trail junction as catching feature
b) From jeep trail junction aim off to east of control at sharp curve to east of jeep trail keeping eyes open for control in clearings
c) Use same trail as Beginner route as catching feature (for drift)

I. Finish

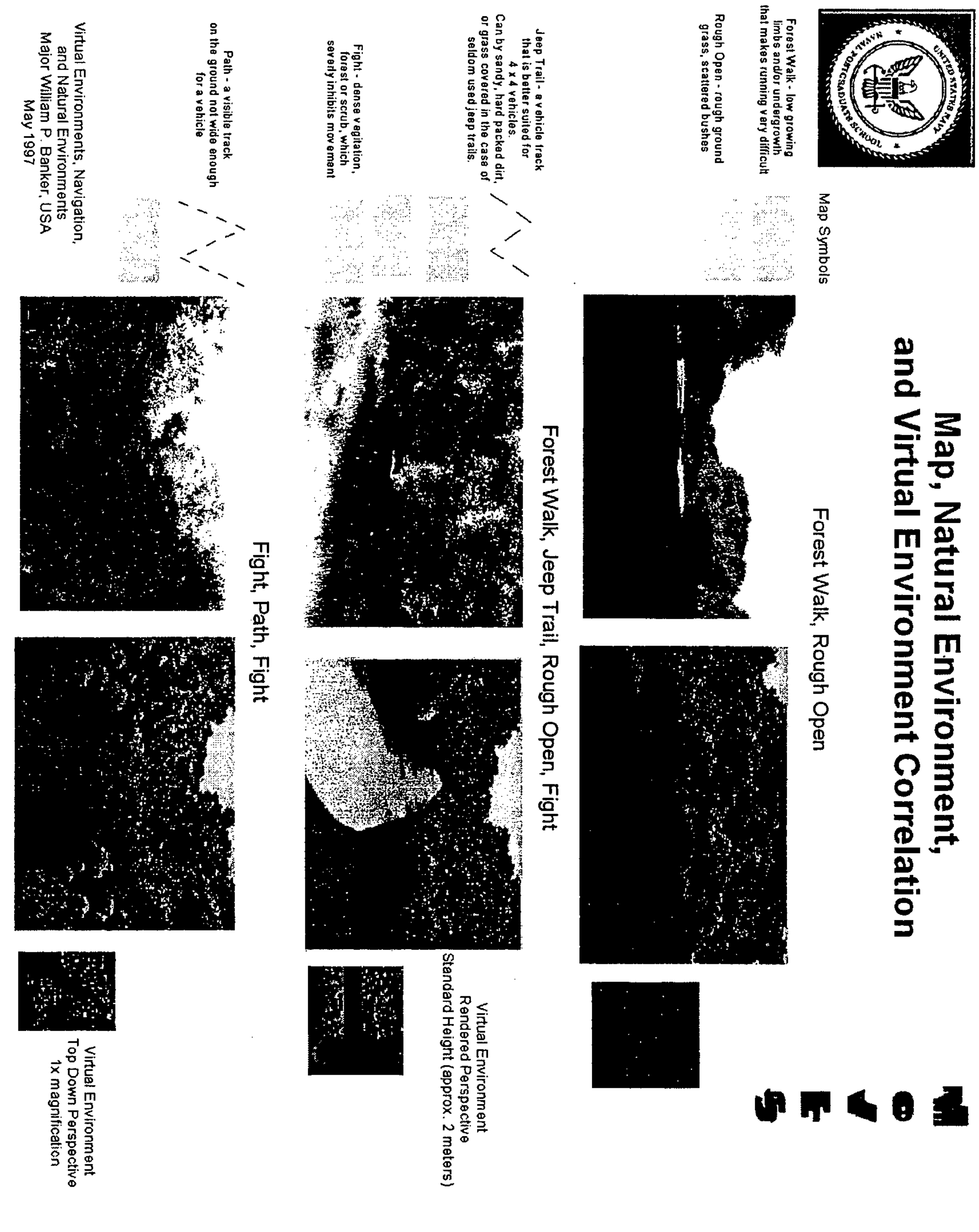
1. Beginner
a) Move back out to jeep trail just to east of control 8
b) Take trail south to four way junction with other trails (handrail)
c) Take southeasterly running trail to trail fork
d) Take northeasterly running fork to five way junction (handrail)
e) Take northwesterly running trail keeping eyes open for small break in fight to the east (catching feature)
f) Take indistinct path into clearing and hook to north
g) Control on east edge of clearing

2. Intermediate
a) Move back out to jeep trail just to east of control 8
b) Move off trail using rough open to move closer to control
c) Take rough open out onto jeep trail which runs NE to SW
d) Take trail to junction with North South jeep trail

e) follow jeep trail looking for indistinct path
f) Take indistinct path into clearing and hook to north
g) Control on east edge of clearing

3. Advanced
   a) Move straight at control on east by northeast azimuth
   b) Use trail as catching feature
   c) Fight to north and south of route used as catching features
   d) Locate opening in fight
   e) Take indistinct path into clearing and hook to north
   f) Control on east edge of clearing

Appendix G.
Map, Actual, and Virtual Environment Correlations



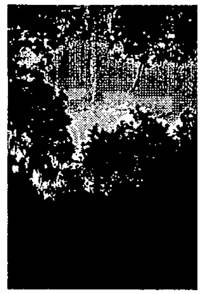
Appendix G.
Map, Actual, and Virtual Environment Correlations

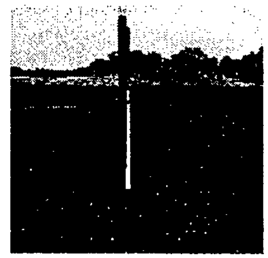
Map, Natural Environment, and Virtual Environment Correlation

Map Symbols

Telephone Pole

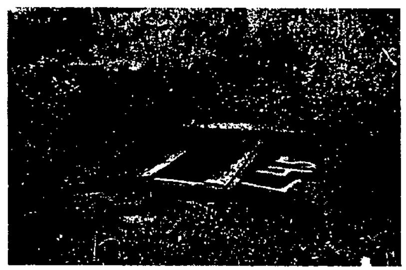
approximately 20 ft in height

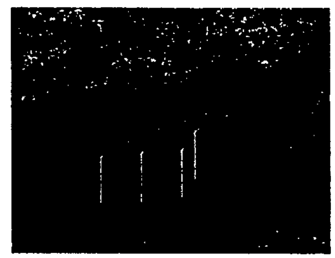




Ruin (latrine)

Concrete foundation with 6ft deep cavity

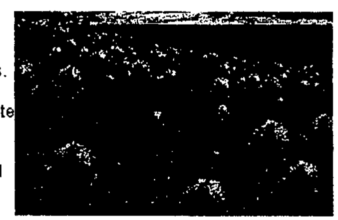




Virtual Environment
Rendered Perspective
Standard Height (approx. 2 meters)

Undergrowth

Undergrowth in the natural environment is represented by many plant species, some of which in maturity become fight.
Undergrowth is ubiquitous in all non open ground areas.
A catalog of photos would be necessary to cover all the types. It is only represented in the VE to correlate with the map or serve as an obstruction to visibliity at 1 meter.
The type depicted to the right correlates with mapped areas of undergrowth

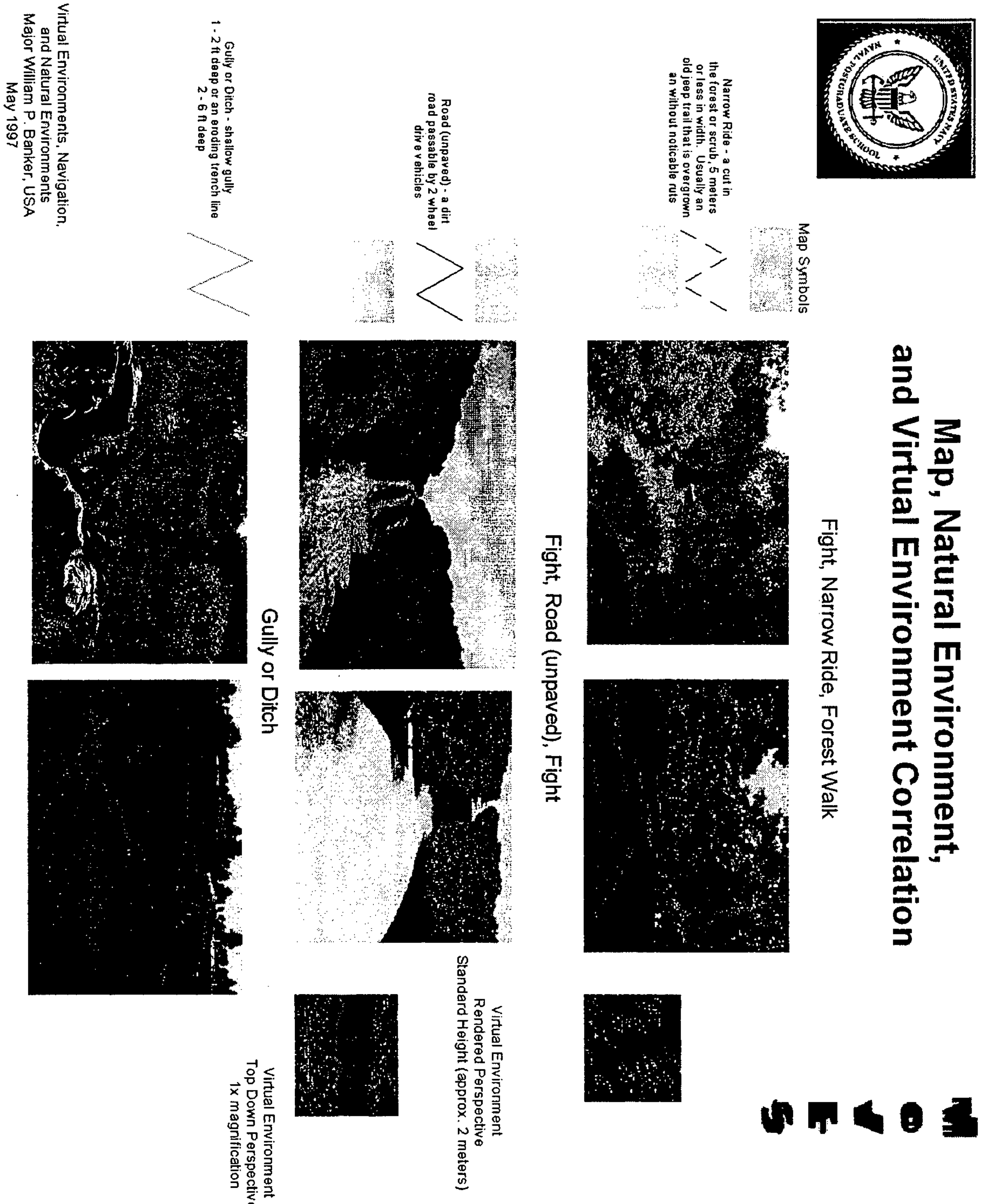


Virtual Environment
Top Down Perspective

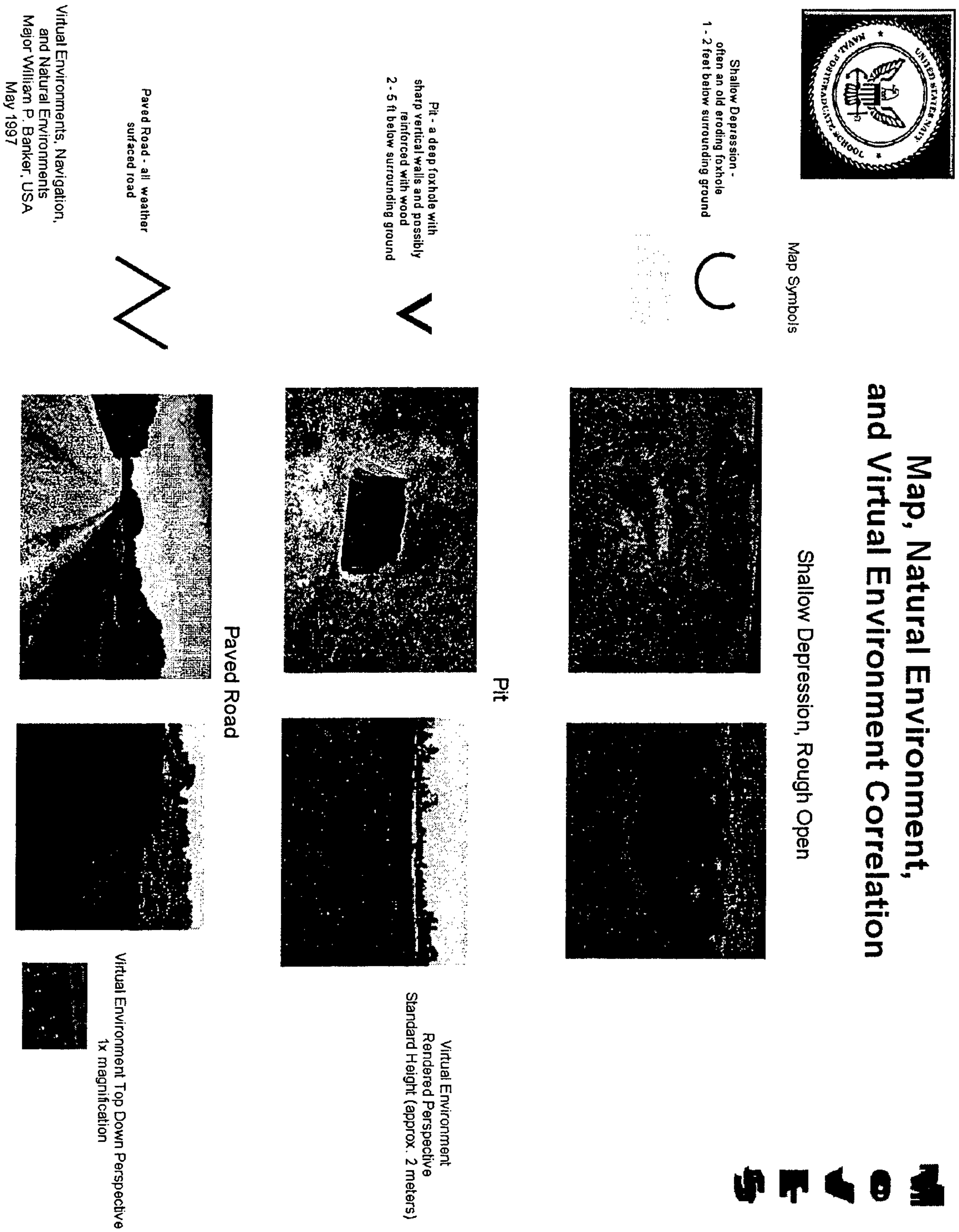
not shown - feature not visible at 1x

Virtual Environments, Navigation, and Natural Environments
Major William P. Banker, USA
May 1997

