



Weapon-Centric Graphic Controller User Evaluation

**by Elizabeth S. Redden, Daniel D. Turner, Christian B. Carstens,
and David E. Miller**

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14. ABSTRACT The purpose of this research was to provide feedback to the designers of dismounted warfighter input devices on the performance and suitability of four different weapon-centric graphic control (WGC) designs. The Human Research and Engineering Directorate of the U.S. Army Research Laboratory's Fort Benning Field Element was requested by the Technology, Systems, and Program Integration Directorate (TSPID) within Natick to perform this research. The experiment took place at Fort Benning, GA, using 48 Soldiers from the 3/11th Infantry Regiment. Four prototype WGC configurations were investigated, and each came in joystick and trackball versions (a total of eight devices). The tasks that were used to evaluate the WGCs required the participants to use the full range of controls (continuous and discrete controls) as well as perform simultaneous actions with both control types. After training, each Soldier completed exercises using the eight different input configurations. The WGC configurations were evaluated for effects on task performance and usability (based on objective performance data, data collector observations and ratings, and Soldier questionnaires). Both objective performance and subjective ratings indicated that the trackball system mounted on the forward pistol grip was the best item evaluated in terms of speed and accuracy.					
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1. Introduction

Computer evolution reflects successive adaptive changes to environmental and consumer demands and constraints. Computers have thus evolved over time to better meet our needs. As an example, consider the huge change in computer size and processing speed. Natural selection arising through consumer demand has resulted in increasingly smaller and faster computers that work well in environments outside of the large air-cooled rooms that were previously required. Now, computers are migrating into diverse and demanding environments that are seemingly incompatible with sophisticated electronics.

One of the most challenging and unlikely environments for a computer is the warfighter's environment. Environmental demands run the extremes of searing heat to bitter cold, desert sand to tropical rain, brightest daylight to darkest night, indoors and outdoors, from moving about in heavily armored vehicles to hiking long distances on foot. The environmental demand posed by the dismounted warfighter presents particular challenge. His posture, equipment, clothing, speed of movement, and multiple task loads create an extremely unfriendly environment for the computer. The military has invested in several programs (e.g., Soldier Integrated Protective Ensemble, Land Warrior, Warrior's Edge, Smart Sensor Web, Future Force Warrior [FFW], etc.) to create a capability that provides a seamless link between the Soldier and available information about the environment and the battle. While each program has created adaptive changes that make the computer more compatible with the warfighter's environment, there are still many challenges.

How do we design a computer input device that suits the dismounted warfighters' needs? First, the device must be small, rugged, and lightweight. It must be worn or carried in a position that is immediately accessible to the warfighters, even when they are firing a weapon or in various body postures such as the kneeling and prone positions. Second, the device must be operable by both right- and left-handed users who may or may not be wearing environmentally protective gloves. It must be easy to activate but resistant to inadvertent activation. Third, it is critical that the device be simple to use by diverse users (e.g., age, rank, education, training, etc.) who may have little experience with the device. Fourth, it must be so intuitive and reliable that it can be easily used, without deliberate thought or effort, during demanding life or death situations, but sophisticated enough to perform a variety of complex tasks. How then can designers afford warfighters the capabilities they need while making the device ever smaller, lighter, and easier to use?

Existing research on input devices has largely focused on computer workstations, laptops, and games, and the results have been inconsistent. The indication is that there is no "one" best input device because many of them excel for some tasks and are woefully inadequate for others. It also seems inappropriate to always characterize input devices by names such as "joystick,"

“trackball,” or “mouse” because even within these categories, there are many varied characteristics. If we group devices together according to some similarity in their mechanical construction, we must also consider other dimensions of design significance (i.e., control display ratio, speed of movement, force control or no force control, size, shape, location, etc.). Ultimately, the driving factors depend on purpose. We cannot identify the “best” input device (mouse, joystick, or trackball) to meet a capability requirement without considering the specific context in which the device will be used so that we may identify the design characteristics that are likely to have the greatest impact. Design dimensions such as placement of controls on the warfighter’s body or weapon, as well as size and type of controls for continuous input (e.g., trackballs or joysticks), type and size of controls for discrete input (e.g., buttons), and feedback provided by the controls are of particular interest.

As we consider the task demands of the dismounted warfighter, it is easy to identify some problems with the usual default continuous input device, the mouse. While easy and intuitively used on a desktop, one can easily imagine the challenge when attempting to use it while on the move (i.e., no flat, relatively large surface across which to move it, the user has to pick it up to move the cursor, etc.). Consequently, two alternatives are considered: trackballs and joysticks. Both devices have been used in previous dismounted warfighter programs, both require a relatively small space in which to operate, and both have demonstrated field reliability.

1.1 Trackballs

A trackball is a mouse alternative designed so that the fingers move a ball that is housed within a unit. Some incorporate a small ball for use by the thumb or a small centrally mounted ball for use by a single finger. It is more commonly a large ball for several fingers to control with control buttons positioned on either side or above the ball. The trackball is especially effective for rapid cursor movement with high accuracy (Bullinger et al., 1997). The control-display gain can be set so that slow-velocity movements of the ball will allow sensitive control of the cursor, and fast movements will allow the ball to move more easily for rapid and large cursor movements. Also, using fingers is more precise than hand and wrist movements. The trackball is comfortable to use for extended periods because often the forearm can be supported (Greenstein, 1997). It provides direct tactile feedback from the ball’s rotation. It never requires repositioning, so little space is required to use it; it can be placed on multiple types of surfaces; and it can be incorporated into a small space (Bullinger et al., 1997). These features result in compatibility with mobile applications. However, tracing and hand drawing are difficult with a trackball (Bullinger et al., 1997). There are both mechanical and optical trackballs, although the former is the most common.

Because trackballs have many advantages (i.e., size and space requirements, use in mobile operations and on many types of surfaces, etc.), they have already been incorporated into some of the Army’s programs. For example, FFW integrated a trackball into the input device used by the Soldiers. The idea of a trackball was well-accepted by the Soldiers because it was readily

available and easily used. However, the specific trackball design had some problems. The buttons on the trackball mouse were inadvertently pressed when stored on the Soldiers' vests. Soldiers complained that the location on the vest chassis was not convenient and suggested mounting it on their weapons because they did not like to have to remove their hands from their weapons to use it. Additionally, the trackball mouse was found to be less than reliable due to the inability to weatherproof the device (Turner and Carstens, 2007).

1.2 Joysticks

Joysticks are also a popular control option for continuous input devices and for handheld pointing. Joysticks are usually vertical lever input devices that can move freely in two or more directions by pivoting on a base and that report their positions to the devices they are controlling. Isometric joysticks are pressure-sensitive devices that have handles that do not move when pushed. Rather, the shaft senses how hard it is being pushed and in what direction. Many joysticks often have buttons located near them that provide additional information to the device. Joysticks have been in use for many years, their operation is fairly apparent to most users, and they usually require minimal space. Using a joystick decreases shoulder muscular load compared to a mouse and allows easy accomplishment of simultaneous functions (Buxton, 1986). Some joysticks allow the user to twist the shaft while moving the lever (it is much harder to twist a trackball while it is being rolled). Silfverberg et al. (2001) found that an isometric joystick is suitable as a pointing device for handheld terminals and can be manipulated with the same hand that holds the device. However, Buxton (1986) found that panning was easier with the trackball than with the joystick because the trackball was more intuitive. The user rolls the trackball in the desired direction at the desired speed of movement and the cursor moves accordingly. In contrast, the speed of cursor movement with the joystick is often controlled by the displacement of the joystick from center, and this often requires significant practice for high performance. Douglas and Mithal (1994) found that joysticks were inferior to a mouse for pointing tasks and were very sensitive to physiological tremors. They are best used for continuous tracking tasks and for pointing tasks in which precision requirements are low. Like trackballs, drawing or tracing tasks are difficult with joysticks.

The Land Warrior system incorporates a thumb joystick cursor controller. In a user survey, experienced Land Warrior users rated the joystick as being good (5.1 on a scale of 1 to 7). Many stated that it was simple to use, that cursor movement worked well, and that thumb control of the joystick was a good concept (Turner, 2008).

1.3 Controller Mounting Location

The ideal location for a Soldier computer controller has been a topic of debate within the Army for several years. Some designers suggest that Soldiers would be resistant to a controller that requires them to remove their hands from their weapons to operate it. Others suggest that Soldiers would only operate their computers in safe and secure environments and that weight added to the Soldiers' weapons is undesirable and can have the unintended consequences of

adversely affecting weapon balance and hit probabilities as well as individual movement techniques. In a Land Warrior user survey, Soldiers rated the ability to mount the controller to the weapon as a low priority for the Land Warrior Soldier Control Unit (Turner, 2008). They were split in their opinions concerning whether a controller should be mounted on a weapon or not. The following comments demonstrate their thoughts on the pros and cons of mounting the controller on a weapon.

Pros:

- Would not have to remove hands from the weapon to control the cursor and would be ready to shoot at all times.
- Would allow the Soldier to maintain better control of his weapon.
- The weapon would always be in the Soldier's hands (constant availability).
- Convenient location.
- Would allow the Soldier to engage the enemy and talk on the radio at the same time.

Cons:

- Soldiers do not like mounting extraneous things on their weapon.
- Would make the weapon too heavy.
- Would make the weapon bulky.
- Would adversely affect weapon balance.
- Changes how the Soldier would hold the weapon.
- Too much mounted on the weapon already.
- Could adversely affect accuracy.
- Would require that the weapon be held in the ready position at all times, hence the Soldier couldn't carry the weapon slung or use the controller in the vehicle (Stryker) from where the weapon is stored.
- Would get in the way of how the Soldier fires the weapon.

1.4 Overview of Present Research

This experiment took place at Fort Benning, GA, during 8–12 December 2008 using 48 Soldiers from the 3/11th Infantry Regiment. The purpose of the research was to provide feedback to the designers of dismounted warfighter input devices on performance and suitability of four weapon-centric graphic control (WGC) configurations. The Human Research and Engineering Directorate (HRED) of the U.S. Army Research Laboratory's Fort Benning Field Element was

requested to conduct this study by the Technology, Systems, and Program Integration Directorate within Natick using four prototype WGCs that incorporated different input configurations. One configuration was mounted on a forward pistol grip attached to the weapon, one was mounted under the barrel of the weapon, one allowed the user to choose between a weapon-mounted and handheld configuration, and one was partially mounted to the M4 carbine (the mouse controls were detachable and mountable to the Soldier's body armor). Each configuration came in joystick and trackball versions for continuous input (a total of eight devices). The systems consisted of typical controls found in a computer mouse (right and left discrete click buttons and a joystick or tracker ball continuous control) and were tethered to a computer.