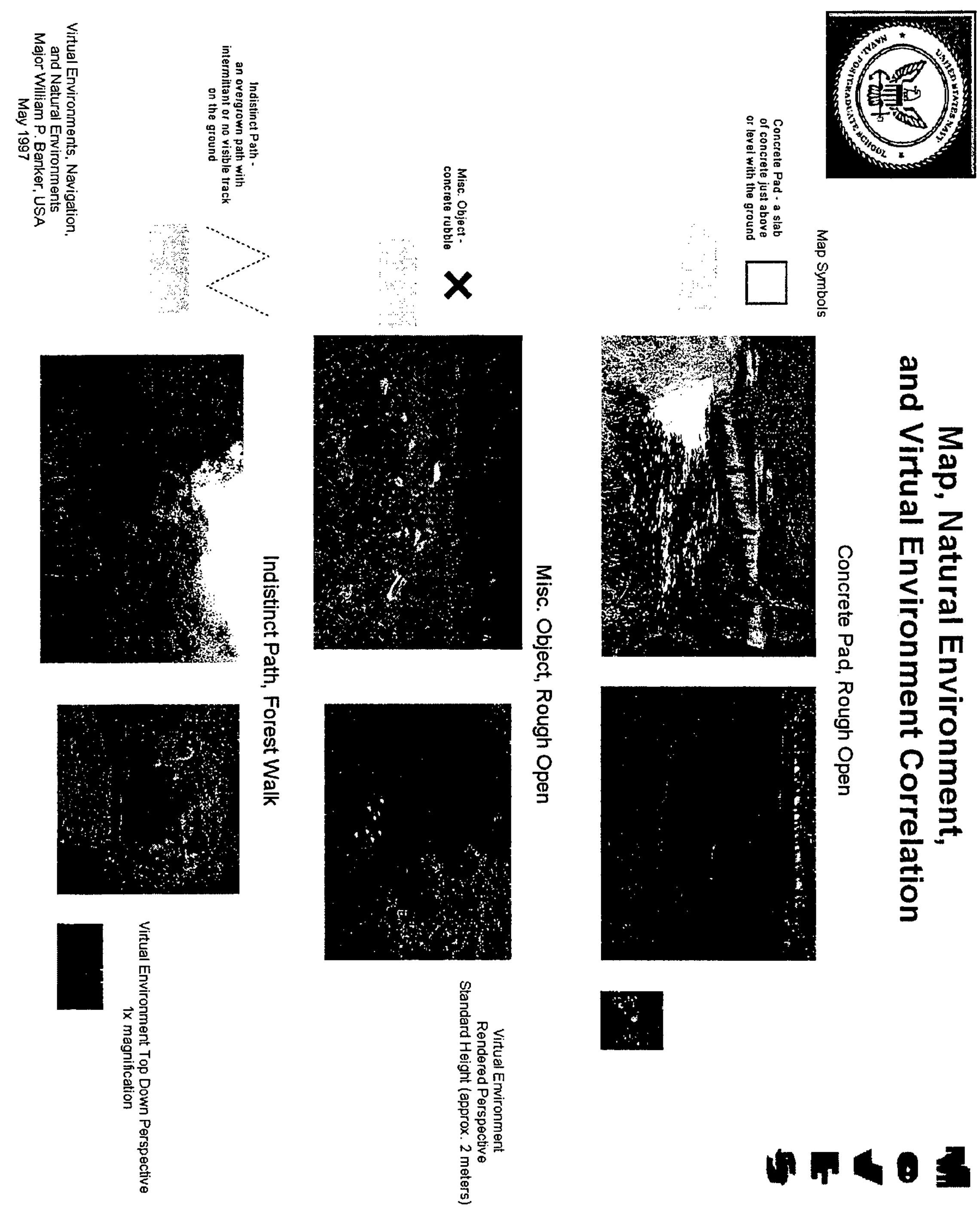
Appendix G.
Map, Actual, and Virtual Environment Correlations



Appendix G.
Map, Actual, and Virtual Environment Correlations



Appendix G.
Map, Actual, and Virtual Environment Correlations



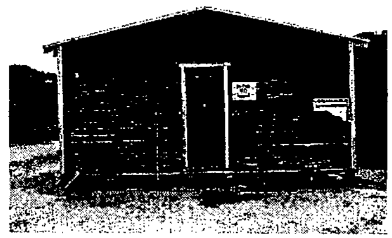
Appendix G.
Map, Actual, and Virtual Environment Correlations

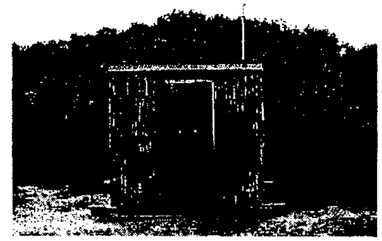
Map, Natural Environment, and Virtual Environment Correlation

Buildings - Latrine, Field Operations Office, Storage Shack, Open Ground

Map Symbols

Open Ground - no obstacles





Forest Walk, Rough Open, Fight

Virtual Environment Rendered Perspective
Standard Height (approx. 2 meters)

Forest Run

Forest Run - mature trees with few low lying limbs and little undergrowth

Virtual Environment Top Down Perspective
1x magnification

Virtual Environments, Navigation, and Natural Environments
Major William P. Banker, USA
May 1997

APPENDIX H.

PARTICIPANT TASK LIST

Thank-you for participating in this study. You will doing an Orienteering course today. However, there are some important differences to note:

1. You will be wearing a light pack with DGPS and Newton MSG Pad 130. Its purpose is to log your route and act as a data capture device for other actions you may perform.

2. Before you run the course you will carefully plan your route through the entire course (see Important Information on Marking Your Map)

3. Use this training time to commit the route and course to memory. You are expected to do the following on the actual course run:

   a. Navigate without aid of map and compass, but go off of memory as best you can.]
   b. Try not only to find all the controls but do so within your planned route

Summary of objectives
<u>All Objectives are equally important!!</u>

1. Choose the most efficient route for you based on your abilities in this context
2. Minimize the number of map checks you request from the administrator
3. Minimize the number of compass checks you request from the administrator
4. Minimize the number of map with compass checks you request from the administrator
5. Stay on your route
6. Find all the controls (you have as much time as you need for this task)

- If you need to make a map check then say so and the administrator will give you the map for 30 seconds. Additional time can be requested in 30 second increments at the additional cost of a map check each.
- If you need to make a compass check then say so and the administrator will give you the compass for 15 seconds. Additional time can be requested in 15 second increments at the additional cost of a compass check each.
- If you need both map and compass then say so and the administrator will give you both for 30 seconds. Additional time can be requested in increments of 30 seconds.
- If you want to change your route announce to the administrator that you are changing your route plan. At that point the administrator will hand you the map, compass, and blue pen. From the time that he gives you the materials you will have 30 seconds to plot the new route. If you need more time then tell him you need more time and you will get another 30 seconds. Request additional time as needed but remember that one of your objectives is to make as few map checks as necessary. **Every 30 seconds that you are looking at the map beyond the original 30 seconds for the route change counts as a map check.**

APPENDIX I.

IMPORTANT INFORMATION ON MARKING YOUR MAP

Pay close attention to how you mark your route, be as precise as the map and pen allow. Before your actual run you are expected to preview your map within your group's prescribed context. Mark your **planned route using the RED pen**. You may correct any mistakes you make while planning with the white eraser. Once the planning period is up or you elect to finish you will not be allowed to erase any of the red route marks you have made. **SO BE PRECISE** in marking your map, detail does matter. Later during the actual course run anytime that you are going to deviate from your planned route you must stop:

1. Announce to the administrator that you are changing your route plan. At that point the administrator will hand you the map. From the time that he gives you the map you will have 30 seconds to plot the new route. If you need more time than tell him you need more time and you will get another 30 seconds. Request additional time as needed but remember that one of your objectives is to make as few map checks as necessary. **Every 30 seconds that you are looking at the map beyond the original 30 seconds for the route change counts as a map check.**
2. Take the blue pen and draw in your new route with the same attention to detail that you applied for the original route planning in red.
3. Leave your original route on the map. The eraser is provided so that you may make corrections to a route as you draw it. Once you finish drawing and begin navigating you are not allowed to erase routes, or corrections to planned routes (blue penned routes)
4. You may make as many corrections to your route(s) as necessary while navigating the course.

Importance of detail in map marking and navigation

You are allowed to deviate from your planned route within the following tolerances while still being considered on that route:

Jeep Trails, Paved Roads, Unpaved Roads, Indistinct Paths, Narrow Rides and Paths -- If your marked route is on any of these features you are allowed **5 meters either side** of the feature and you are still considered as being "on your route".

All other features -- On all other types of non road/trail terrain you may travel **15 meters to either side** of your marked route and you are still considered as being "on your route"

APPENDIX J.

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943

PRIVACY ACT STATEMENT

1. Authority: Naval Instruction

2. Purpose: Spatial Cognition information will be collected to enhance knowledge, or to develop tests, procedures, and equipment to improve the development of Virtual Environments.

3. Use: Spatial Cognition information will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was collected. Use of the information may be granted to legitimate non-government agencies or individuals by the Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act.

4. Disclosure/Confidentiality:

a. I have been assured that my privacy will be safeguarded. I will be assigned a control or code number which thereafter will be the only identifying entry on any of the research records. The Principal Investigator will maintain the cross-reference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which is not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 3 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

c. I also understand that disclosure of the requested information, including my Social Security Number, is voluntary.

____

Signature of Volunteer   Print Name, Grade/Rank(if applicable)   DOB   SSN   Date

____

Signature of Witness   Date

APPENDIX J.

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943

MINIMAL RISK CONSENT STATEMENT

Subj: VOLUNTARY CONSENT TO BE A RESEARCH PARTICIPANT IN: Virtual Environments and Navigation in Natural Environments

1. I have read, understand and been provided "Information for Participants" that provides the details of the below acknowledgments.

2. I understand that this project involves research. An explanation of the purposes of the research, a description of procedures to be used, identification of experimental procedures, and the extended duration of my participation have been provided to me.

3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

7. I have been informed of that since the risks are minimal any injury I suffer while participating in the experiment will be at my own risk and that I accept full responsibility for my own medical treatment.

8. I understand that my participation in this project is voluntary, refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

9. I understand that the individual to contact should I need answers to pertinent questions about the research is Rudy Darken, Ph.D., Principal Investigator, and about my rights as a research subject or concerning a research related injury is the Modeling Virtual Environments and Simulations Chairman. A full and responsive discussion of the elements of this project and my consent has taken place.

____
Signature of Principal Investigator Date

____
Signature of Volunteer Date

____
Signature of Witness Date

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4. Disclosure/Confidentiality:

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c. I also understand that disclosure of the requested information, including my Social Security Number, is voluntary.

____

Signature of Volunteer   Print Name, Grade/Rank(if applicable)   DOB   SSN   Date

____

Signature of Witness   Date

APPENDIX J.

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943

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3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonably foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

7. I have been informed of any compensation and/or medical treatments available if injury occurs and is so, what they consist of, or where further information may be obtained.

8. I understand that my participation in this project is voluntary, refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

9. I understand that the individual to contact should I need answers to pertinent questions about the research is Rudy Darken, Ph.D., Principal Investigator, and about my rights as a research subject or concerning a research related injury is the Modeling Virtual Environments and Simulations Chairman. A full and responsive discussion of the elements of this project and my consent has taken place.

Medical Monitor: Flight Surgeon, Naval Postgraduate School

____

Signature of Principal Investigator Date

____

Signature of Volunteer Date

____

Signature of Witness Date

APPENDIX K.

GENERAL DEBRIEF

Participant Number____________

1. **Have you ever been on this part of Ft. Ord Before?** If so how familiar were you with the course area prior to running it?

a. Not very familiar – passed through area two of fewer times.
b. Familiar – have hiked or biked though are more than twice and am somewhat confident about my knowledge of the trail network
c. Very familiar – come through here often and could navigate to a prominent feature such as a building, road junction, or hilltop without a map.

2. **Have you been out navigating on Ft. Ord before?** If so do you think your previous exposure to a different area of Ft. Ord helped you solve today's navigation problem. If it did help then explain how it helped you, be specific.

3. **If you have not been out on Ft. Ord before** have you been on similarly vegetated terrain. If so, do you believe that prior exposure helped you with today's navigation problem. If it did help then explain how it helped you, be specific.

4. **What did you think of the map quality?**

a. Excellent – accurate, easy to read, portrayed all significant features.
b. Good – some minor discrepancies that created a little confusion (please explain why in space below).
c. Fair – Several significant flaws that lead me to make major mistakes in navigation (please explain why in space below).
d. Poor – Numerous flaws that made accurate navigation a matter of luck (please explain why in space below).

Questions asked in context of actual route (Recorded)

SEE ORIENTEERING SKILLS AND STRATEGIES FOR TAXONOMY OF ORIENTEETING ERRORS

1. If an **unintentional error and caught**

   a. When did you recognize that you had deviated off your planned route?
   b. Why did you plan your original route as you did?
   c. Why did you revise your route the way you did?
   d. Attribute the error to what factors?

2. If **unintentional error and not caught** but participant arrives at control

   a. What made you think you were still on your planned route?
   b. How do you think you arrived at the control when it was not planned by you?
   c. Attribute the error to what factors?

3. **If an intentional error** – route revision

   a. What caused you to revise your route?
   b. Attribute the error to what factors?
   c. If route revision is successful (leading to no more corrections)
      1. What do you attribute the successful route correction to?
   d. If unsuccessful
      1. Why was this correction not successful?

4. **Upon successful completion of a planned route to a control**

a. Rank the aids (map, course preview, VE --- whichever are relevant to the you) in order of importance that helped you successfully complete this control

b. How did each aid help?
c. What were the shortcomings of the aids you had for this control?
d. What were the strengths of the aids you had for this control?

APPENDIX L.

VE DEBRIEF

For VE participants only

1. Within the context of helping familiarize you with the environment prior to having to navigate in it please comment on the below items as to whether is was helpful or not and why. (*note this form has been condensed for space saving inclusion as an appendix. The actual form contained space in between each question for a reply*)

   a. The Spatial fidelity (perceived relative distance of one virtual feature to another compared to the actual features on the course)

   b. The navigation options:
      1. Walking
      2. Squatting to 1 meter height
      3. Rising to 10 meters height
      4. Rising to 30 meters height
      5. Teleporting from location to location using the "Hole View"

   c. The vegetation type portrayals.
   d. Vegetation density portrayal.
   e. Road/Trail network portrayal.
   f Elevation portrayal.
   g. Building portrayal
   h. Ground surface portrayal.
   i. Telephone wire poles
   j. The "Hole" restriction.
   k. The interface (mouse and monitor)
   l. Other features - pits, depressions.

2. What improvements (in order of importance) would you make to the VE and why?

3. What aspects of the VE did you think did not support the task?

4. Did exposure to the VE give you greater confidence that the environment would be familiar to you when you went out into it.? If so then explain how the VE created this confidence.

5. If the VE did not inspire confidence that you would be familiar with the actual world then explain why it did not.

6. If it did inspire confidence, but later experience proved that confidence unfounded then explain why your experiences in the actual world undermined your confidence in the VE model.

APPENDIX M.