The tasks used to evaluate the WGCs required the participants to use the full range of controls (continuous and discrete controls) as well as perform simultaneous actions with both control types. Soldiers were trained on the evaluation tasks using a computer mouse, so there would be no learning curve due to the task itself. After training, each Soldier completed exercises using the eight different input configurations. The WGC configurations were evaluated for effects on task performance and usability (based on objective performance data, data collector observations and ratings, and Soldier questionnaires).

2. Method

2.1 Participants

Forty-eight Soldiers from Headquarters Company 3/11 Officer Candidate School (OCS) participated in this evaluation. Their mean age was 29 years and their grades ranged from E4 to E7.

2.2 Instruments and Apparatus

2.2.1 Demographic Questionnaire

A demographic questionnaire was administered to collect information pertaining to Soldier characteristics and experience. Detailed demographic information can be found in appendix A.

2.2.2 Input Device Evaluation Apparatus (IDEA)

The IDEA (appendix B) is an integrated group of timed tasks designed in Microsoft PowerPoint that require the user to exercise discrete and continuous input device functions. These tasks were developed for this evaluation and pilot tested before being administered to the Soldiers to ensure that each task could be performed in the given time limit and that performing the tasks did not have a steep learning curve after training on the tasks with a mouse. Tasks include tracing a line, pointing, clicking and dragging objects, selecting items from two or more tier drop-down menus, highlighting, and creating geometric shapes. Task time limits range from 20 to 45 s.

2.2.3 Questionnaires

Two types of questionnaires were developed specifically for this experiment and administered during this evaluation. The first type was a post-iteration questionnaire, which was administered at the completion of each trial with each system. The questionnaire consisted of seven-point semantic differential scaled questions and open-ended questions. Questions covered ratings of the adequacy of training the Soldiers received with each system, specific design features present in the systems, and ease of task performance. Open-ended questions requested the Soldiers to evaluate the devices. The second type of questionnaire was an end-of-experiment questionnaire. This questionnaire consisted of seven-point semantic differential scales, which asked the Soldiers to rank the types of systems on different dimensions and open-ended questions.

2.2.4 WGCs

There were four candidate systems with two versions (joystick and trackball) of each for a total of eight systems. Descriptions of the systems, designed by Artisent, Inc., follow.

2.2.4.1 System A. This system mounts under the M-4 carbine on the Picatinny rail. It is designed to be ambidextrous and have a 45° rotation capability. All controls are in a single location on a forward handgrip. Figures 1 and 2 show system A in the trackball control configuration

2.2.4.2 System B. This system is designed to attach under the barrel of the M-4. It is ambidextrous and has all the controls in a single location. The system is designed to conform to the handgrip. Figures 3 and 4 show the system B in the trackball configuration.

2.2.4.3 System C. This system is designed to be a split-design concept with the mouse controls located in a separate module that can be mounted on the Soldier's body and the "push to talk" and other controls mounted on a small module attached to the M-4. This provides a low profile on the weapon with integrated "push to talk" radio communications readily available. Figures 5 and 6 show the system in the trackball configuration.

2.2.4.4 System D. This system is designed to be a split-design concept with the control unit removable from the weapon if desired. It presents a low profile on the weapon with the graphic controller mounted on the weapon or removable and handheld. Figures 7 and 8 show the system in the trackball configuration.

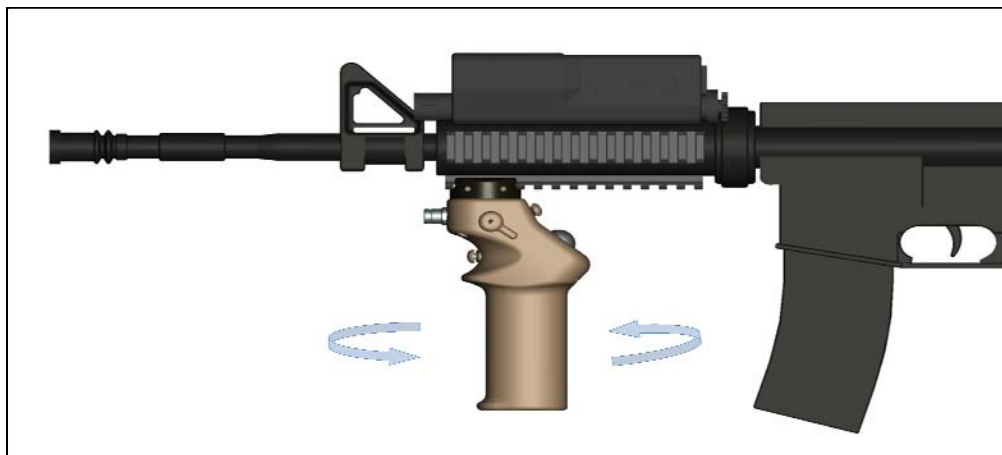


Figure 1. System A mounted on M-4.

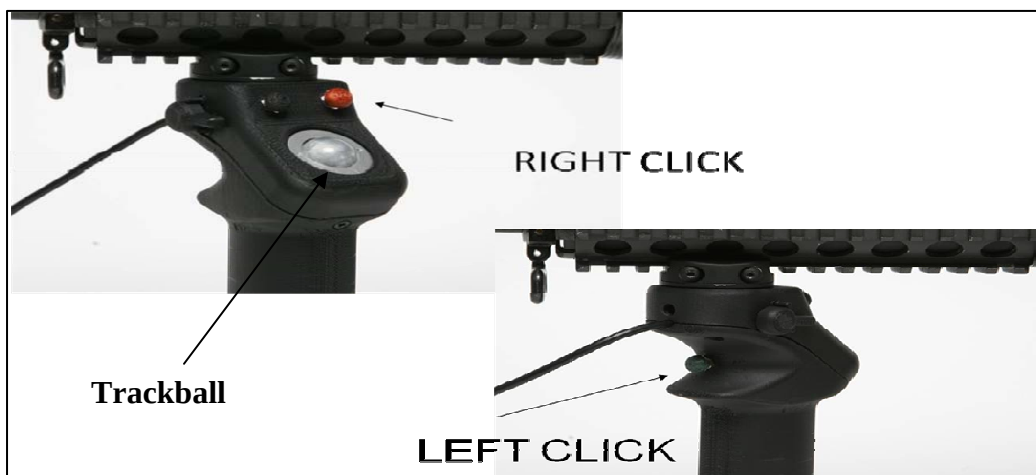


Figure 2. System A control locations.



Figure 3. System B mounted on an M-4.

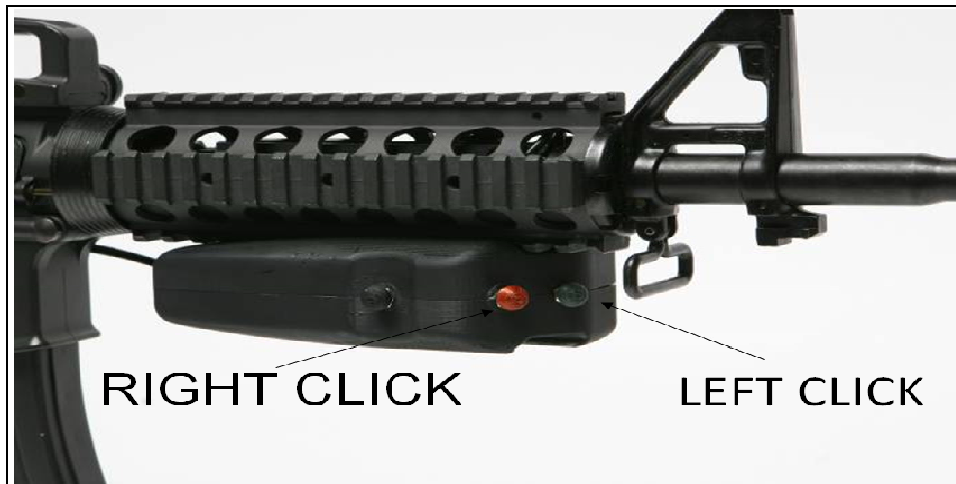


Figure 4. System B controls.

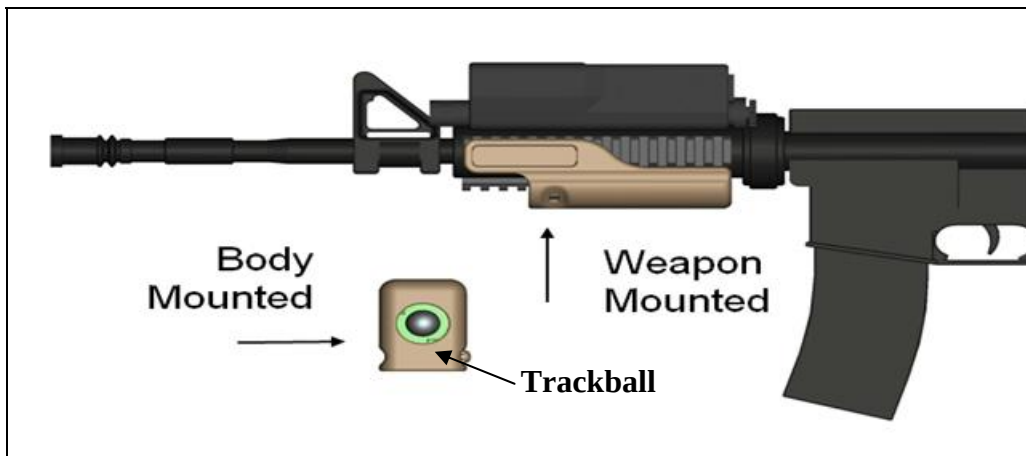


Figure 5. System C mounted to weapon and separate module.



Figure 6. System C controls.

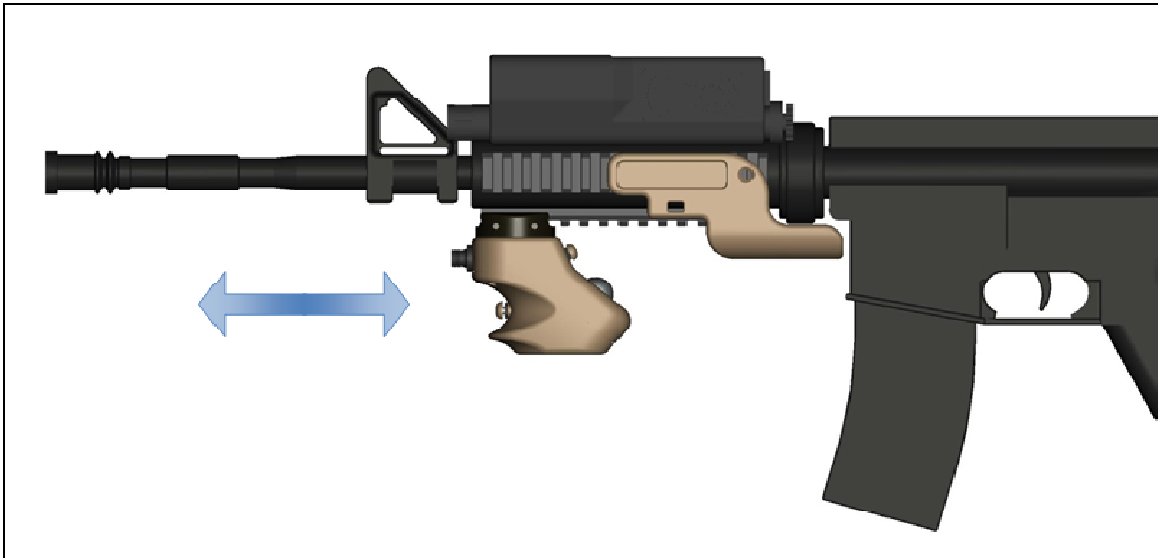


Figure 8. System D mounted to weapon.