EQUIPMENT USED IN THE STUDY

The following list of equipment was used in the study

1. One Pentium (166) PC Workstation with Windows NT 4.0 with a 20" Sony Trinitron Monitor
2. Jack Nicklaus Golf 4.0 Course Designer used for VE.
3. ArcView 3.0a GIS used for map production, DGPS plotting, and spatial analysis.
4. 15 master maps acetated for durability.
5. Transparencies for overlays.
6. Alcohol Pens for marking routes.
7. Newton MSG Pad 130 used for DGPS map survey work and route participant route capture
8. Fieldworker 2.3 software used for DGPS map survey work and experiment data capture.
9. Compass
10. Clipboard
12. Head mounted Hi8 camcorder for recording participants course run.

Equipment common to all participants:

1. Map
2. Compass
3. Clue Sheet

Equipment unique to VE group:

1. Overlay of "VE Lanes" for map. These lanes outline the extant of each VE lane. This overlay provides a reference between the VE and the map that will be used by the participant during the course. This overlay will only be used as a contextual reference while the participant plans his route on the overlay that he will take out to the course with him. The VE Lane overlay will NOT go out to the course with the participant.

2. Map, Natural Environment, and VE correlation. This is a set of six diagrams that have photographs of the actual terrain with its VE correlation. Photographs do not always depict the area portrayed in the VE. Ideally the VE would have photographic fidelity. Due to bandwidth constraints this is not possible so the diagrams are meant to prevent negative training transfer by creating images in the participant's mind that are at great variance to the actual terrain.

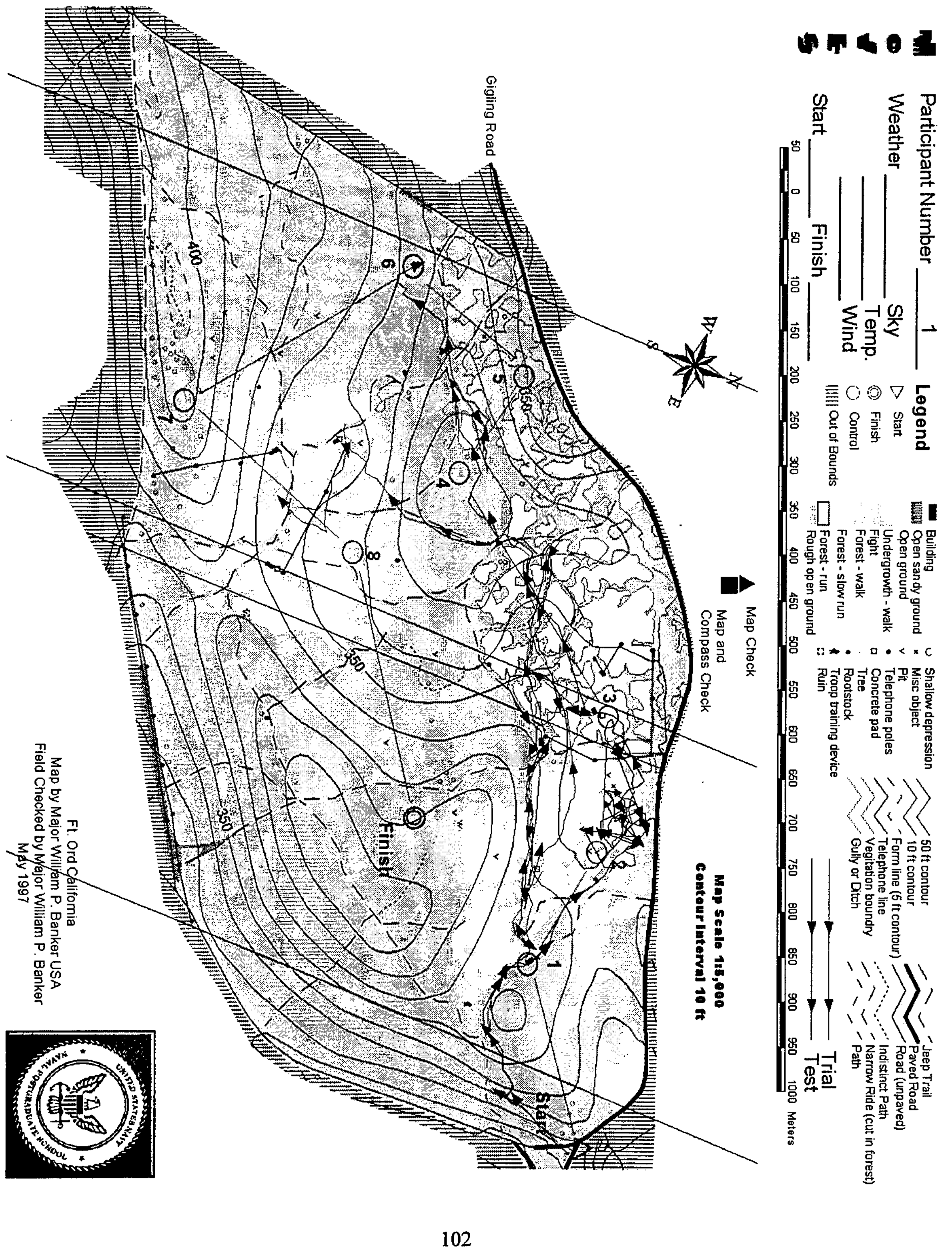
3. The Virtual Environment itself.

APPENDIX N.

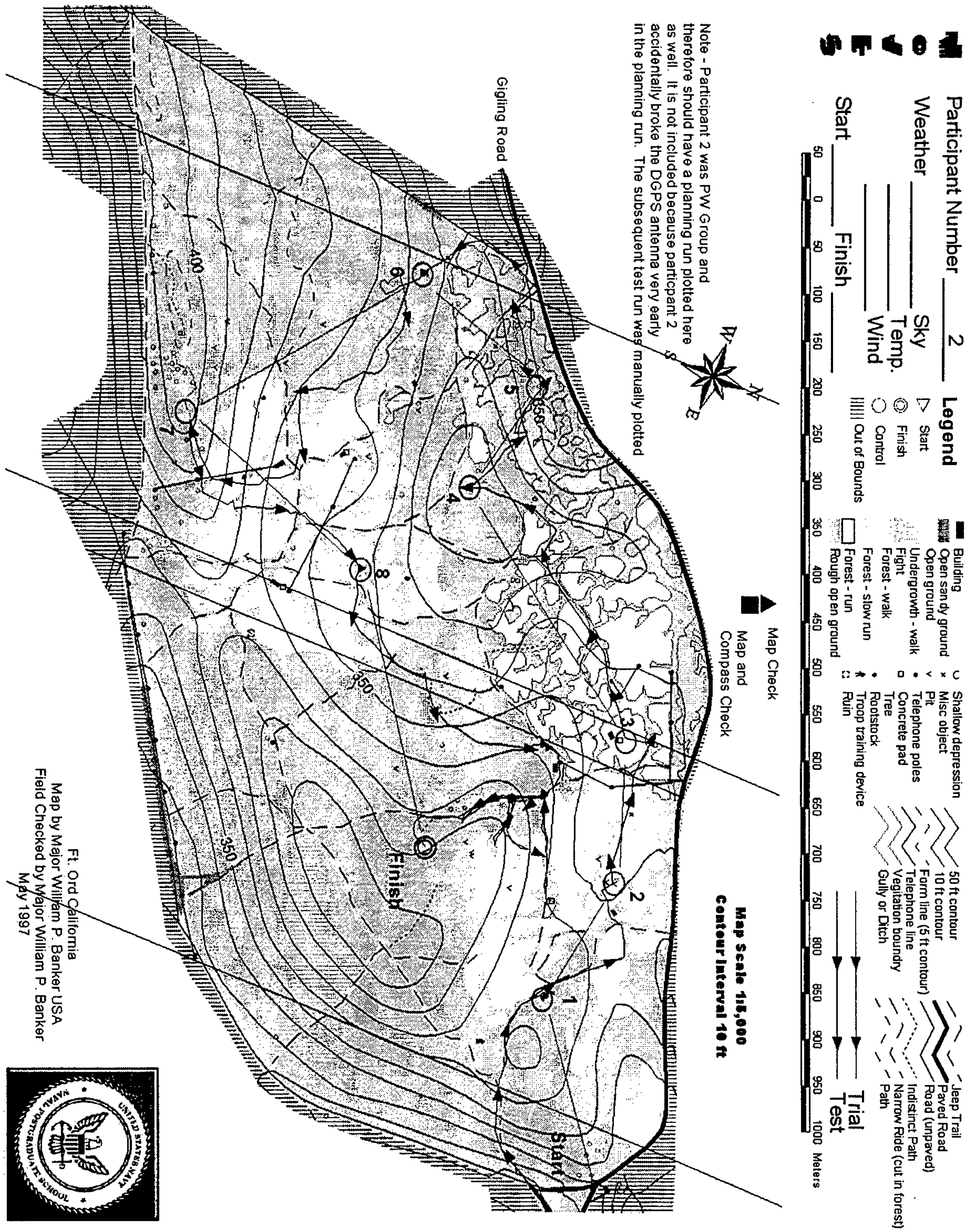
PARTICIPANT MAPS

The following maps portray the routes that participants took during the test phase, and in the Real World Condition, the route they took during the training phase (trial). The routes that the participant drew onto the map during their training phase has not been included on these maps because map scale and the limitations of black and white reproduction would have made for a cluttered and less readable reproduction. I am planning to provide the interested reader with the color versions of these maps which will include the planned route on an NPS web site. If interested in the link for downloading these maps (a high speed connection is recommended as they approximately 1.5 MB's each), please contact Dr. Darken at darken@cs.nps.navy.mil.

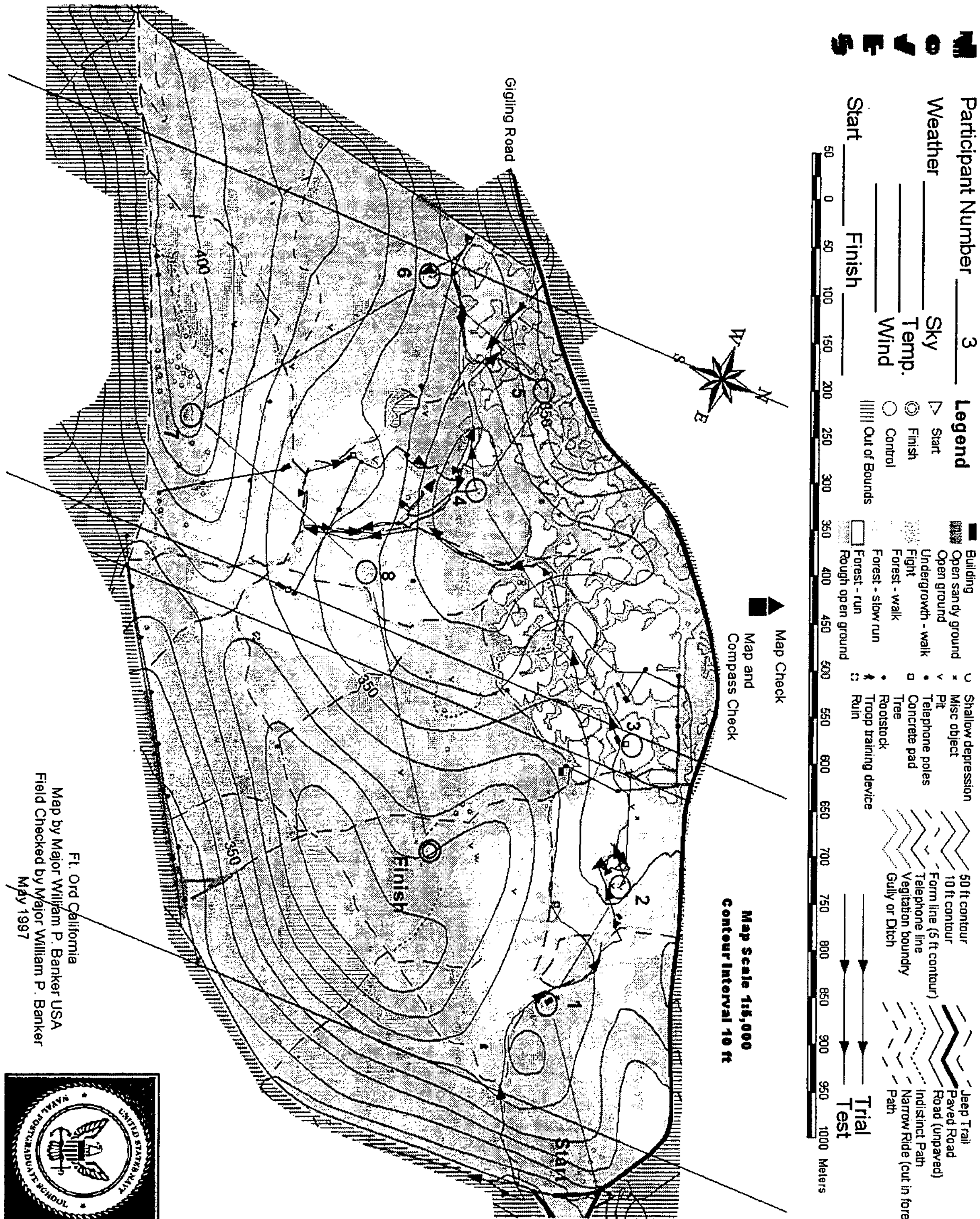
APPENDIX N.
Participant 1 Map
Real World Group