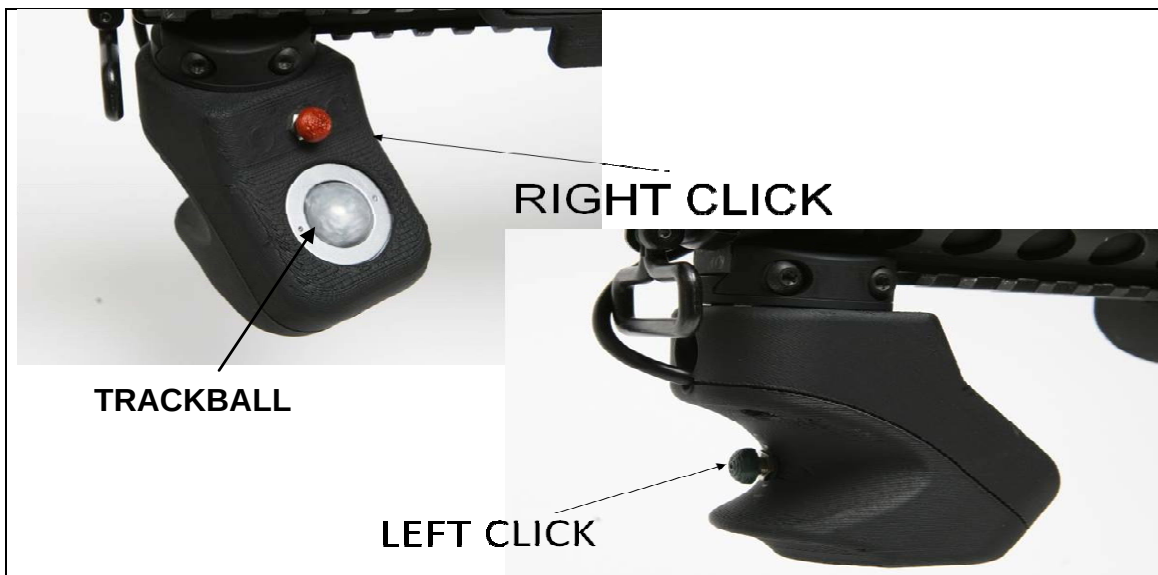


Figure 9. System D controls.

2.3 Procedures

2.3.1 Demographics

Upon arrival, the Soldiers were briefed on what was expected of them and how the information they provided would be used. Each Soldier then completed a demographic questionnaire and was given a roster number. Eight Soldiers reported each morning, and eight different Soldiers reported each afternoon to participate in the experiment.

2.3.2 Training

During each 15-min session, HRED experimenters trained the Soldiers on the IDEA tasks (see appendix B), and they were given time to practice each task using a standard mouse and laptop computer. Each group of eight Soldiers was then trained on the eight different WGC configurations by Artisent, Inc., personnel and given time to practice with each system.

2.3.3 Experiment Trials

Each eight-person group used the WGCs as shown in table 1. The Soldiers were given time to familiarize themselves with the WGC configuration. When they had become familiar with the WGC configuration, they started conducting the tasks under the control of the lead experimenter and in accordance with the IDEA task list shown in appendix B. Each of the seven tasks had a time limit (table 2). For the purposes of data analysis, tasks that were incomplete when the time expired were coded as the time limit plus 25%, rounded to the nearest second (see the third column in table 2). This ensured that tasks that were not completed and tasks completed near the maximum time limit did not receive similar scores. (Analyses were also performed on the data before a penalty was included [see the second column in table 2] and on the number of tasks completed within the time allotted.) The Soldiers were also qualitatively evaluated by the data collectors on whether they completed the task or how much of the task they accomplished within the allotted time as well as the quality of their work on each task. The scale in table 3 was used for this data collector evaluation. At the end of each iteration, the Soldiers completed a post-iteration questionnaire (appendix C) concerning the configuration they just used and then returned to the task station for the next iteration. The questionnaire was designed for this experiment and included their perception of the training adequacy, time allotted for practice, the features of the WGC, and their rating of the device.

Table 1. Order of WGC presentation.

Roster	Iteration							
	1	2	3	4	5	6	7	8
1, 9, 17, 25, 33, 41	AJ	DT	AT	DJ	BJ	CT	BT	CJ
2, 10, 18, 26, 34, 42	AT	AJ	BJ	DT	BT	DJ	CJ	CT
3, 11, 19, 27, 35, 43	BJ	AT	BT	AJ	CJ	DT	CT	DJ
4, 12, 20, 28, 36, 44	BT	BJ	CJ	AT	CT	AJ	DJ	DT
5, 13, 21, 29, 37, 45	CJ	BT	CT	BJ	DJ	AT	DT	AJ
6, 14, 22, 30, 38, 46	CT	CJ	DJ	BT	DT	BJ	AJ	AT
7, 15, 23, 31, 39, 47	DJ	CT	DT	CJ	AJ	BT	AT	BJ
8, 16, 24, 32, 40, 48	DT	DJ	AJ	CT	AT	CJ	BJ	BT

Notes: A–D = WGC configuration.

J = WGC with joystick.

T = WGC with trackball.

Table 2. Time limits for IDEA tasks.

Task	Time Limit (s)	Penalty Time (s)
1	45	56
2	20	25
3	30	38
4	30	38
5	20	25
6	45	56
7	30	38

Table 3. Data collector rating scale.

Task Score	Description
1	Little or no progress toward task completion
2	Partial task completion or poor quality task completion
3	Good quality task completion

2.3.4 Post-Experiment Questionnaire

Upon completing the IDEA tasks with each WGC configuration, the Soldiers were given a questionnaire designed for this experiment to assess the degree of acceptance for each WGC configuration and their overall preferences.

3. Results

3.1 Demographics

The 48 OCS Soldiers who participated in this experiment averaged 5 years in the military. Some of the subjects were prior-service, enlisted from a variety of Army fields, including Infantry, Military Police, and Field Artillery. Other subjects were recent basic-training graduates that enlisted under the college option for OCS. Six of the Soldiers were left-handed and 19 wore prescription lenses. Forty-one used a computer daily and 43 had their own personal computer. The majority classified themselves as having intermediate computer skills, and 31 reported that they used the computer more often for games than for other tasks. The average age of these Soldiers was 29 years. See appendix A for detailed demographic information.

3.2 Training

The participants were generally positive about the quality and quantity of training on the use of the controls. Soldiers rated the training on each trackball version of the device as better preparing them to complete the IDEA tasks than the training on each joystick version of the device. Several reported that it took more practice to train effectively with the joystick than it did with the trackball.

3.3 Experiment Trials

3.3.1 Performance Data

The mean task completion times (aggregated across all IDEA tasks) for each WGC system are shown in figure 9. Included in these mean times are the 25% penalties added for not completing tasks. The means were compared using a repeated measures 2×4 analysis of variance (ANOVA) with control (joystick or trackball) and system (A, B, C, or D) as the independent variables. The ANOVA indicated that there was a significant main effect for system [$F(3,141) = 23.1, p < .001, \eta^2_p = .330$], a significant main effect for control [$F(1,47) = 128.8, p < .001, \eta^2_p = .730$], and a significant system by control interaction [$F(3,141) = 12.3, p < .001, \eta^2_p = .207$]. (Partial eta squared (η^2_p) is an index of effect size, the proportion of variance in the dependent variable that is accounted for by the independent variable.)

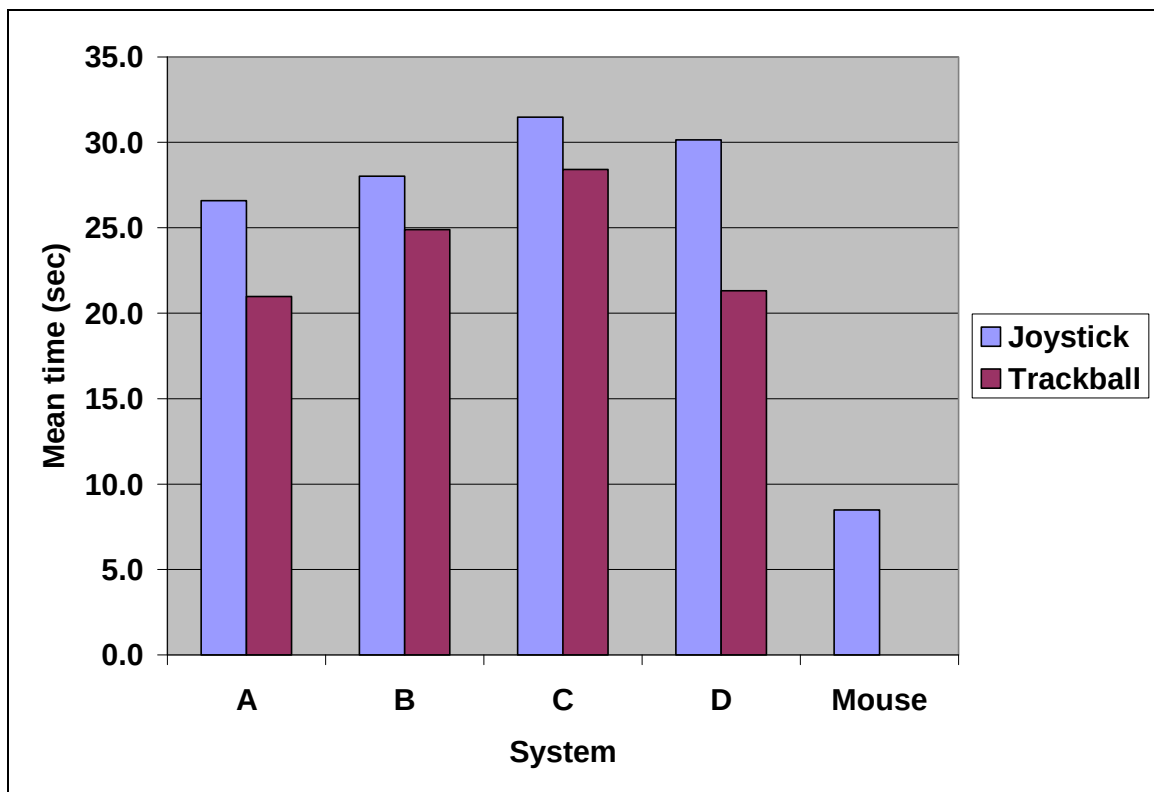


Figure 9. Mean task completion times.