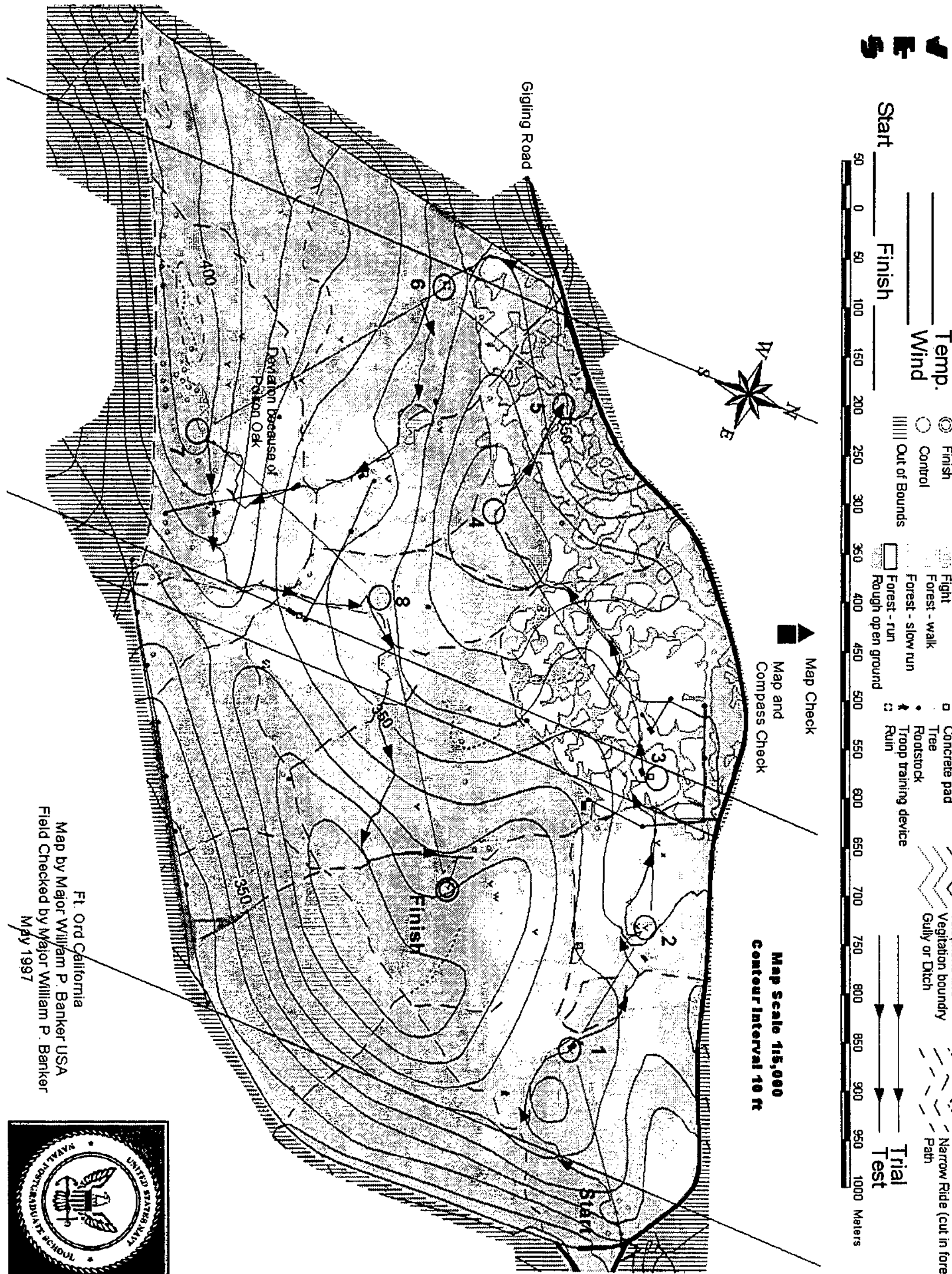
APPENDIX N.
Participant 2 Map
Real World Group



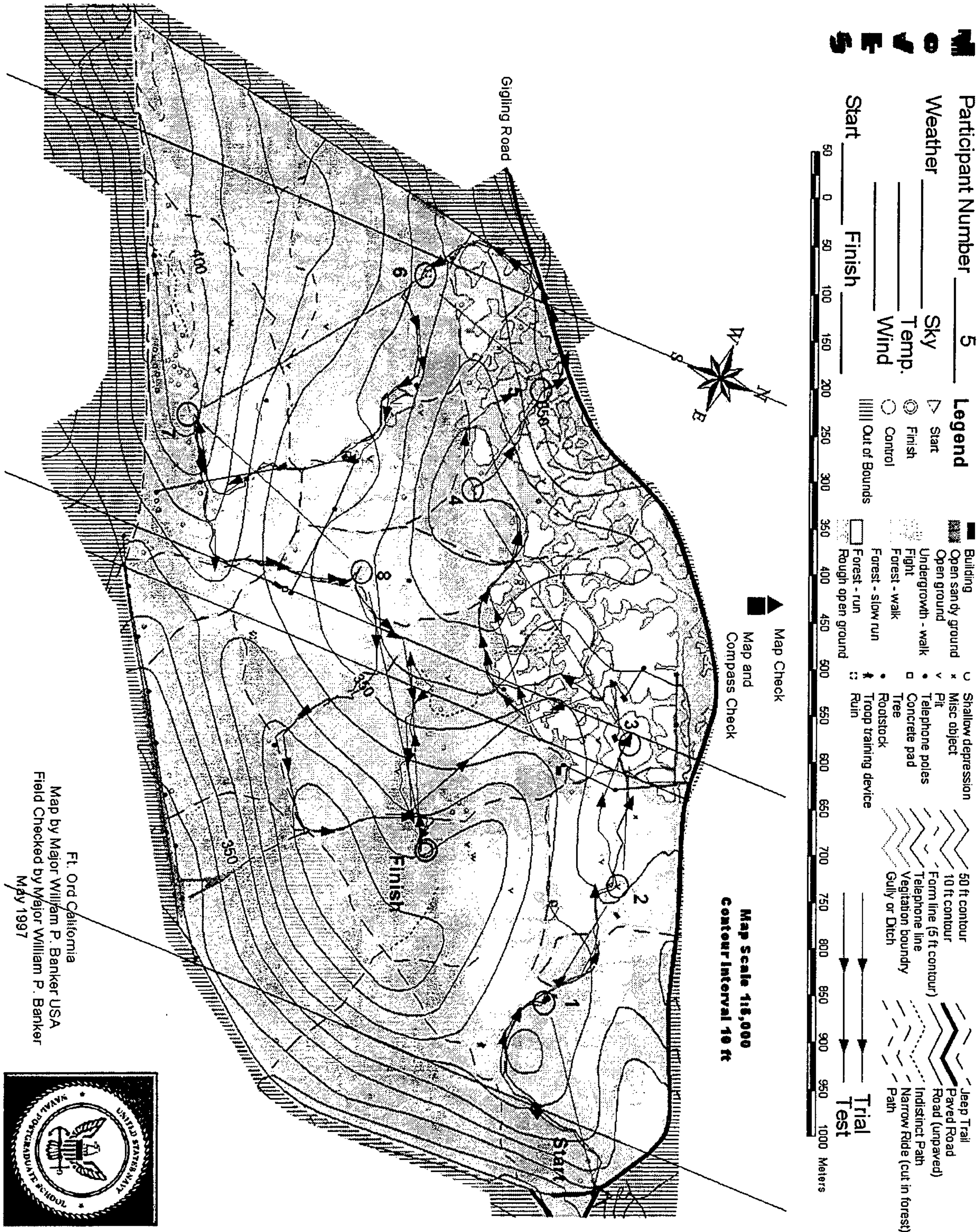
APPENDIX N.
Participant 3 Map
Control Group



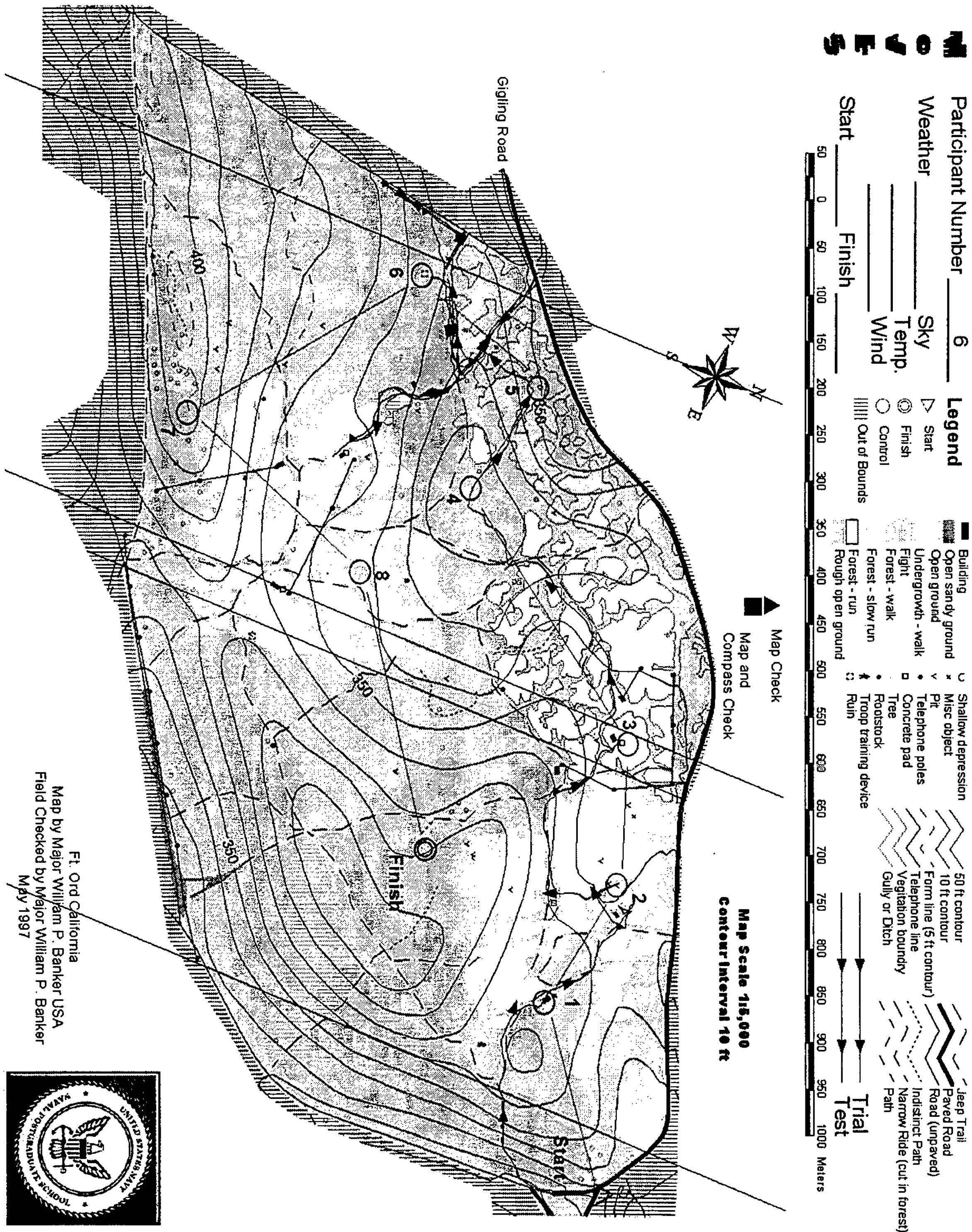
APPENDIX N.
Participant 4 Map
Control Group



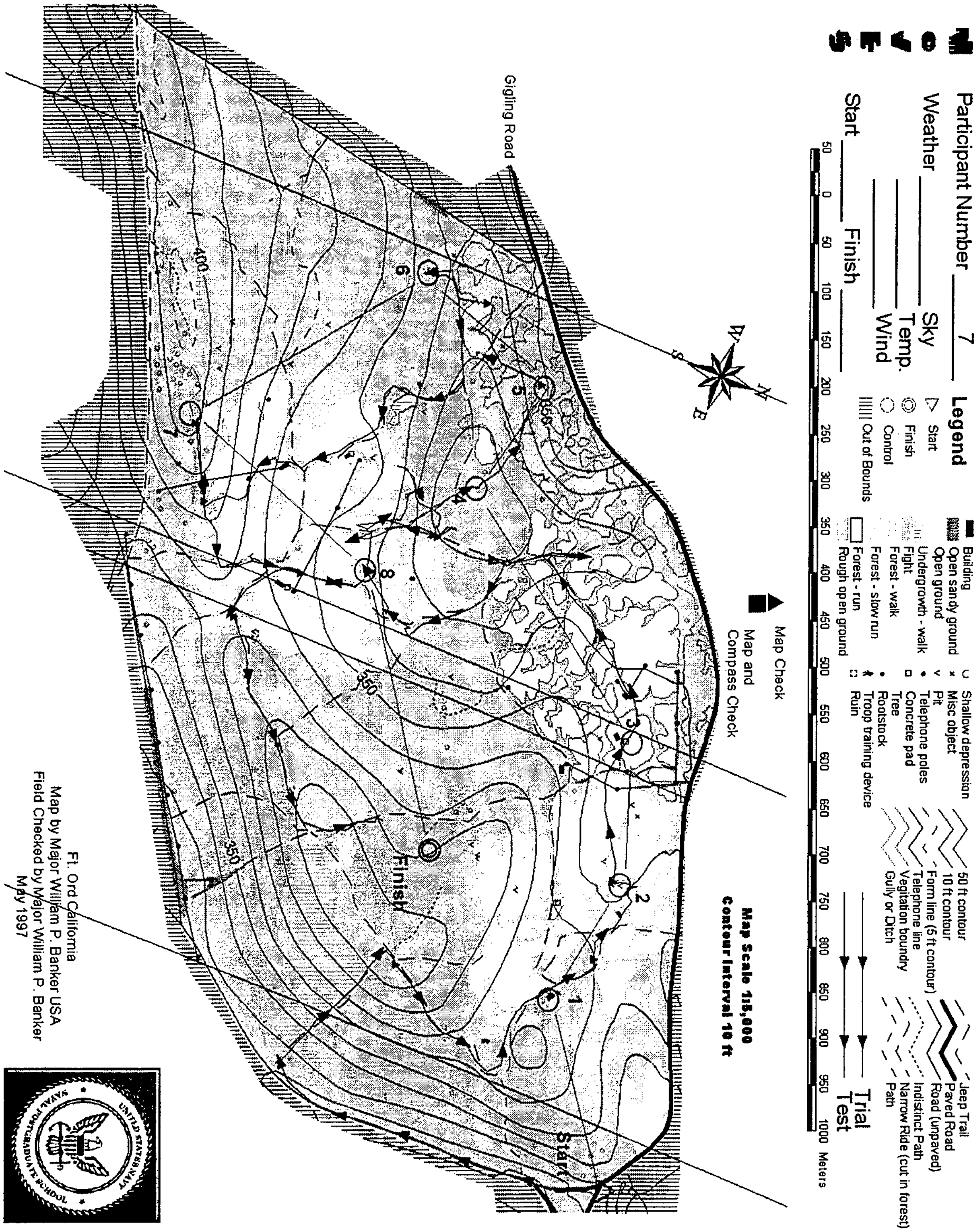
APPENDIX N.
Participant 5 Map
Real World Group



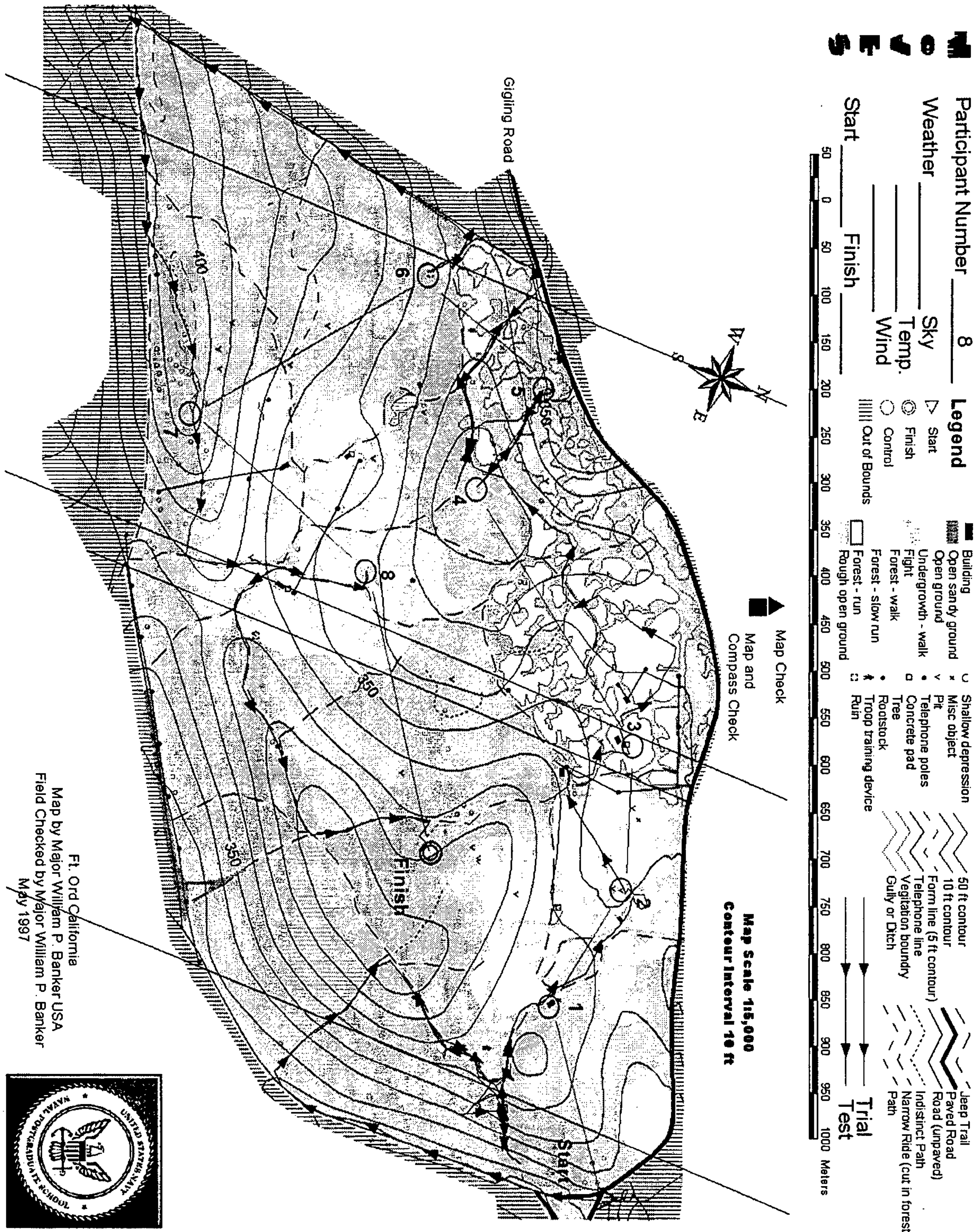
APPENDIX N.
Participant 6 Map
VE Group



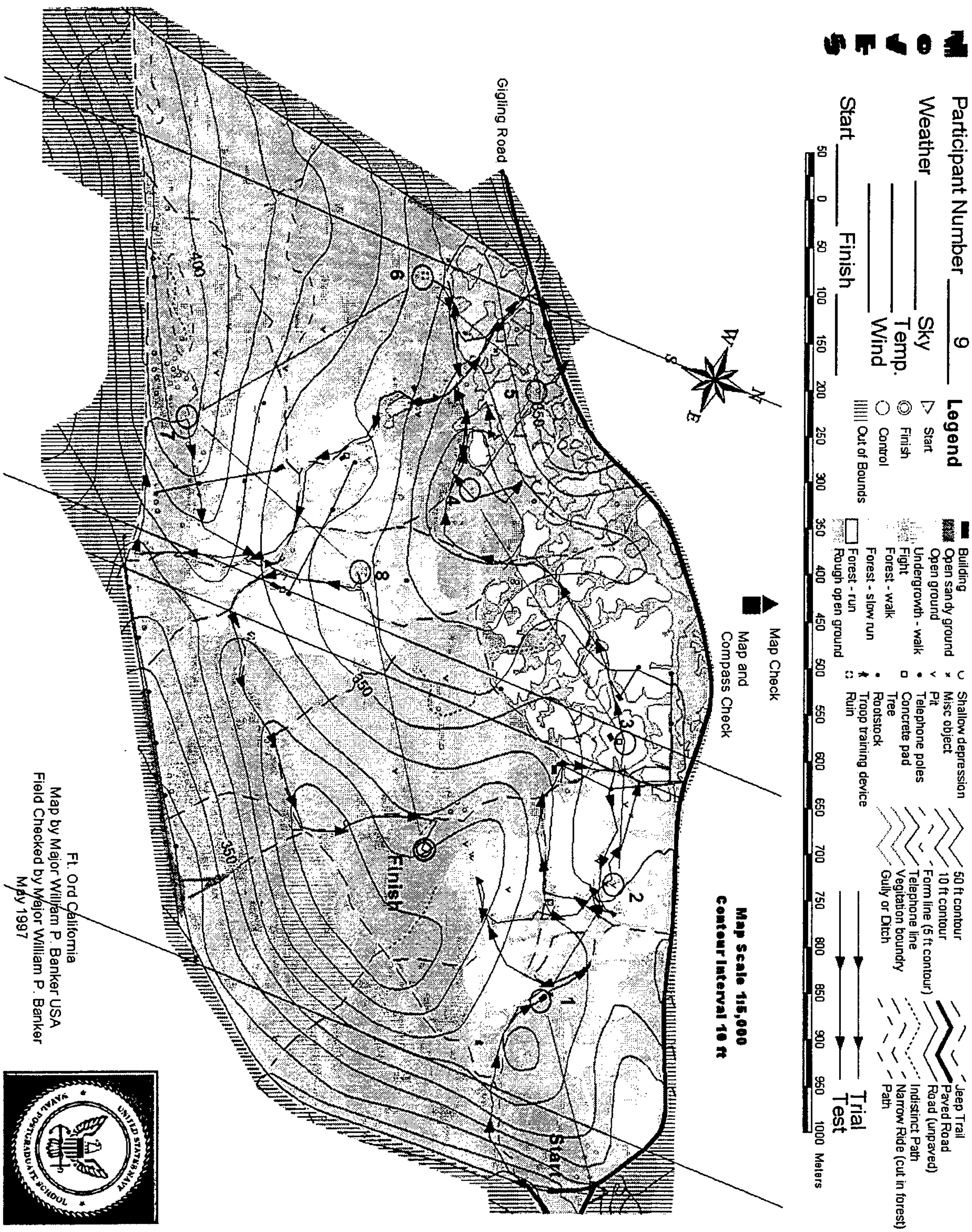
APPENDIX N.
Participant 7 Map
VE Group



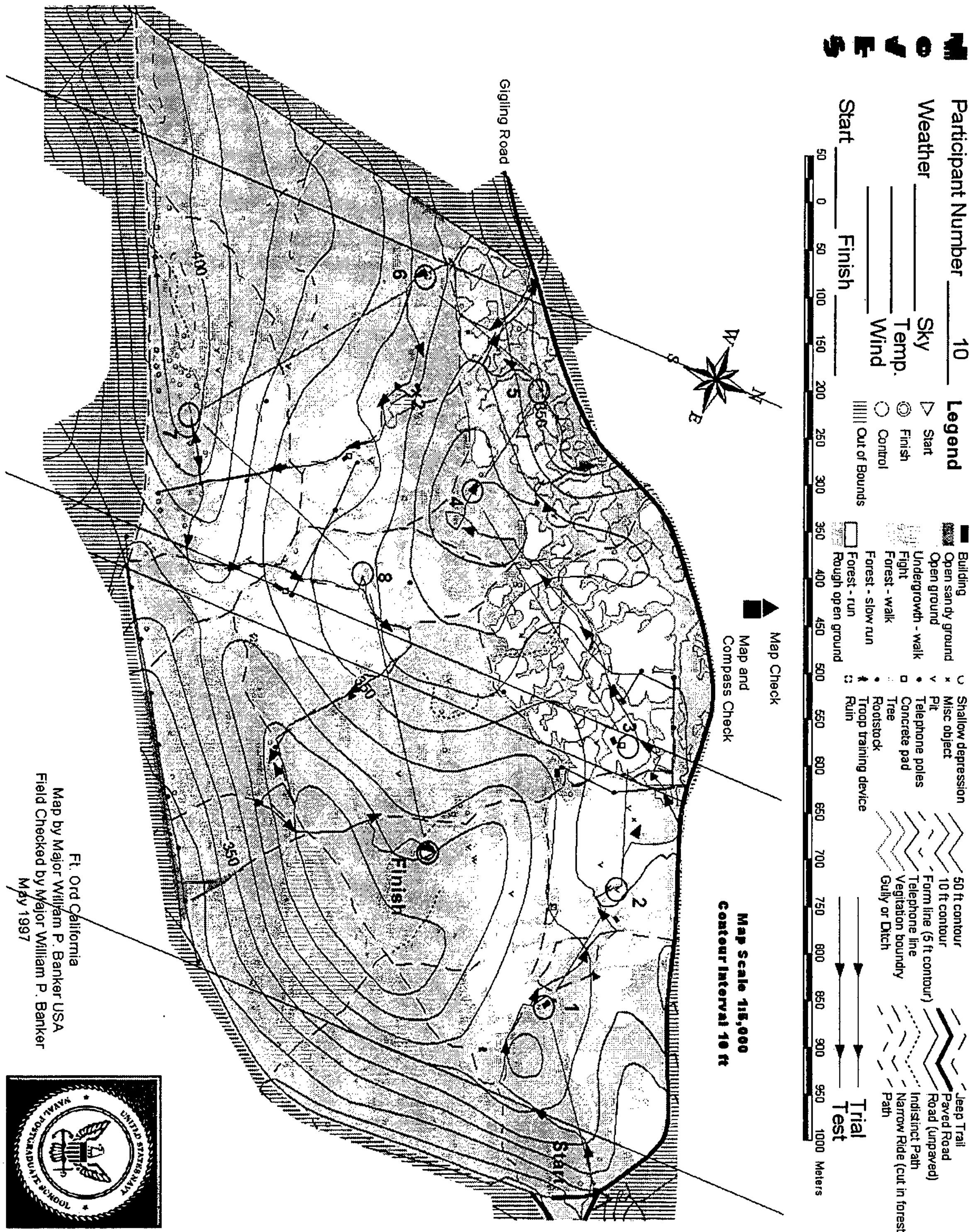
APPENDIX N.
Participant 8 Map
Control Group