The mean task completion times for each condition, system type (aggregated across control device), and control type (aggregated across systems) are shown in table 4. Mean times were faster with the trackball than with the joystick ($p < .001$). Follow-on comparisons for systems were conducted using Holm's Bonferonni correction for family-wise error rate. The follow-on paired comparisons are summarized in table 5. Each paired comparison, with the exception of

system B vs. system D, was statistically significant. Performance with system A was significantly faster than performance with any of the other systems. The mean times for systems B and D were significantly faster than the mean times for system C.

Table 4. Mean task completion times divided by system and control type, system type, and control type.

System	Control	Mean	SD
A	Joystick	26.6	6.2
	Trackball	21.0	6.4
B	Joystick	28.0	6.3
	Trackball	24.9	6.5
C	Joystick	31.5	4.5
	Trackball	28.4	5.4
D	Joystick	30.1	5.8
	Trackball	21.3	6.6

System	Mean	SD
A	23.8	5.5
B	26.5	5.7
C	29.9	4.3
D	25.7	5.7

Control	Mean	SD
Joystick	29.1	4.6
Trackball	23.9	4.4

Table 5. Follow-on paired comparisons, systems, mean times.

Pair	t	df	Obtained p	Required p
A vs. B	-3.75	47	<0.001 ^a	0.0167
A vs. C	-7.66	47	<0.001 ^a	0.0083
A vs. D	-2.52	47	0.015 ^a	0.0250
B vs. C	-5.09	47	<0.001 ^a	0.0125
B vs. D	0.88	47	0.382	0.0500
C vs. D	5.82	47	<0.001 ^a	0.0100

^a $p < 0.05$, two-tailed.

The significant system by control interaction simply indicates that the magnitude of the trackball vs. joystick difference varied from system to system. For example, the trackball vs. joystick performance was not as different when system C was used as it was when system D was used. The same analyses were run without a timed penalty for incomplete tasks (incomplete tasks were given the maximum time for the tasks), and the results did not change.

Table 6 and figure 10 show the mean number of tasks completed in each of the eight experimental conditions. A repeated measures ANOVA run on the number of tasks completed with each system indicated that the main effects for system [$F(3,141) = 12.9, p < .001, \eta^2_p = .215$] and control [$F(1,141) = 48.8, p < .001, \eta^2_p = .510$] were statistically significant. In addition, the system by control interaction was statistically significant [$F(3,141) = 7.53, p < .001$,

$\eta^2_p = .138$]. Significantly more tasks were completed with the trackball than with the joystick. The follow-on paired comparisons (table 7) of the four systems indicated that system A was significantly better than systems C and D in terms of number of tasks completed. Significantly fewer tasks were completed with system C than with the other three systems. The significant system by control interaction indicates that the magnitude of the discrepancy between number of tasks completed with the trackball and the joystick differed from system to system.

Table 6. Number of tasks completed divided by system and control type, system type, and control type.

System	Control	Mean	SD
A	Joystick	5.10	2.20
	Trackball	6.08	1.29
B	Joystick	4.94	2.04
	Trackball	5.46	1.56
C	Joystick	3.83	1.98
	Trackball	4.71	1.74
D	Joystick	3.92	2.02
	Trackball	5.98	1.45

System	Mean	SD
A	5.59	1.53
B	5.20	1.53
C	4.27	1.64
D	4.95	1.55

Control	Mean	SD
Joystick	4.45	1.64
Trackball	5.56	1.04

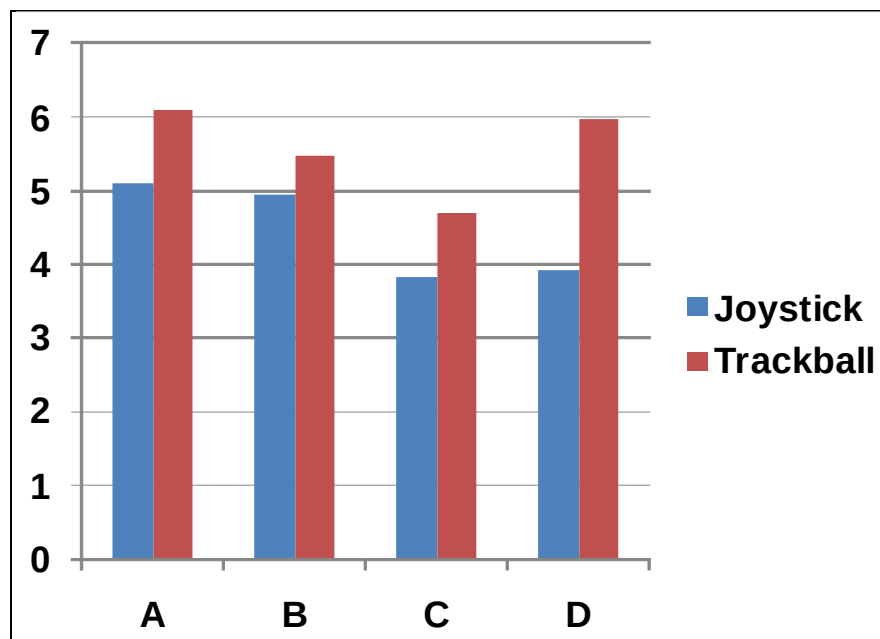


Figure 10. Mean number of tasks completed.

Table 7. Follow-on paired comparisons, systems, mean tasks completed.

Pair	t	df	Obtained <i>p</i>	Required <i>p</i>
A vs. B	2.05	47	0.046	0.025
A vs. C	5.18	47	<0.001 ^a	0.0083
A vs. D	3.29	47	0.002 ^a	0.0125
B vs. C	4.00	47	<0.001 ^a	0.01
B vs. D	1.22	47	0.227	0.05
C vs. D	-3.01	47	0.004 ^a	0.0167

^a*p* < 0.05, two-tailed.

In order to assess the reliability of or agreement between the data collectors on the qualitative rating scale, two of the data collectors independently assessed the quality of Soldier performance on a sample of 56 IDEA tasks. The Kendall coefficient of correlation, used for ordinal data, was as follows: tau-b = .66, *p* < .001. This large value indicates that raters strongly agreed on their evaluations, and the rating procedure had adequate reliability (Hays, 1973; Neter et al., 1996).

The mean data collector qualitative ratings for joystick and trackball control devices are shown in figure 11. The trackball quality of performance was significantly better than the joystick: [χ^2 (df=2) = 99.1, *p* < .001].

Figure 12 shows the mean performance ratings as a function of the four systems. The differences among the systems were statistically significant: [χ^2 (df=6) = 124.7, *p* < .001]. Performance quality was best with the A and D systems and poorest with the B system.

3.3.2 Subjective Soldier Data

3.3.2.1 Post-Iteration Questionnaire Results. The majority of the Soldiers responded very favorably to the design of system A. They felt that it was easy to control quickly and accurately and that there was minimum interference from the controls during weapon operation. The controls on system A were placed on a forward pistol grip. This forced right-handed users to perform fine motor tasks (joystick or trackball movement) with their nondominant hands. One Soldier felt that the forward pistol grip design would interfere with holding the weapon properly in the low ready position. Another was concerned that the forward grip design would not be rugged enough to withstand vibrations from repeated firing, pounding from Soldiers falling to the prone position, and strong force from Soldiers gripping it tightly during the heat of battle. There were several reports that the right click button was too small.

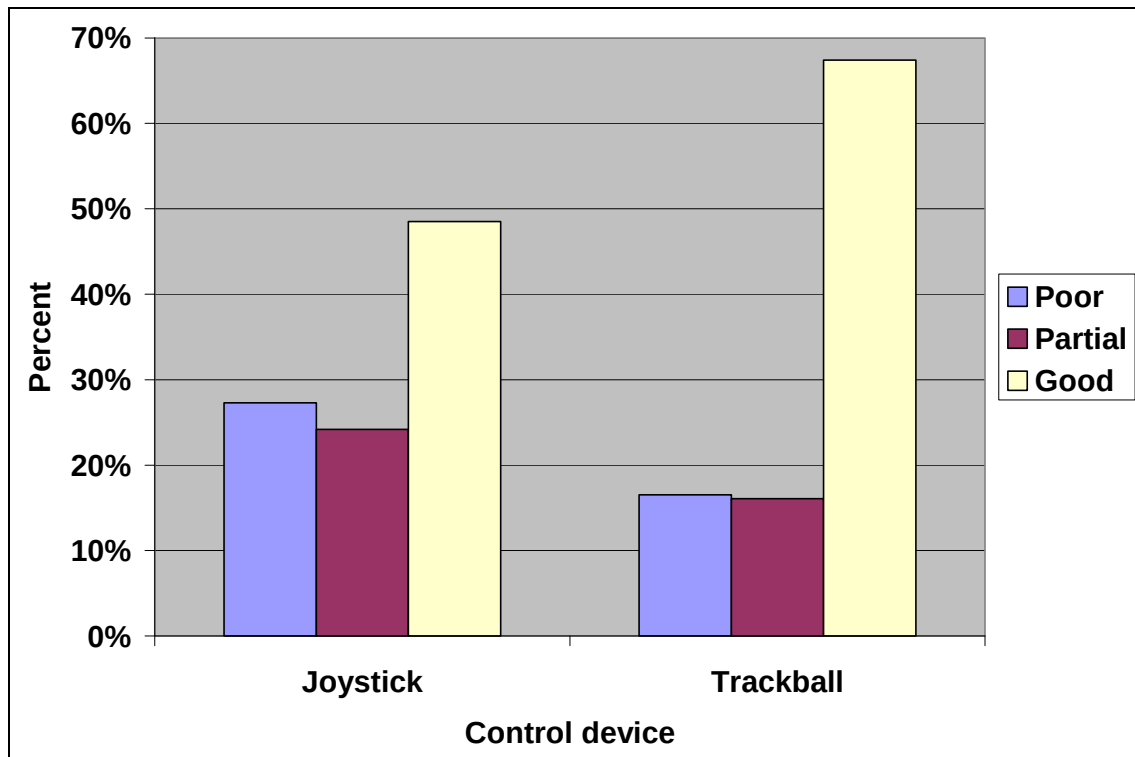


Figure 11. Mean data collector task qualitative ratings by continuous control device.

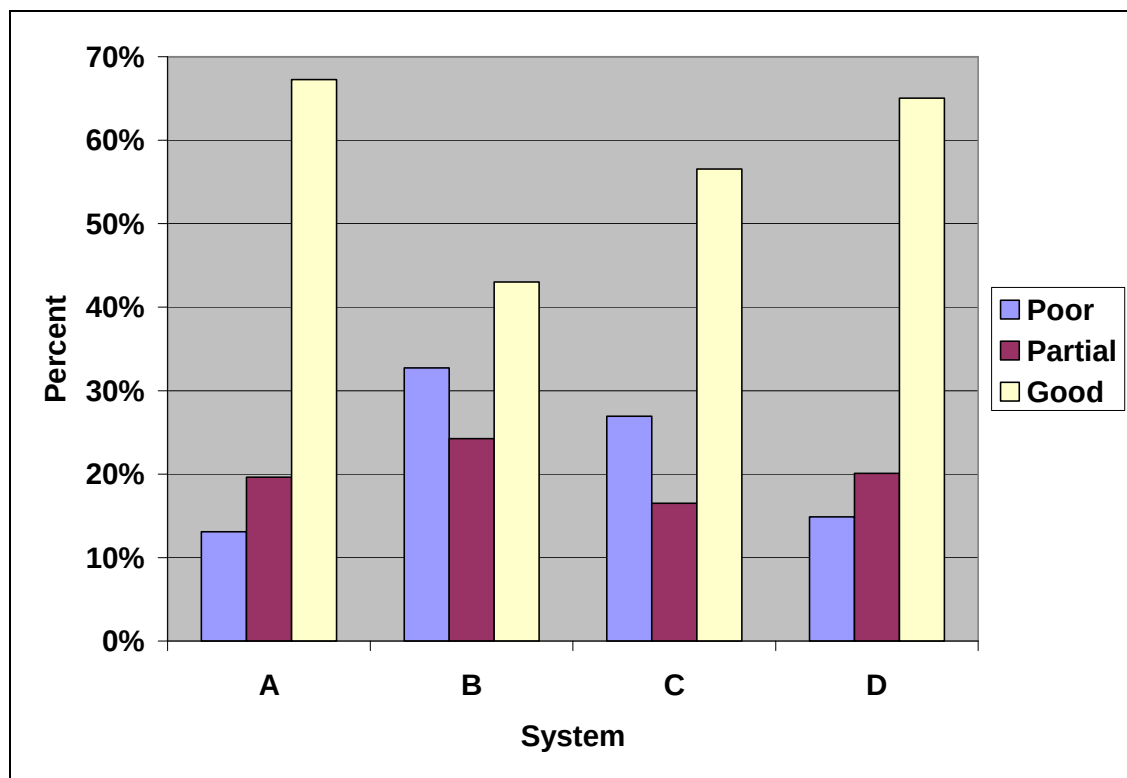


Figure 12. Mean data collector task qualitative ratings by configuration.

System B also required right-handed users to perform fine motor tasks with their nondominant hand. The width of system B caused problems for Soldiers with different hand sizes. One Soldier commented that his hands were of average size, and his left hand felt cramped when gripping the device, which adversely affected his performance. He felt it would be even more uncomfortable for Soldiers with larger hands. A Soldier with smaller hands felt the shape of system B was too big for his left hand, which made it difficult for him to keep a firm grip on the weapon. Several Soldiers commented that the control buttons were poorly placed. Some thought they were too close together (especially for use with gloves), another thought that their locations made it uncomfortable to press down on them for extended periods (such as during a drag and drop operation). Still another thought that their forward locations made it difficult to push them while maintaining a proper weapon orientation and a firm grip on the weapon. Several Soldiers indicated that the buttons were too small and too stiff. The trackball on system B was mounted on the side. This made it difficult to associate trackball movement with cursor movement (i.e., rolling the trackball up resulted in cursor movement to the right).

Soldiers expressed concern that system C required them to remove their hands from their weapons for operation. They also indicated that placement on the chest put their wrists at an awkward angle and expressed concern that the amount of equipment attached to the uniform would interfere with its placement. Two Soldiers felt that the design required them to use two hands to be effective. Several felt that the buttons were too small and positioned poorly.

Soldier comments were generally very favorable concerning the trackball version of system D. However, some did complain that both the trackball and the joystick versions of this design gave them nothing to hold on to (it was too small to get a proper grip) and this caused strain. System D also required right-handed users to perform fine motor tasks with their nondominant hands. Several Soldiers complained about having to use it with their left hands. There were also several complaints about the small size of the buttons. The similar shapes of the system D's joystick and the right click button made them easy to confuse.

The Soldiers rated the trackball version of each of the four systems higher than the joystick versions. Soldiers complained that the joystick was so short that it created comfort problems. For example, one Soldier reported that the size and placement of the joystick mandated that he could only use his thumb and that a joystick that could be gripped with the entire hand would provide more stability and comfort. Many complained that it was more difficult to move the cursor as accurately with the joystick as they could with the trackball. Some indicated that the joystick had too much resistance and moved too slowly. Others indicated that the trackball moved too quickly and needed more resistance. Soldiers expressed concern about the reliability of a trackball during inclement weather and when exposed to dirt, mud, and sand. They were also concerned about use of the trackball when wearing heavy gloves.

Detailed results from the post-iteration questionnaire can be found in appendix C.

3.3.2.2 End of Experiment Questionnaire Results. The trackball configuration of each WCG was preferred over the joystick configuration. Some Soldiers indicated that although the joystick was a little more precise than the trackball, it was slower and not as responsive. Others indicated that it was less accurate because it required a lot of force to move it and the use of the thumb to operate it. There were some concerns expressed about a potential reliability problem with the trackball in a rugged environment.

On the questionnaire administered at the end of the experiment (appendix D), the participants were asked to rank each of the eight system/control configurations on a number of dimensions. In each of the figures that follow, the higher the mean rank, the greater the preference for the system/control configuration.

The vast majority of the Soldiers felt that a weapon-mounted configuration was preferable. One rationale for this preference was because it would not get lost in the field and would therefore be more compatible with the Soldiers' mission and equipment. Figure 13 shows the rank order in terms of compatibility with weapon, equipment, and mission.

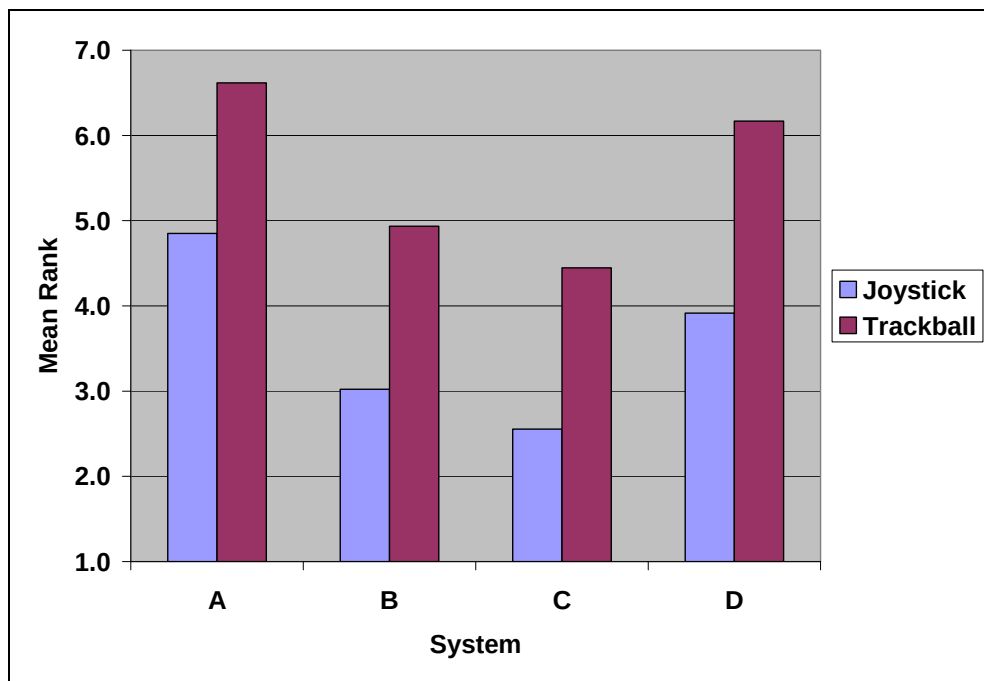


Figure 13. Rank order of systems in terms of compatibility with weapon, equipment and mission.

Soldiers rated the forward handgrip as the preferred location of the WGC. They rated system A's forward handgrip location the highest. Even though system D allowed the flexibility of choosing whether to mount the WGC on the forward handgrip or on the body, it was rated lower

in terms of mounting configuration than system A. The handguard mounting location of system B was rated a distant third, and the body-mounted location of system C was rated the lowest. However, one Soldier did point out that the weapon was a bad place to mount the WCG because of vibrations, blows to the device and sand, mud, and dirt from prone positions, low crawls, and combat rolls. Figure 14 shows the rank order of the location of WGCs (i.e., on the body, on the weapon, etc.).

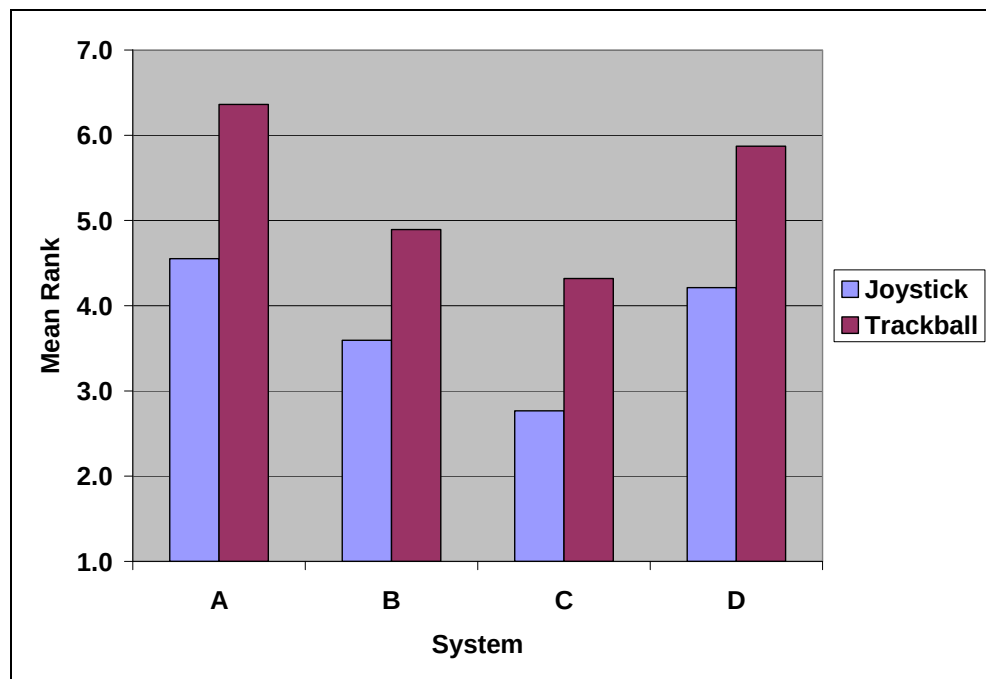


Figure 14. Rank order of systems in terms of mounting locations.