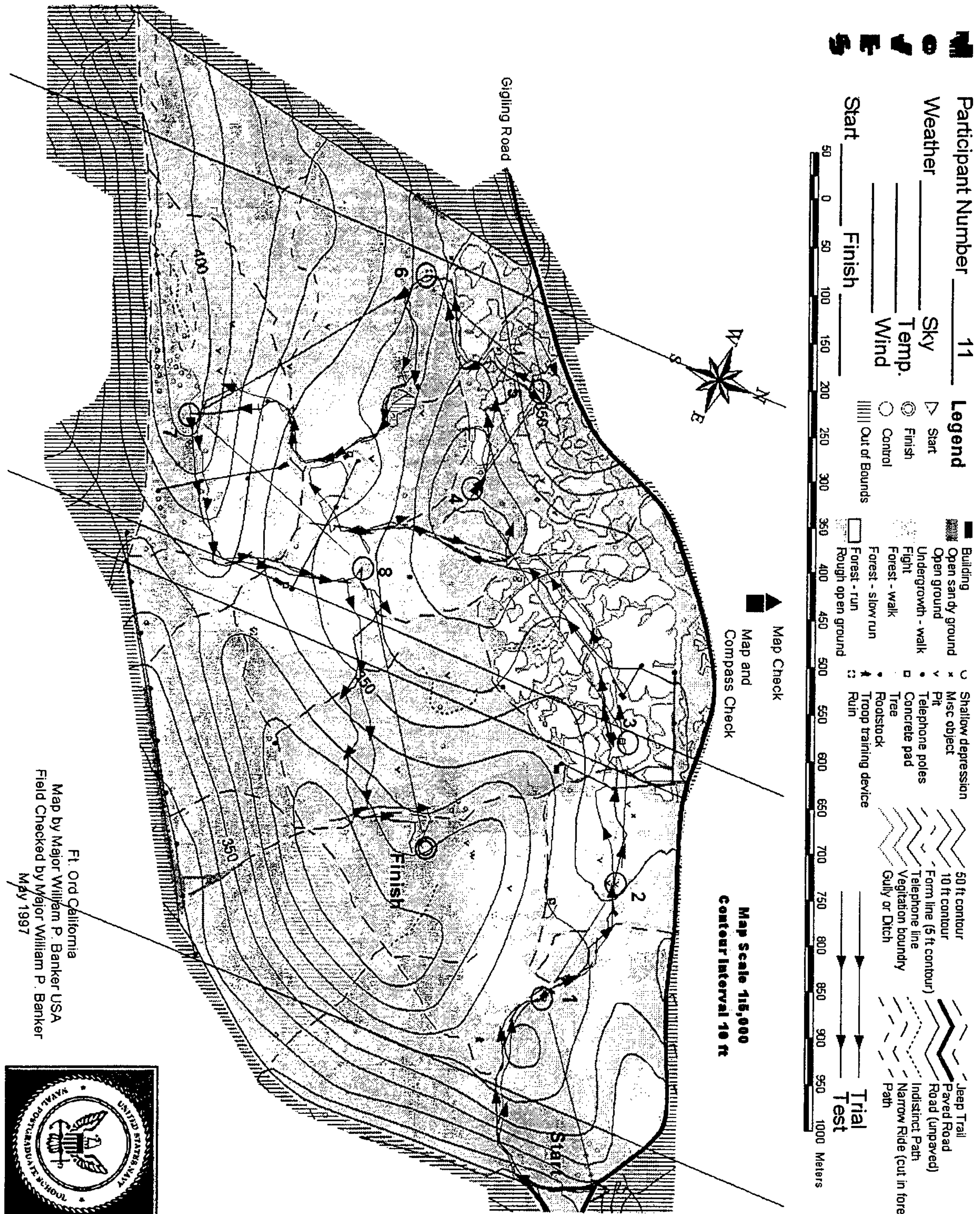
APPENDIX N.
Participant 9 Map
VE Group



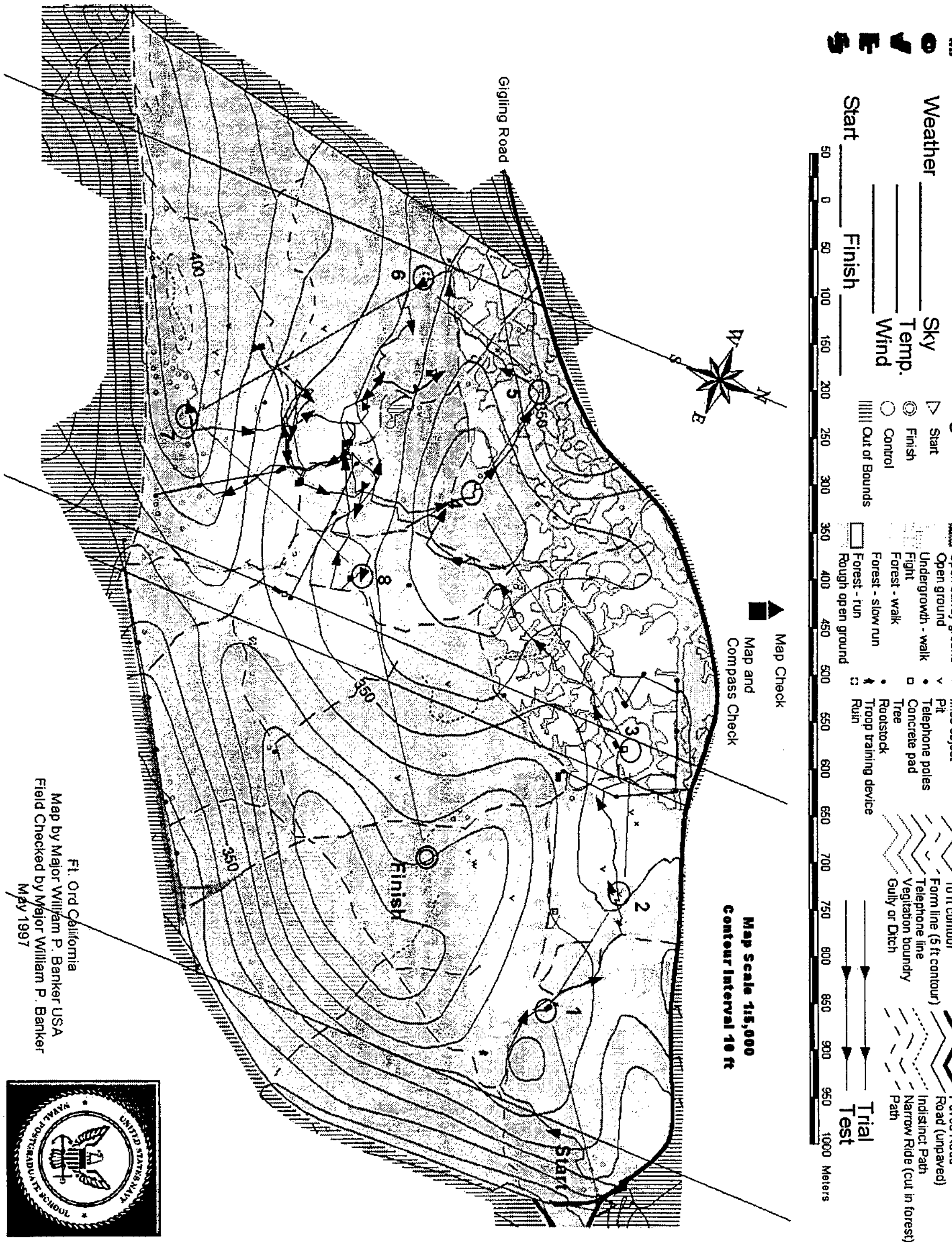
APPENDIX N.
Participant 10 Map
VE Group



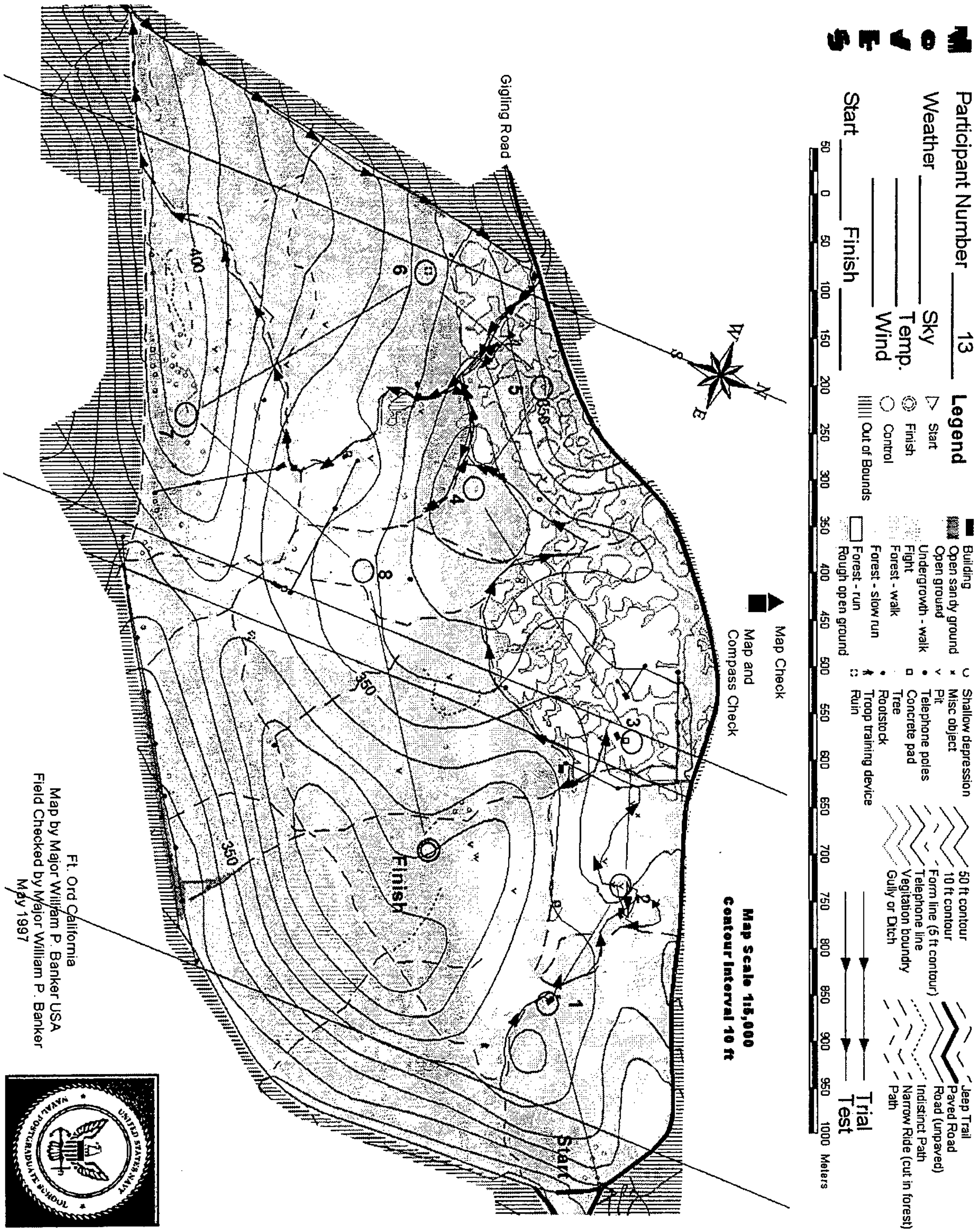
APPENDIX N.
Participant 11 Map
Real World Group



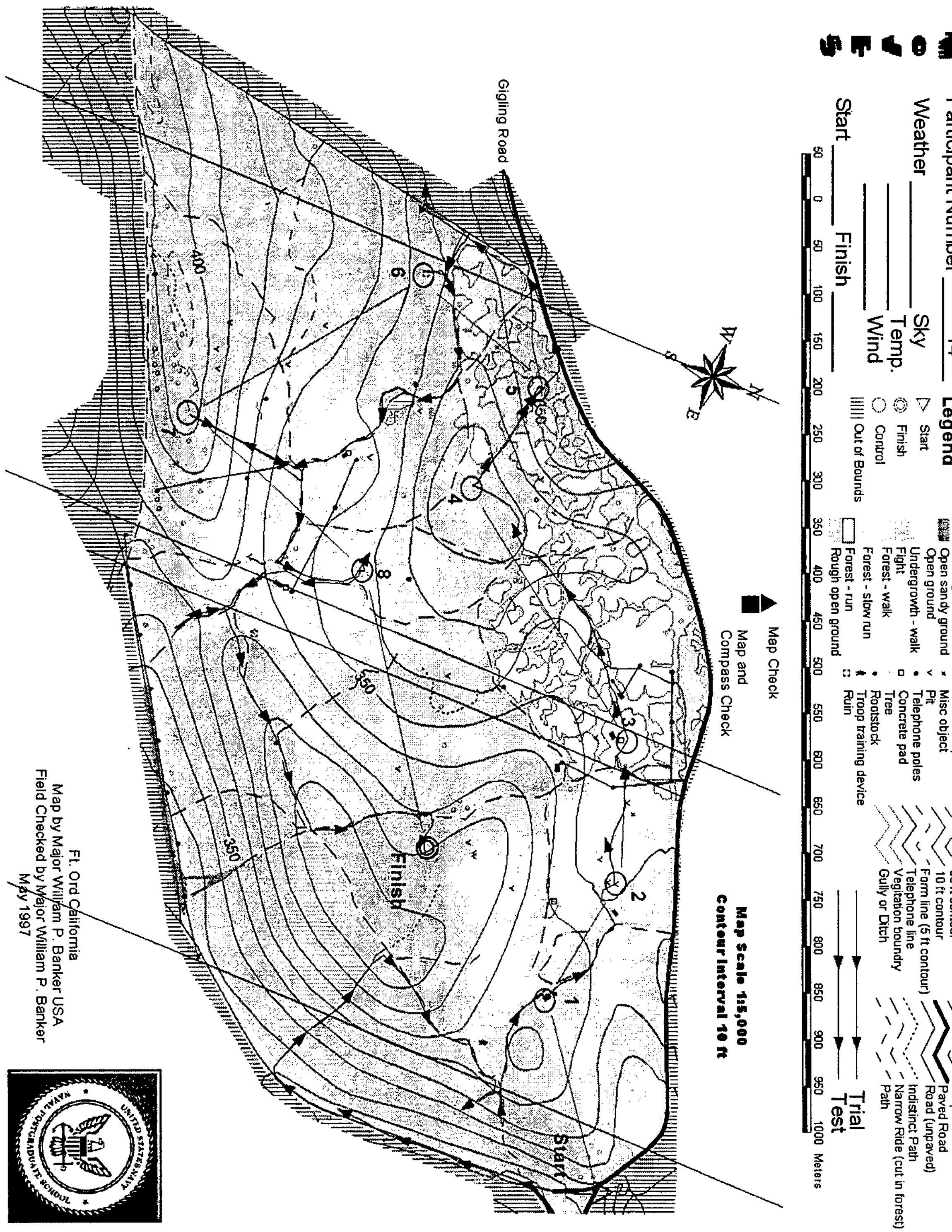
APPENDIX N.
Participant 12 Map
Control Group



APPENDIX N.
Participant 13 Map
Control Group

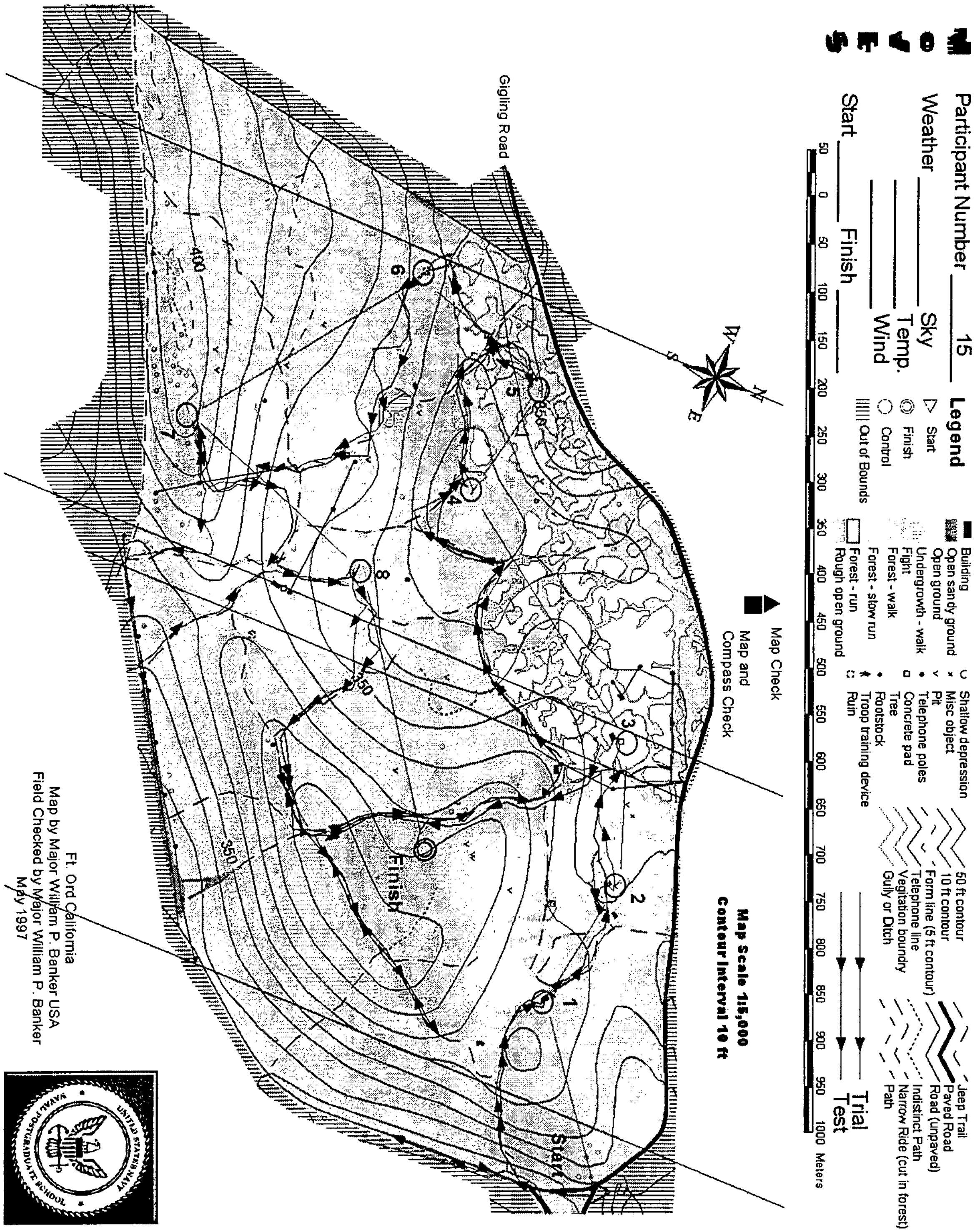


APPENDIX N.
Participant 14 Map
VE Group



APPENDIX N.

Participant 15 Map
Real World Group



APPENDIX O.

THINK OUT LOUD

Your thoughts are important to this research. As you navigate the course you should be "thinking out loud".

As you move through the environment and experience it directly express what you are thinking. The mental preconception you had of this environment before you stepped into it will now be evaluated by you as you experience the course directly. As this image is confronted with direct experience your expectations and plan may be confirmed, modified, or refuted. Be sure to talk out loud these thoughts.

The process of talking out loud and paying close attention to your route will slow you down. This is expected. You are under no time constraint to finish the course.

PLEASE SPEAK LOUDLY SO THAT YOUR VOICE WILL BE PICKED UP BY THE MICROPHONE

APPENDIX P.

ADMINISTRATORS TASK LIST

Admin. TASK LIST (All)

1. Welcome
2. Equipment you will need
3. Consent form
4. Administer questionnaire
5. Give procedure (Group Dependent)

Procedure Control Group

1. Issue
   a. Participant Task List
   b. Map Marking Information
1. Give map to participant for study away from site, plan route allow 1 hour take map back when finished with planning
2. Movement from NPS out to course area
3. Administration of blindfold prior to entrance into course area.
4. Arrival at start point, removal of blindfold
5. Issue and fit Pack
6. Issuance of Course Procedure (see course procedure all)
7. Ask Survey Knowledge question (you are at control 3, shoot azimuths to controls Finish, Six, and Eight)
8. Issue map back, pen, eraser (put on ground with map turned over face down on clipboard)
9. Any questions
10. Start participant
11. Navigate Course
12. Return to NPS
13. Debrief (General only)

Procedure Real World

1. Movement from NPS out to course area
2. Administration of blindfold prior to entrance into course area.
3. Arrival at start point, removal of blindfold
4. Issue and fit Pack
5. Issuance of Course Preview Procedure
   a. Participant Task List
   b. Map Marking Information
6. Issue map, pen, eraser (put on ground with map turned over face down on clipboard)
7. Any questions
8. Start participant on preview
9. Preview Course (1 hour max.)
10. Return to start point
11. Collect up materials
12. Issuance of Course Procedure (see course procedure all)
13. Ask Survey Knowledge question (you are at control 3, shoot azimuths to controls Finish, Six, and Eight)

14. Issue map back, pen, eraser (put on ground with map turned over face down on clipboard)

APPENDIX P.

ADMINISTRATORS TASK LIST

15. Any questions
16. Start participant
17. Navigate Course
18. Return to NPS
19. Debrief (General Debrief Only)

Procedure Virtual Environment Group

1. Give participant briefing form on what they will do in this group
2. Acquaint participant with interface on practice course
3. Any questions
4. Issue map, Correlation pictures, overlay, pen, eraser (put on table with map turned over face down on clipboard)
5. Any questions
6. Start participant on Virtual Preview (1 hour allowed for route planning)
7. Collect up materials
8. Movement from NPS out to course area
9. Administration of blindfold prior to entrance into course area.
10. Arrival at start point, removal of blindfold
11. Issue and fit Pack
12. Issuance of Course Procedure (see course procedure all)
13. Ask Survey Knowledge question (you are at control 3, shoot azimuths to controls Finish, Six, and Eight)
14. Issue map back, pen, eraser (put on ground with map turned over face down on clipboard)
15. Any questions
16. Start participant
17. Navigate Course
18. Return to NPS
19. Debrief (General and Virtual Environment Group)

Equipment Check

Check GPS
Check Newton
Check camera is on

Appendix Q.
Raw Data

Participant #	Study Group	Ability	Test Date	Test Time	Confirmed?	Age	Sex	Self Assessed Ability	Debrief 1
4	Control	Advanced	35574	0.458333333	Yes	42	Male	Advanced	0
5	PW	Advanced	35575	0.458333333	Yes	34	Male	Advanced	0
10	VE	Advanced	35581	0.583333333	Yes	54	Male	Advanced	0
8	Control	Beginner	30-May	14:00	Yes	31	Male	Beginner	1
1	PW	Beginner	22-May	9:00	Yes	54	Male	Beginner	0
6	VE	Beginner	29-May	15:00	Yes	29	Male	Beginner	0
3	Control	Intermediate	23-May	9:00	Yes	68	Male	Intermediate	0
12	Control	Intermediate	14-Jun	8:00	Yes	32	Male	Intermediate	1
13	Control	Intermediate	14-Jun	14:00	Yes	34	Male	Intermediate	1
2	PW	Intermediate	22-May	13:30	Yes	28	Male	Intermediate	0
11	PW	Intermediate	13-Jun	14:00	Yes	37	Male	Intermediate	1
15	PW	Intermediate	15-Jun	14:00	Yes	38	Male	Intermediate	0
7	VE	Intermediate	30-May	9:00	Yes	30	Male	Intermediate	2
9	VE	Intermediate	31-May	9:00	Yes	33	Male	Advanced	1
14	VE	Intermediate	15-Jun	8:00	Yes	30	Male	Advanced	1
Avg Control						35.8			
Avg VE						42			
Avg PW						37			
									Never = 0
									Not Familiar = 1
									Familiar = 2

Appendix Q.
Raw Data

Debrief 2	Debrief 3	Debrief 4	Questionnaire 1	Questionnaire 2	Questionnaire 3	Questionnaire 4	Questionnaire 5
0	N/A	1	2	2	2	N/A	0
1	1	2	2	1	2	Yes	0
1	N/A	2	2	1	2	N/A	0
0	N/A	2	0	0	0	N/A	0
1	N/A	2	0	0	0	N/A	0
0	0	2	0	0	0	N/A	0
1	N/A	2	0	0	1	N/A	0
1	N/A	2	0	0	1	N/A	0
1	N/A	1	0	0	1	N/A	0
0	N/A	2	1	0	1	N/A	0
1	N/A	2	0	0	1	N/A	0
1	N/A	2	0	0	1	N/A	0
1	N/A	2	1	0	1	N/A	0
1	N/A	1	2	0	2	N/A	0
1	N/A	2	2	0	2	N/A	0
No = 0	No = 0	Poor = 0	a = 0	a = 0	Beginner = 0		No = 0
Yes = 1	Yes = 1	Good = 1	b = 1	b = 1	Intermediate = 1		Yes = 1
		Excellent = 2	c = 2	c = 2	Advanced = 2		

Appendix Q.
Raw Data

Survey 3 to Finish	Error 3 to Finish	Survey 3 to 8	Error 3 to 8	Survey 3 to 6	Error 3 to 6	C1 Planned Route	C1 Attempted	C1 Found
150	24	270	80	180	44	1	1	1
125	1	216	26	163	61	1	1	1
110	16	250	60	150	74	0	1	1
130	4	240	50	180	44	0	1	1
150	24	170	20	180	44	2	1	1
120	6	270	80	210	14	0	1	1
100	26	190	0	170	54	0	1	1
120	6	270	80	240	16	2	1	1
270	144	60	130	280	56	0	1	1
80	46	130	60	95	129	0	1	1
155	29	205	15	230	6	0	1	1
110	16	205	15	142	82	0	1	1
150	24	230	40	170	54	0	1	1
130	4	250	60	170	54	0	1	1
120	6	230	40	160	64	0	1	1
	19.8		46		40.4	0.6	1	1
	21.2		42		57	0.4	1.0	1
	34.2		63.2		61.8	0.2	1	1
126		190		224		Beginner = 0	No = 0	No = 0
						Intermediate = 1	Yes = 1	Yes = 1
						Advanced = 2		
					Adv	0.666666667		
					Inter	0.222222222		
					Begin	0.666666667		

Appendix Q.
Raw Data

C1 Intentional Errors	C1 Unintentional Errors	C1 Distance off route	C1 Map Checks	C1 Map w/ Compass Checks	C1 Total Checks
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	1	1040	1	0	1
0	1	278	0	0	0
0	0	0	0	0	0
0	1	92	1	0	1
0	1	204	1	2	3
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	1	655	1	0	1
0	0	0	0	0	0
0	1	734	0	0	0
0	0.4	267	0.6	0.4	1.0
0	0.6	278	0.2	0.0	0.2
0	0.2	56	0.0	0.0	0.0

Appendix Q.
Raw Data

C2 Planned Route	C2 Attempted	C2 Found	C2 Intentional Errors	C2 Unintentional Errors	C2 Distance off route	C2 Map Checks
0	1	1	0	0	0	0
0	1	1	0	0	0	0
0	1	1	0	0	0	1
1	1	1	0	1	13	0
2	1	0	0	1	2145	8
0	1	1	0	1	34	1
1	1	1	0	1	230	2
1	1	1	0	0	0	0
1	1	1	0	1	260	1
1	1	1	0	1	74	0
1	1	1	0	0	0	0
1	1	1	0	0	0	0
0	1	1	0	1	66	1
0	1	1	0	1	822	3
0	1	1	0	0	0	0
0.8	1	1.0	0	0.6	101	0.6
0.0	1.0	1.0	0	0.6	184	1.2
1.0	1	0.8	0	0.4	444	1.6
Beginner = 0	No = 0	No = 0				
Intermediate = 1	Yes = 1	Yes = 1				
Advanced = 2						

Appendix Q.
Raw Data

C2 Map w/ Compass Checks	C2 Total Checks	C3 Planned Route	C3 Attempted	C3 Found	C3 Intentional Errors
0	0	2	1	1	0
0	0	2	1	1	0
0	1	2	1	1	0
0	0	0	1	1	0
0	8	2	0	0	0
0	1	0	1	1	0
0	2	2	1	1	0
0	0	2	1	1	0
1	2	2	1	1	0
0	0	2	1	1	0
0	0	2	1	1	0
0	0	2	1	1	0
0	1	2	1	1	0
0	3	2	1	1	0
0	0	2	1	1	0
0.2	0.8	1.6	1	1.0	0.0
0.0	1.2	1.6	1.0	1.0	0.0
0.0	1.6	2.0	0.8	0.8	0.0
		Beginner = 0	No = 0	No = 0	
		Intermediate = 1	Yes = 1	Yes = 1	
		Advanced = 2			

Appendix Q.
Raw Data

C3 Unintentional Errors	C3 Distance off route	C3 Map Checks	C3 Map w/ Compass Checks	C3 Total Checks	C4 Planned Route
0	0	0	0	0	2
0	0	0	0	0	1
1	136	1	0	1	2
1	194	0	0	0	0
1	152	1	0	1	2
0	0	1	0	1	2
0	0	0	0	0	0
1	51	0	0	0	2
0	0	0	0	0	0
1	21	0	0	0	2
0	0	0	0	0	2
0	0	0	0	0	0
0	0	1	0	1	0
1	18	0	0	0	0
0	0	0	0	0	1
0.4	49	0.0	0	0.0	0.80
0.4	31	0.6	0	0.6	1.00
0.4	35	0.2	0.0	0.2	1.40
					Beginner = 0
					Intermediate = 1
					Advanced = 2

Appendix Q.
Raw Data

C4 Attempted	C4 Found	C4 Intentional Errors	C4 Unintentional Errors	C4 Distance off route	C4 Map Checks
1	1	0	0	0	0
1	1	0	1	60	1
1	1	0	1	58	0
1	1	0	1	882	0
0	0	0	1	328	3
1	1	0	0	0	0
1	1	0	1	950	4
1	1	0	1	1457	3
1	0	1	1	1960	5
1	1	0	1	125	0
1	1	0	0	0	0
1	1	0	1	768	2
1	1	0	1	744	4
1	1	0	1	457	2
1	1	0	0	0	0
1	0.8	0.2	0.8	1050	2.4
1.0	1	0	0.6	252	1.2
0.8	0.8	0	0.8	256	1.2
No = 0	No = 0				
Yes = 1	Yes = 1				

Appendix Q.
Raw Data

C4 Map w/ Compass Checks	C4 Total Checks	C5 Planned Route	C5 Attempted	C5 Found	C5 Intentional Errors
0	0	1	1	1	0
0	1	1	1	1	0
0	0	1	1	1	0
0	0	0	1	1	0
5	8	1	0	0	0
0	0	0	1	1	0
0	4	0	1	1	0
6	9	0	1	1	0
17	22	0	0	0	0
0	0	1	1	1	0
0	0	1	1	1	0
0	2	0	1	1	0
0	4	1	1	1	0
0	2	0	1	1	0
0	0	1	1	1	0
4.6	7	0.2	0.8	0.8	0
0	1.2	0.6	1.0	1	0
1	2.2	0.8	0.8	0.8	0
		Beginner = 0	No = 0	No = 0	
		Intermediate = 1	Yes = 1	Yes = 1	
		Advanced = 2			

Appendix Q.
Raw Data

C5 Unintentional Errors	C5 Distance off route	C5 Map Checks	C5 Map w/ Compass Checks	C5 Total Checks	C6 Planned Route
0	0	0	0	0	0
0	0	0	0	0	0
1	260	1	0	1	0
0	0	0	0	0	0
1	128	1	1	2	0
0	0	0	0	0	0
1	64	1	1	2	0
0	0	0	1	1	0
1	265	1	1	2	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	2
0	0	0	0	0	2
0	0	0	0	0	0
0	0	0	0	0	0
0.4	65.8	0.4	0.6	1	0
0.2	52	0.2	0.0	0.2	0.4
0.2	25.6	0.2	0.2	0.4	0.4
					Beginner = 0
					Intermediate = 1
					Advanced = 2

Appendix Q.
Raw Data

C6 Attempted	C6 Found	C6 Intentional Errors	C6 Unintentional Errors	C6 Distance off route	C6 Map Checks
1	1	0	0	0	0
1	1	0	0	0	0
1	1	0	1	204	1
1	1	0	0	0	0
0	0	0	1	255	3
1	0	0	1	1450	7
1	1	0	1	61	2
1	1	0	0	0	0
0	0	0	1	216	1
1	1	0	1	105	0
1	1	0	0	0	0
1	1	0	0	0	1
1	1	0	1	25	2
1	1	0	0	0	0
1	1	0	1	110	1
0.8	0.8	0	0.4	60	0.6
1.0	0.8	0	0.8	358	2.2
0.8	0.8	0	0.4	72	0.5
No = 0	No = 0				
Yes = 1	Yes = 1				

Appendix Q.
Raw Data

C6 Map w/ Compass Checks	C6 Total Checks	C7 Planned Route	C7 Attempted	C7 Found	C7 Intentional Errors
0	0	1	1	1	0
0	0	1	1	1	0
0	1	1	1	1	0
0	0	0	1	1	0
0	3	2	0	0	0
0	7	2	0	0	0
0	2	1	1	0	0
0	0	2	1	1	0
0	1	1	0	0	0
0	0	2	1	1	0
0	0	2	1	1	0
0	1	1	1	1	0
0	2	1	1	1	0
0	0	0	1	1	0
0	1	2	1	1	0
0	0.6	1	0.8	0.6	0
0	2.2	1.2	0.8	0.8	0
0	0.8	1.6	0.8	0.8	0
		Beginner = 0	No = 0	No = 0	
		Intermediate = 1	Yes = 1	Yes = 1	
		Advanced = 2			

Appendix Q.
Raw Data

C7 Unintentional Errors	C7 Distance off route	C7 Map Checks	C7 Map w/ Compass Checks	C7 Total Checks	C8 Planned Route
0	0	1	0	1	0
0	0	0	0	0	0
0	0	2	0	2	0
0	0	0	0	0	0
1	377	1	1	2	2
1	664	1	1	2	1
1	388	0	0	0	1
1	450	1	1	2	1
1	486	1	1	2	0
1	450	1	0	1	2
0	0	0	0	0	0
0	0	0	0	0	1
0	0	0	0	0	1
0	0	1	0	1	0
0	0	0	0	0	2
0.6	265	0.6	0.4	1.0	0.4
0.2	132.8	0.8	0.2	1.0	0.8
0.4	165	0.4	0.2	0.6	1
					Beginner = 0
					Intermediate = 1
					Advanced = 2