Soldiers cautioned that the WCG controls should be placed in a position that would not interfere with the grip of the weapon and that would not contribute to inadvertent activation. They also advised that there should be enough separation between the controls for gloved operation. The rank order of the systems' component locations within the WGC device (i.e., button separation, distance from button to joystick or trackball, vertical vs. horizontal mounting, etc.) is shown in figure 15. Figure 16 shows the systems' rank order by form factor (i.e., size, weight, balance, etc.). The rank order by overall ease of use is shown in figure 17.

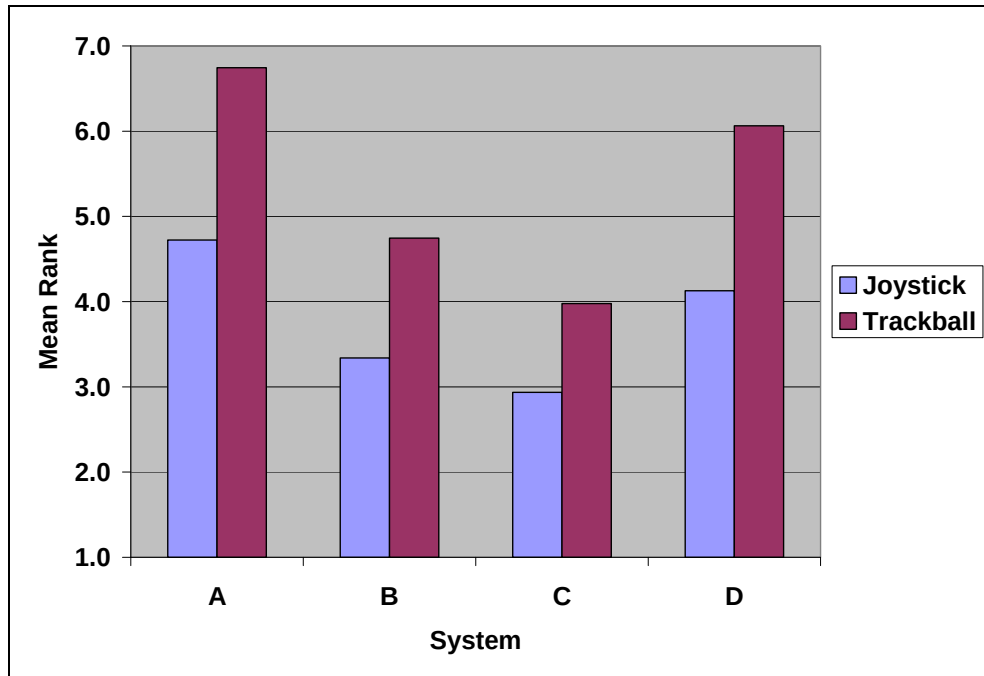


Figure 15. Rank order of systems in terms of location of components within the system.

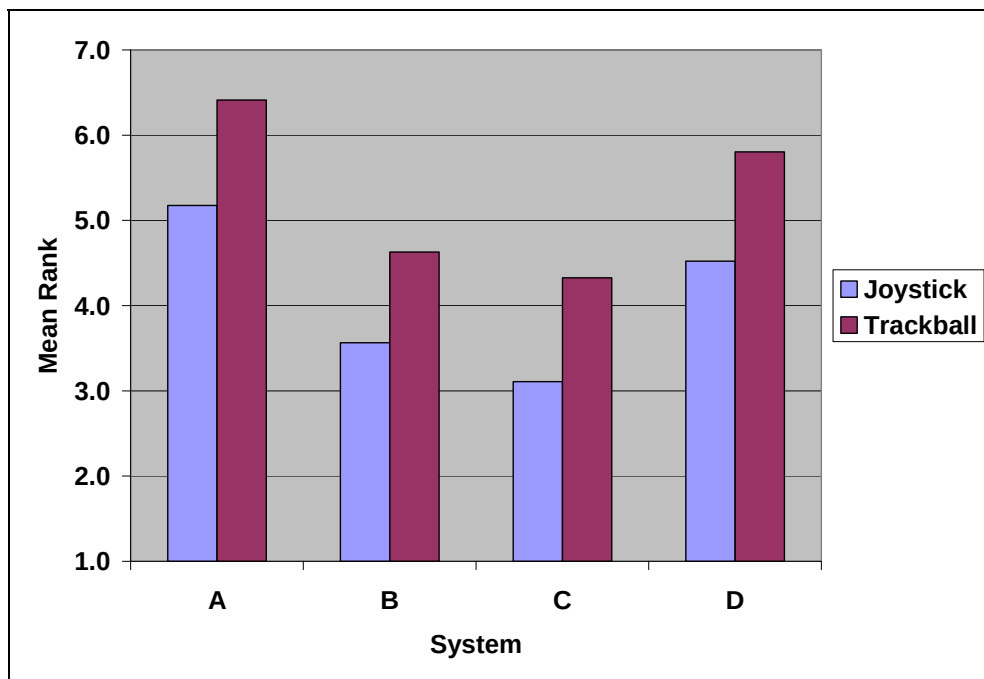


Figure 16. Rank order of systems in terms of their form factors.

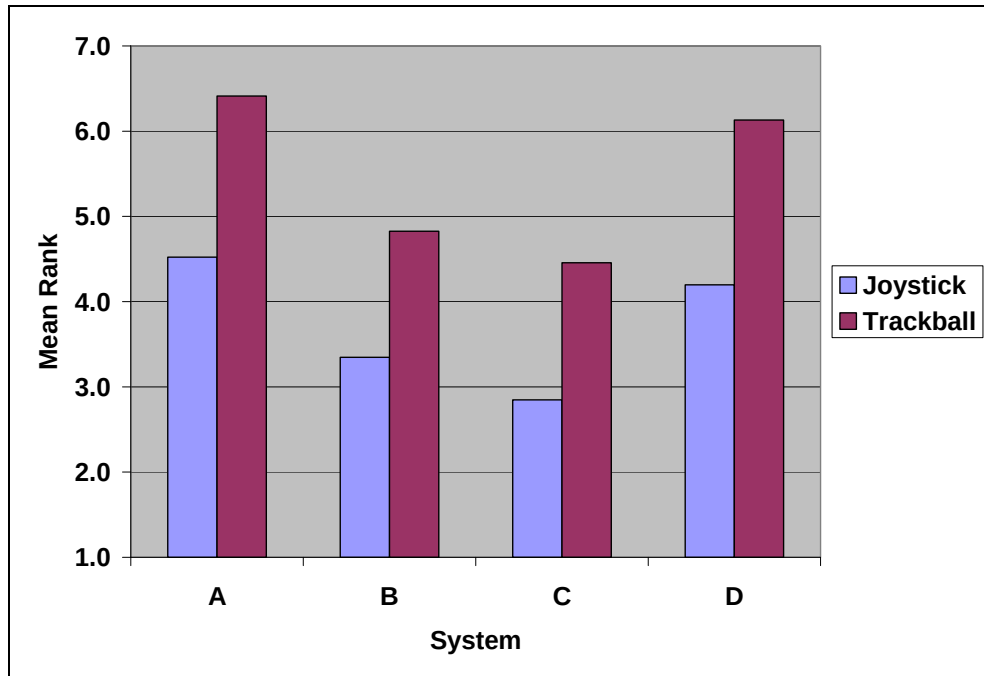


Figure 17. Rank order by overall ease of use.

On each of the evaluative dimensions, the trackball control was preferred over the joystick control for every system. Additionally, systems A and D were preferred over systems B and C for every evaluative dimension.

Soldiers rated the following design considerations of a WCG to be most important: waterproof, wireless, compatible with equipment, precision cursor control, ruggedness, quick operation, noise security, lightweight, use with gloves, and use in prone position. The least important design consideration was use while running.

4. Discussion and Recommendations

For each system, mean times were faster and ratings were higher with the trackball than with the joystick. These consistent findings might be attributed to several factors. The first two factors are attributes of the specific joystick design that was used in this evaluation. The pointer speed setting that was placed on all the computers used in this evaluation resulted in much slower and less responsive movement with the joystick than the same speed setting on the computer with the trackball. Complaints of the joystick being too slow could be addressed by changing the speed setting on the computer. The short design of the specific joystick used also resulted in complaints of discomfort. However, the short design is a positive attribute when the device is weapon mounted because it results in a lower profile. Other factors that adversely affected the

joystick are inherent in the design of a joystick. Joysticks typically take more practice than a trackball because they are not as intuitive and not normally as precise as a trackball. The few complaints expressed about the trackball dealt with concerns about the potential for its reliability to be adversely affected by dirt and other environmental factors and about it being too fast and somewhat imprecise.

Mounting the WGC on the forward pistol grip was the preferred mounting location in this evaluation. However, the current design required the majority of the Soldiers to use their nondominant hands for cursor control, and the impact of this design factor is not clear. Right-handed Soldiers performed the IDEA tasks in a benign environment under ideal conditions, and the impact of activation by many Soldiers' nondominant hands may be understated in this evaluation.

Interpretation of the findings of this evaluation should be cautiously made for two reasons. First, this was a static evaluation (Soldiers were seated at a computer when using the systems), and these results need to be confirmed in the field during dynamic operations. Second, not all variables were controlled across systems. For example, the sizes of the controls were not standardized across systems, and control spacing was not consistent across systems. These and other variables could have influenced the outcome as well as the location of the controls.

5. Conclusions

Mean times were faster with the trackball than with the joystick. The data collector qualitative ratings of performance with the trackball were significantly better than the ratings with the joystick, and the trackball control was preferred over the joystick control on each of the evaluative dimensions.

Task performance with system A was significantly faster than performance with any of the other systems. The mean task completion times for systems B and D were significantly faster than the mean times for system C. Data collector performance quality ratings were best with the A and D systems and poorest with the B system. Additionally, systems A and D were preferred by the Soldiers over systems B and C for every evaluative dimension.