Appendix Q.
Raw Data

C8 Attempted	C8 Found	C8 Intentional Errors	C8 Unintentional Errors	C8 Distance off route	C8 Map Checks
1	1	0	0	0	0
1	1	0	0	0	0
1	1	0	0	0	0
1	1	0	0	0	0
0	0	0	1	253	1
0	0	0	1	540	1
0	0	0	1	356	1
1	0	0	1	748	1
0	0	0	1	382	1
1	1	0	1	87	0
1	1	0	0	0	0
1	1	0	0	0	0
1	1	0	1	152	1
1	1	0	1	194	1
1	1	0	0	0	0
0.6	0.4	0	0.6	297.2	0.6
0.8	0.8	0	0.6	177	0.6
0.8	0.8	0	0.4	68	0.2
No = 0	No = 0				
Yes = 1	Yes = 1				

Appendix Q.
Raw Data

C8 Map w/ Compass Checks	C8 Total Checks	C9 Planned Route	C9 Attempted	C9 Found	C9 Intentional Errors
0	0	2	1	1	0
0	0	2	1	1	0
0	0	2	1	1	0
0	0	0	1	1	0
1	2	2	0	0	0
1	2	1	0	0	0
1	2	0	0	0	0
1	2	2	0	0	0
1	2	0	0	0	0
0	0	2	1	1	0
0	0	2	1	1	0
0	0	1	1	1	0
0	1	0	1	0	0
0	1	0	1	1	0
0	0	0	1	1	0
0.6	1.2	0.8	0.4	0.4	0
0.2	0.8	0.6	0.8	0.6	0
0.2	0.4	1.8	0.8	0.8	0
		Beginner = 0	No = 0	No = 0	
		Intermediate = 1	Yes = 1	Yes = 1	
		Advanced = 2			

Appendix Q.
Raw Data

C9 Unintentional Errors	C9 Distance off route	C9 Map Checks	C9 Map w/ Compass Checks	C9 Total Checks	Avg Planned Route
1	234	0	0	0	1
1	420	1	0	1	0.9
1	469	2	0	2	0.9
0	0	0	0	0	0.1
1	310	2	0	2	1.7
1	572	2	0	2	0.7
1	614	2	0	2	0.6
1	330	2	0	2	1.3
1	609	2	0	2	0.4
1	826	7	0	7	1.3
1	282	0	0	0	1.1
1	550	0	0	0	0.9
1	105	2	0	2	0.8
0	0	0	0	0	0.2
1	118	0	0	0	0.9
0.8	357.4	1.2	0	1	0.7
0.8	253	1.2	0	1.5	0.7
1	478	2	0	0.75	1.2

Appendix Q.
Raw Data

Controls Attempted	Controls Found	% Controls Found	Active Errors	Default Errors	Total Errors	Active Distance off Route
9	9	100%	1	0	1	234
9	9	100%	2	0	2	480
9	9	100%	5	0	5	1127
9	9	100%	4	0	4	2129
2	1	11%	2	7	9	2800
6	5	55%	2	3	5	1364
7	6	66%	6	2	8	1397
8	7	77%	5	1	6	2483
4	3	33%	3	5	8	2037
9	9	100%	7	0	7	1688
9	9	100%	1	0	1	282
9	9	100%	2	0	2	1318
9	8	89%	5	1	6	1642
9	9	100%	4	0	4	1491
9	9	100%	3	0	3	962
7.4	6.8	75%	3.8	1.6	5.4	1656
8.4	8	89%	3.8	0.8	4.6	1317.2
7.6	7.4	82%	2.8	1.4	4.2	1313.6

Appendix Q.
Raw Data

Default Distance off Route	Total Distance Off-Route	Active % of Total Distance off Route	Active Map Checks
0	234	100%	1
0	480	100%	2
0	1127	100%	8
0	2129	100%	1
1426	4226	66%	8
1896	3260	42%	9
1358	2755	51%	10
757	3240	77%	5
2141	4178	49%	6
0	1688	100%	8
0	282	100%	0
0	1318	100%	3
105	1747	94%	12
0	1491	100%	7
0	962	100%	1
851.2	2507	75%	5
400.2	1717	87%	7
285.2	1599	93%	4

Appendix Q.
Raw Data

Default Map Checks	Total Map Checks	Active Map w/Compass Checks	Default Map w/Compass Checks
0	1	0	0
0	2	0	0
0	8	0	0
0	1	0	0
12	20	0	8
4	13	0	2
3	13	1	1
3	8	10	1
6	12	18	3
0	8	0	0
0	0	0	0
0	3	0	0
0	12	0	0
0	7	0	0
0	1	0	0
2	7	5.8	1
1	8.2	0	0.4
2	6.6	0	1.6

Appendix Q.
Raw Data

Total Map w/ Compass Checks	Total Active Checks	Total Default Checks	Total Checks	Active % of Total Checks	% Controls Found
0	1	0	1	100%	100%
0	2	0	2	100%	100%
0	8	0	8	100%	100%
0	1	0	1	100%	100%
8	8	20	28	29%	11%
2	9	6	15	60%	55%
2	11	4	15	73%	66%
11	15	4	19	79%	77%
21	24	9	33	73%	33%
0	8	0	8	100%	100%
0	0	0	0	100%	100%
0	3	0	3	100%	100%
0	12	0	12	100%	89%
0	7	0	7	100%	100%
0	1	0	1	100%	100%
6.8	10.4	3.4	13.8	85%	75%
0.4	7.4	1.2	8.6	92%	89%
1.6	4.2	4	8.2	86%	82%

Appendix Q.
Raw Data

Average number of route errors per control	Average Length of Error	Average Checks per Control
0.1	234	0.1
0.2	240	0.2
0.6	225.4	0.9
0.4	532	0.1
9.0	470	28.0
1.0	652	3.0
1.3	344	2.5
0.9	540	2.7
2.7	522	11.0
0.8	241	0.9
0.1	282	0.0
0.2	659	0.3
0.8	291	1.5
0.4	373	0.8
0.3	321	0.1
1.1	434.6	3.3
0.6	372.4	1.3
2.1	378.3	5.9

APPENDIX R.

Glossary

Landmark Knowledge

This is where the navigator orients himself by highly salient visual landmarks. In the case of the natural environment this may be a prominent hill top, road junction, or small lake. This type of knowledge is characterized by having a direct visual image of the feature. The existence of landmarks is key in the early formation of navigational knowledge upon which subsequent learning will create route and survey knowledge (Thorndyke, 1980).

Route Knowledge

The ability to navigate from one spot to another utilizing landmarks or other visual features to prompt the navigator to turn left, turn right, or proceed in a new direction. The ability to recall these features allows you to give directions to another person from a point located along the known route. Not being able to recall the features only gives you the ability to recognize them on site but not give directions to others. Route knowledge is knowledge from an ego-centered frame of reference usually gained by personal exploration of the area. It does not recognize alternate routes or short-cuts. Knowledge of the relationships among features along the route is unidirectional where the knowledge may be known of how to go from point A to B, but not from point B to A (Allen and Kirasic, 1985).

Survey Knowledge

Sufficient navigational experience eventually provides what Thorndyke refers to as survey knowledge. The knowledge resides internally as a "cognitive map". The ability to describe the relative locations of landmarks, and the distances among them even though a route among them has never been traveled is an example of survey knowledge. Survey knowledge, unlike route knowledge, is based on an exocentric point of view, much like a birds eye point of view for the navigator restricted to foot travel. It is tantamount to having a mental representation of a physical map (Goldin & Thorndyke, 1982). Survey knowledge built through personal experience of the actual environment is referred to as "primary" experience (Presson & Hazelrigg, 1984). Survey knowledge acquired through some other means such as map, picture, or VE is known as "secondary" experience (Goldin & Thorndyke, 1982) (Thorndyke & Hayes-Roth, 1982). Presson & Hazelrigg (1984) and Scholl (1993) have shown that survey knowledge obtained in this fashion is inferior to primary survey knowledge. The inferiority has been shown to arise with the location and orientation of landmarks. If a person has both route knowledge and primary survey knowledge they have complete navigational awareness (Satalich, 1995).

Orienteering

A sport that utilizes a specialized map and simple compass. Orienteering competitions (events) are varied in type, but they all involve the use of map and compass to find 12" x 12" three sided markers called controls. The controls are normally half white, half international orange, separated along the diagonal of the 12" x 12" square, on each of the three sides. Thus the control is designed for equal visibility no matter what direction it is approached from (presuming there are no intervening obstacles). Orienteering events are usually held in natural environments as opposed to urban settings where several course are offered reflecting different levels of difficulty.

Difficulty is determined by a two fold metric that examines course length and the technical difficulty of the controls placed therein. Courses levels are identified by color names where white is for a beginner course of about 3km in total straight line distance connecting all the controls (there are anywhere from 7 to 15 controls per course depending on course level and the course setter's discretion). Controls are normally found in a prescribed sequence, indicated by the map, and skipping or missing a control results in participant disqualification (all controls must be found in sequence in order for the participant's run to qualify for ranking.

All starts for the different courses are typically from the same point with the courses diverging from there. Control features are contained within a circle normally 30 to 50 meters in diameter with the feature itself being located at or near the center of the circle and a description of the feature provided on the attached clue sheet (see clue sheet below). Lines connect the controls so that the participant can see the sequence that the controls must be visited from start to finish. Participants prove that they have visited a control by "punching" a score card with a pattern producing punch (about the size and shape of a pocket stapler) which is unique to that control.

Unlike most other outdoor distance events route selection is left up to the participant. Route selection is extremely important in the sport and allows for more mature and experienced participants to outperform younger more athletic ones.

Orienteering Map

A highly detailed map normally produced at a 1:15,000 scale for official competitions with larger scales of 1:10,000 or 1:7,500 used sometimes for unofficial events.

Vegetation is portrayed in a much more detailed way than what is normally done for either military topographic maps, USGS topographic maps, or trail maps. Vegetation is categorized by its ability to be run through, which reflects the sport's characteristic of racing against the clock over unfamiliar terrain with map and compass to guide you to the controls marked on your map. Typically vegetation is classified as easy running (no obstructions) to fight (obstructing vegetation so thick it is best avoided). It should be noted here that the ability to move rapidly through vegetation does not necessarily correlate with an ability to see easily through that same vegetation. Thus low lying scrub that provides excellent visibility over its top may nonetheless by classified as fight due to an impenetrable density.

Orienteering maps also normally contain "micro" features normally too small to be included in military or USGS maps. These micro features include but are not limited to small pits 1 meter deep and 1 meter in diameter, isolated boulder(s), individual trees or bushes when mapping them does not make clutter and contributes to the course setters options by providing more features, minor cliffs, embankments, telephone poles and wire, indistinct paths, and many other manmade and natural features.

By containing more features the Orienteering map provides the course setter and competitor with a finer more detailed representation of an environment and in turn greater opportunities for testing navigation skills while under the clock. Standardized colors, patterns, markers, and lines are used to depict the various features. For more information on Orienteering maps see the International Orienteering Federation's (IOF) Specifications for Orienteering Maps in Appendix 1.

Clue Sheet

A description sheet attached to each map that has the details on the location of each control. Beginner's descriptions are written in English. On intermediate and advanced courses, IOF symbols are used. (see Figure 1 for clue sheet with descriptions used in this experiment).

Rough Map Reading

A technique for map simplification where all but large or conspicuous guiding features are eliminated from the participant's route planning consideration in order to only include those features that will help guide the participant into the vicinity of the control. This method is commonly used exclusively by beginners and selectively by intermediate and advanced orienteer (Lowry and Sidney, 1989).

Precision Map Reading

A concentration on the fine detail of a map as an orienteer approaches the vicinity of a control. This method is normally used by intermediate and advanced orienteers as they move down the last quarter of a route and approach the vicinity of the control on a map with many details vicinity of the control (Lowry and Sidney, 1989).

Attack Point

A distinct easily found feature usually within 200 meters of the control. The point serves to break up the route in segments thereby minimizing the probability of drift off the route. Typical attack points are trail junctions, field corners, trail bends, hills, and re-entrants (also known as a draw where the land rises on three sides and drops on one creating a natural funnel that leads up hill to a ridge or hill top.

Handrail

A linear feature such as a road, trail, stream, or ridge that allows the orienteer to follow it as a guide which is parallel or congruent with the desired or most direct route.

Catching Feature

A prominent feature included in a route plan so that when encountered it triggers a change in direction.

Attacking From Above

A method for finding a control which advocates when possible approaching a control from above and walking downhill towards it thereby gaining the widest field of vision, and being fresher (of clearer mind) by eliminating a fatiguing uphill climb while simultaneously scanning for the control.

Aiming Off

A method where the orienteer deliberately plots a route to one side or the other of the direct route. It exploits the existence of handrails to one side or the other when used *along the route*. It is also used to *extend the control* by aiming off to a distinct linear feature that will lead you directly into the control. It also can be used for going *behind the control* into a large catching feature which when found tells you to turn one direction or the other and go into the control (Lowry and Sidney 1989).

Parallel Error

The confusion of one part of the map or terrain with another similar section.

Default Error

A penalty applied against those who due to running out of time, did not get to look for a given control(s) . Within the context of this experiment, a failure on a participant's part to begin looking for a control because of the expiration of allotted time while searching (unsuccessfully) for the preceding control. An example would be where a participant finds controls 1 - 4, and while searching for control 5, the allotted hour expires. In this example this participant would be given four default errors (one for each of the four remaining controls in the nine control course that the participant failed to even begin searching for. This is a penalty applied to participants who do not finish the course so that better statistical comparisons can be made between them and those who do finish the course.

Default Distance Off Route

A penalty applied against those who due to running out of time, did not get to look for a given control(s) . It is calculated by summing all planned route distances (in meters) on all controls where a Default Error occurred, and the most probable (an inference on the likely route a participant would take to get from their current location to back onto their planned route – if they are not already on it) route into the control they were looking for when official time expired. This is a penalty applied to participants who do not finish the course so that better statistical comparisons can be made between them and those who do finish the course.

Default Checks

A penalty applied against those who due to running out of time, did not get to looking for a given control . It is calculated by taking the treatment group with the highest average for map checks on a given control and if it is not a whole number, rounding that number up, and assigning that number to that participant's map checks for that control. . This is a penalty applied to participants who do not finish the course so that better statistical comparisons can be made between them and those who do finish the course.

Default Map with Compass Checks

Identical to the Default Checks above except this penalty is for the Map with Compass Checks category as opposed to the map only checks (Default Checks). This is a penalty applied to participants who do not finish the course so that better statistical comparisons can be made between them and those who do finish the course.

Active Errors

The sum of actual observed deviations from planned route over a participants course run. Every instance is where the participant left the tolerances of his marked route. See Active Distance Off Route below for tolerances.

Active Map Checks

An actual observed participant's map only check. Each instance represents a 30 second period where the participant was given the map to orient themselves.

Active Map with Compass Checks

An actual observed participant's map and compass check. Each instance represents a 30 second period where the participant was given the map and compass to orient themselves.

Active Distance Off Route

The sum of all deviations (in meters) of where the participant went off their marked route while looking for the controls. This figure is only for those controls that a participant found, and in the case of not finishing the course, the actual distance off route while looking for that control when time expired. The tolerances for what is considered "on route" are:

1. If the route is marked on road or trail then on route is not straying beyond five meters to left or right of that trail.
2. If the marked route is not on road or trail then staying within 15 meters to the left or right of the marked route is considered as being on route,

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