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Appendix A. Demographics Results

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APPENDIX A

DEMOGRAPHICS

SAMPLE SIZE = 48

<u>MOS</u>			<u>AGE</u>	<u>RANK</u>
09S – 21	42A – 1	FA – 1	29 years (mean)	E-4 – 10
11B – 3	54B – 1	09S – 1		E-5 – 31
14E – 2	68R – 1	OCS – 1		E-6 – 4
27D – 2	68W – 1	NR – 11		E-7 – 2
31B – 1	AG – 1			NR – 1
1. With which hand do you most often write?			Right – 41	Left – 6 NR -1
2. With which hand do you most often fire a weapon?			Right – 42	Left – 5 NR -1
3. Do you wear prescription lenses?			Yes – 19	No – 26 NR - 3
4. If Yes, which do you most often wear?			Glasses - 10	Contacts – 9
5. How many months in military?			63 (mean)	
6. How often do you use a computer?				
Never – 0	Infrequently – 1	Sometimes – 5	Daily – 41	NR -1
7. How often do you use a computer on a weekly basis?				
1-10 hrs – 15	11-20 hrs – 14	21-30 hrs – 9	NR -1	More than 30 hrs – 9
8. Evaluate your own computer skill level.				
None – 0	Novice – 4	Intermediate – 31	Advanced – 12	NR -1
9. Do you have experience with any type of digital or electronic military displays (e.g. FBCB2, fire control systems FB(ITAS, IBAS, Land Warrior, etc.)?				
No – 42	Yes – 4 (FBCB2)	NR – 2		
10. What is your Microsoft PowerPoint experience skill level?				
None – 2	Novice – 16	Intermediate – 21	Advanced – 6	NR -1

11. With what type of mouse or input device do you normally use?

2-button mouse	– 26
3-button mouse	– 3
Scroll wheel	– 10
Track ball	– 3
Joystick	– 1
Touch pad	– 4
Touch screen (stylus)	– 26
No preference	– 4

12. Are you color blind or have problems distinguishing between colors, for example like those used for a military map?

No – 46 Yes – 1 NR -1

13. If you use a computer for both games and other tasks (word processing, internet, etc.), please identify what the majority of use is:

More “other tasks” than games	– 0
More games than “other tasks”	– 33
About equal use	– 8
I do not do either kind of activity	– 4
NR	-- 1

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Appendix B. IDEA

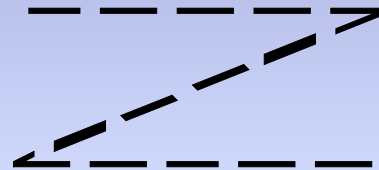
This appendix appears in its original form, without editorial change.

45-Second
Time Limit

TASK 1

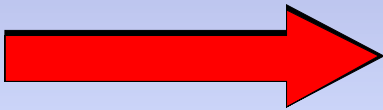
Make the first "z" line above
solid by:

1. Selecting auto shapes
on the toolbar below
2. Choosing the "lines"
option from the auto
shapes menu
3. Choosing the scribble
line (the last option on
the "lines" menu)
4. Then trace over the
dash line



20-Second
Time Limit

TASK 2



Change arrow color to black by clicking on the arrow and using the "fill color" option (the paint can) on the formatting tool bar below

30-Second
Time Limit

TASK 3

Move arrow to bottom right of this slide by clicking and dragging and reverse direction by grabbing the green Arrow at top and rotating the arrow 180 deg.

Move here

30-Second
Time Limit

TASK 4



Copy this picture and place it in the box to the right by right clicking on the picture and choosing the "copy" option, then right click on paste and move the cursor to the box, and drag the copied picture to the box on right

20-Second
Time Limit

TASK 5

Increase the size of the picture by grabbing the upper right and then the lower left circle and increase to fill box top to bottom not side to side.

Paste here

45-Second
Time Limit

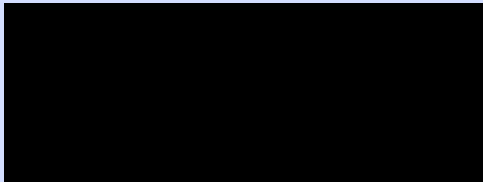
TASK 6

1 2 3

Move numbers above to the box on the right by highlighting and dragging each number individually and place in reverse order. Place numbers as close to straight as possible

30-Second Time Limit

TASK 7



Create rectangle approximately the same size as the one above in the box to the right using tool bar below and change color to red

Move here

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Appendix C. Post-Iteration

This appendix appears in its original form, without editorial change.

APPENDIX C

POST ITERATION

SAMPLE SIZE (N): See below

1. Using the scale below, please rate the degree to which your training on this device prepared you to use it effectively.

1	2	3	4	5	6	7
Extremely ineffective	Very ineffective	Ineffective	Neutral	Effective	Very Effective	Extremely effective

	MEAN RESPONSE							
	JOYSTICK				TRACKBALL			
	A	B	C	D	A	B	C	D
*N=	48	48	48	47	48	48	48	48
Training effectiveness	4.57	4.09	4.19	4.58	5.17	5.04	4.55	5.19

*N=sample size; applies throughout document.

Comments

No. of Responses

JOYSTICK

A

Better than the quicker joystick.	1
Joystick still hard to control, but concept A was a little easier.	1
Hard to control device.	1
I don't really care for the joystick. The trackballs are better.	1
I half-fell asleep during the copy/paste exercise.	1
If this system was implemented, the training would require modification for real world application.	1
Short.	1
Training is starting to get old and boring. It's taking too long too complete.	1
Using the joystick on the weapon system is confusing because you are only testing the mouse and not the weapon system and the set up of the buttons are not ergonomically comfortable. Possibly use the weapon to test operations of the mouse in a shoot to move or something dealing with use of the weapon as a functionality, not as just testing the mouse, i.e., use the weapon as the mouse maybe the trigger or a component of the weapon instead of adding components.	1

B

Felt better.	1
Difficult to move.	1
It's difficult using your non-dominant hand.	1
Joystick controls need to be adjusted to the user's thumb, not the weapon.	1
Joystick is very poor, nothing like a mouse.	1

<u>Comments</u>	<u>No. of Responses</u>
More effective with the use of a mouse.	1
Short learning curve.	1
You will need plenty of time with the joystick.	1
Don't like the non-spin kind of track ball/knob .	1
Very hard to concentrate on task due to operation of equipment.	1
<u>C</u>	
The way the equipment is designed makes it difficult to use but as far as functionality, there is no problem in controlling the equipment or making selections using the B.	1
Allowed to use device before test.	1
Stimulating but it may be too advanced for some individuals.	1
Did not like the movement of the joystick!	1
Very difficult to maneuver.	1
Horrible, no way will this work.	1
Would need more time to train with the device to get use to the controls.	1
It took me a little longer to figure out which was right click/left click.	1
<u>D</u>	
Don't like the track button. It should spin. Everything else was good.	1
I had no idea how to use the device. I did not complete the first task.	1
It is rare that I use my left hand and I don't play video games so I had difficulty using the mouse with my left hand.	1
Needed more time to get use to controls.	1
Short learning curve.	1
The joystick was hard to maneuver.	2
Using a regular mouse didn't help me at all to use the joystick.	1
<u>Trackball</u>	
<u>A</u>	
This was the best unit so far; was really comfortable and the trackball was fast and relatively effective.	1
Excellent. This is the right one for me.	1
Short, concise and to the point; very good.	1
Trackball is much more effective than joystick.	1
By placing the roller ball on the rear ball and grip might be more effective but overall concept good as far as movement of the tracking ball.	1
I am a Linux user and PC FPS gamer; prior practice with a mouse may have affected my performance.	1
More successful with the use of the mouse as opposed to using the joystick and trackball.	1
Paper aid confusing.	1

Comments**No. of Responses****B**

Easy to use.	1
Very good, but left side mouse did not seem to work effectively.	1
Very interesting.	1
Trackball is better.	1
Allowed to use device before test.	1
Better since the use of a mouse was incorporated.	1
Need more time to read the instructions.	1
The device is uncomfortable and hurts the thumb.	1
There was no training on a trackball; the only training consisted of practicing the actual tasks.	1
While the test successfully measured the ability to do simple tasks, it does not necessarily correspond to the requirements of field use. Perhaps a simulation of what this device is actually designed for would be more appropriate, such as selecting and issuing comments.	1
You have to restart your task if the mouse button is released, not a normal function.	1

C

Better than the joystick version.	2
Difficult for my hand-eye coordination after using a mouse for so long. A bit more practice and it could become natural.	1
Given a short amount of time to play with the trackball.	1
The joystick is too flimsy. It needs to be a little stiffer.	1
Training was not helpful at all for this configuration.	1

D

Tracking ball is the way to go; much easier than joystick!	1
Balls are better than the joystick.	1
Like the ball on the device but once again the ergonomics is not comfortable for the remaining fingers not used on the device.	1
Best one I've used up to this point.	2
Felt natural.	1
Good future training.	1
Introductory.	1

2. Using the scale below, please rate the following features of the WCG device you used for this trial.

1 2 3 4 5 6 7
Extremely bad Very bad Bad Neutral Good Very good Extremely good

FEATURES	MEAN RESPONSE							
	JOYSTICK				TRACKBALL			
	A	B	C	D	A	B	C	D
Overall size of device	4.88	4.45	4.65	4.36	5.50	4.79	4.88	4.88
Size of buttons	4.63	4.36	4.33	4.47	5.63	4.98	4.69	5.27
Size of trackball or joystick	3.88	4.02	3.98	3.98	5.77	5.10	4.85	5.42
Overall weight of device	4.93	4.79	4.96	5.04	5.75	5.26	5.25	5.48
Shape of device(s)	5.10	4.26	4.02	4.28	5.76	4.54	4.02	4.91
Integration of the device into the weapon and Soldier equipment	4.98	4.36	3.43	4.89	5.52	4.71	3.74	5.02
Location of the buttons when you are fully loaded with equipment	4.68	3.83	3.54	4.58	5.65	4.09	3.44	5.38
Location of trackball or joystick when fully loaded with equipment	4.63	3.91	3.50	4.62	5.78	4.68	3.62	5.47
Type of buttons	4.40	4.11	3.79	4.07	5.63	4.75	4.31	5.23
Type of trackball or joystick	3.33	3.32	3.15	3.17	5.51	4.92	4.50	5.42
Potential compatibility with gloves	3.50	2.94	2.89	3.45	4.98	3.89	3.57	4.56
Will not interfere with Soldier tasks	3.94	3.40	3.13	3.65	5.09	4.23	3.36	4.79

Comments

No. of Responses

JOYSTICK

<u>A</u>	
Well placed; seemed it would work well given time to train.	1
Felt this device was slow to react and move on the screen.	1
Device did not complement the ergonomics of a right handed user.	1
Good, much better than the faster joystick.	1
I don't think placing on the center of the outfit will workout, not secure but is easy to get to.	1
Joystick is better than trackball but it needs to be improved a little with responsiveness and fine cursor movements	1
I liked this configuration, but I hate the joystick.	1
Joystick feels sticky for fine movements of mouse.	1
Joystick not as effective.	1
The joystick was a little large, I feel like it would possibly get in the way of other equipment.	1
Only concern is the size of the left and right buttons and their location. Put both together. Don't like the joystick; prefer the trackball.	1
Right click button to far away.	1
Still disliking the joystick.	1

<u>Comments</u>	<u>No. of Responses</u>
The design was a little bulky and the joystick driver needs to be improved. Cursor speed was a bit erratic.	1
The type of trackball on this joystick was horrible.	1
This design gets in the way of holding the weapon properly, i.e., low-ready.	1
Trackball superior to joystick. Perhaps if joystick were slightly taller, it might fare better? Also, device mandates use of joystick with only one thumb. Any other time I use a joystick for gaming, I always like to grip it with my entire hand to maximize control. One thumb only is a big disadvantage.	1
<u>B</u>	
Good.	1
The best device because of its location, and ease of use.	1
These buttons responded a little better than the last device I used. Still do not like this specific concept. I have average hand size and my hands felt cramped gripping the device, so I think it would be even more uncomfortable and difficult for soldiers with larger hands. Performance definitely affected by it.	1
I liked the placement of the controls, but the joystick was difficult to manipulate for short, precise movements.	1
Shape of the device made for an uncomfortable grip.	1
Did not like the placement of the buttons.	1
The right and left click buttons are too close together in this concept for use with gloves IMO. Thick enough gloves could accidentally click both buttons simultaneously accidentally.	1
Left and right mouse buttons should have some identifying feature so left handed shooters can identify left and right buttons.	1
Hate the joystick. It's too jerky and doesn't move too fast.	1
I didn't like this device at all. The joystick was sluggish and moves only laterally.	1
Do not like at all; would not use or recommend using.	1
Joystick is set too slow, wears on the thumb with repeated use. With gloves, the buttons may be hard to find.	1
I had a very difficult time operating this device.	1
Not a totally practical design outside of cover and concealment range. Potential room for user error and injury during employment in live fire scenarios.	1
The setup of the joystick makes it so that you cannot hold the weapon at the low ready, which is a big safety hazard.	1
WCG didn't move and was in a very uncomfortable location.	1

Comments**No. of Responses****C**

Perfect for virtual gaming scenarios.	1
Good that it was separate from the rifle. Although I wonder where it would fit on with full gear, there is no question that its shape makes it the most versatile.	1
The idea is good but in combat would be difficult to have left hand away from weapon. Also, such a small device would easily get covered up by all the other gear.	1
Bad for uniform attachment.	1
Need two hands to use it.	2
If you have to keep it where your rank patch is, horrible. The way you have to angle your wrist is awkward and it's not in a firm location as ACUs tend to move.	1
This was by far the least comfortable to use. Holding my hand against my chest was not a good angle, and could get strenuous over extended periods of time. Overall controls were awkward.	1
Joystick removes the problem of trackball becoming unseated but is difficult to use.	1
I do not like the joystick. It is too hard to control its movement	2
Joystick is terrible.	1
This device was very slow and hard to maneuver.	1
This joystick is difficult to bond with. I believe gloves will be very difficult to use with the device. Going back with this type of technology is a mistake unless the joystick is easier smoother with its motion.	1
Did not find the joystick to be as accurate as the trackball.	1
Don't like this device.	1
Not exactly practical for live fire engagements.	1

D

Better location, was horrible at using it with my left hand.	1
Prefer a full handle, though half handle makes proper firing grip easier.	1
Nothing to hold on to, no grip for hand.	1
The device was really too small to properly grasp in your hand. This definitely effected how well you could use the device.	1
Buttons seemed out of place, at a bad angle, and joystick was difficult to control.	1
Buttons were extremely hard to use even hurt for the left click mouse was hard to control.	1
The location of the left and right buttons should be next to each other or put the left button in front and right button in rear.	1
The thumb button is much too easily confused with the joystick! Move it and change the shape of one of them.	1

<u>Comments</u>	<u>No. of Responses</u>
The size and type of joystick that I used was good on the hand grip and on the fingers.	1
Have I mentioned I hate the joystick? Otherwise I like this design.	1
Configuration is better than Charlie and Bravo, but Alpha is still superior in ease and comfort of handling.	1
Difficult to move.	1
I could not get the device to go in the direction I needed. The device was very hard to use.	1
Joystick did not respond and buttons would not click and drag. I could click but couldn't drag the item.	1
The joystick would be great with firing gloves on, but the speed would need to be easily adjustable by the user.	1
Very hard to work properly.	1
Weight of the rifle will rest on middle finger for D configuration.	1
<u>Trackball</u>	
<u>A</u>	
Best unit so far.	3
Outstanding.	1
Good future use.	1
My favorite configuration! It was the easiest to control quickly and accurately.	1
Good design; easy to use.	6
Worked well.	1
More effective in overall usage.	1
This should be the type produced.	1
This is my favorite one thus far. Buttons placed perfectly, trackball easy to maneuver, and minimal interference in safely holding the weapon during use.	1
Trigger button too long and loose.	1
Most convenient handle and button locations so far; also roller ball a plus.	1
The trackball function is definitely more user accessible than the joystick, but will it hold up in the elements? Or work with gloves?	1
Not certain that the weapon is the best place to put this thing. Also I am concerned about its location: It will have to be VERY rugged as it is serving as a vertical fore grip on the weapon. Expect it to be struck repeatedly as soldiers go to ground from contact, vibrated endlessly from sustained firings of the weapon, pulled back on hard by troopers in the heat of battle as they fire their weapon. It will need to be extremely well built to resist these pressures, and I have doubts as to whether it will hold up.	1
The only thing I would change is to make the trackball have a little friction in movement similar to the clicks of a wheel on a mouse.	1
More successful with the use of the mouse as opposed to using the joystick and trackball.	1
<u>B</u>	
This is to me the best device because of it's location, and ease of use.	1

<u>Comments</u>	<u>No. of Responses</u>
Much better.	2
Very good device.	1
Fits well with the M4.	1
Overall concept is good, but still having a hard time incorporating this in the weapon system due to control of equipment , location of buttons, and being able to hold the weapon comfortably.	1
The two button locations were good.	1
Like the ball but buttons are poorly placed and difficult to use.	1
Buttons are too close together.	1
The buttons were easy to find, but difficult to press down for extended periods of time, such as dragging items. The trackball was not very sensitive, and often required repeated attempts at the same movement. However, in a field environment the settings might be too sensitive.	1
The forward buttons were difficult to push while maintaining proper weapon grip. Also, left handed track ball on side was difficult to follow spatially. Would have to train with new grip as new left hand position would change firing lines - target grouping.	1
This was difficult for me to use with my non dominant hand with the placement of the buttons.	
Clumsy.	1
I think trackballs are the worst idea possible. I also do not like having to use my non-dominant hand when performing tasks, especially on the computer. If there was some way to integrate the device closer the trigger so that your dominant hand can use the device, that would be perfect. Also, maybe put more research into a touch pad, however gloves wouldn't work with that. Trackballs are horrible though. They will get sand, dirt, grit, etc. in them as quick as you can say Army and become ineffective.	1
Impractical outside of being used during cover and concealment.	1
With gloves I imagine the trackball will be especially difficult to control.	1
Not sure how device will work with gloves.	2
Wool gloves may not work on trackball. Dirt may become a problem to clean.	1
Poor design.	1
Too big for my taste on the weapon, hard to keep a firm grip on barrel.	1
Trackball's location makes thumb hurt.	1
<u>C</u>	
Very compact.	1
Better use out of trackball, but still should not be attached to uniform.	1

<u>Comments</u>	<u>No. of Responses</u>
I like the trackball and the location of device on the uniform. The potential problem is that you have to remove one hand from your weapon during operation, making you less battle-ready.	1
Because of where you are forced to place this device, it would interfere with a lot of equipment.	1
Don't like this device.	1
Difficult to work with.	1
Horrible! Hard to use and takes too much time to move where desired.	1
I despise this one. It is the hardest and most frustrating one to operate.	1
I can see difficulty reaching across my body with a weapon in my hand or additional gear. I absolutely would not be able to feel the buttons through my gloves.	1
I thought the button push was too long and the release sensitivity was too high. The button would prematurely release on me.	1
The axis needs to be movable for this device. Users are forced to use their right hand to operate the device and hold at a specific angle. The buttons also need to be switched for right handed users if forced to hold in that direction. The buttons need to be either checked or replaced for continuity because it releases the contact when trying to hold for a drag motion.	1
Using this device with one hand proved to be difficult. Using two hands was a little better, though the shape of the device and the location of the buttons still made the assigned tasks difficult.	1
Location of device and size of buttons could cause problems.	1
Not effectively responsive during actual engagement.	1
This particular model had issues with the left click button. It felt sticky, as if worn by being clicked many times before.	1
Trackball is too close to the button. Hard to navigate fingers when that close.	1
<u>D</u>	
Best set up.	1
This device was the easiest for me to control so far.	1
Very good and simple to use.	1
I liked this design a lot, especially with the trackball.	1
Good device.	1
Effective behind cover and concealment.	1
Liked it. Easy to grip.	1
Good design system, although buttons are not that great. Requires too much pressure to hold down.	1
As I said before on this type of device, it is too small to be properly grasped.	1
Poor shape, too small.	1
Prefer a full handle.	1
Had to click the red right-click button fairly hard.	1

Comments**No. of Responses**

I would rather grip the control than cuff it, so make it longer. 1

Nothing to hold on to! Exhausting on hand muscles over long term. By the end of the test, my hand was already starting to feel tired. There is just nothing to rest your palm on, so you must keep it in the correct shape for manipulating the device without any support. 1

Weight of the rifle will entirely rest on left middle finger, causing strain. 1

Right-click may be triggered by thumb in this location. 1

Trackball seemed easier to control than joystick, both moved mouse quickly reducing accuracy. 1

Trackball works very easy with non firing hand. 1

I think this will work well if the ball was placed as the alternate hand behind the trigger housing mechanism.

3. Using the scale below, please rate the ease of performing the following tasks.

1 2 3 4 5 6 7
Extremely difficult Very difficult Difficult Neutral Easy Very easy Extremely easy

TASKS	MEAN RESPONSE							
	JOYSTICK				TRACKBALL			
	A	B	C	D	A	B	C	D
Moving the cursor to desired point	3.19	3.02	2.65	3.34	5.36	4.91	4.10	5.50
Moving the cursor quickly	2.96	2.81	2.54	3.06	5.65	5.11	4.06	5.67
Moving the cursor accurately	3.13	2.81	2.44	2.89	5.17	4.60	3.69	5.04
Selecting the desired object	3.50	3.45	2.92	3.30	5.38	4.85	4.04	5.29
Choosing the correct button on the WCG to perform desired function	4.23	3.93	3.63	3.62	5.50	4.81	3.92	5.42
Using the device with one hand	4.81	4.16	3.60	4.35	5.74	5.20	3.98	5.53
Using the device when mounted in the correct location	4.75	4.04	3.28	4.36	5.70	4.91	3.48	5.58
Overall ease of use	3.58	3.28	2.72	3.26	5.59	4.68	3.54	5.33

JOYSTICK**A**

Can perform the task better with practice. 1

Cursor's pretty accurate. 1

Worked well. Prefer spin track better. 1

Joystick button was hard to move either in a quick fashion or accurately. I did not complete some tasks to standard. 1

Joystick is terrible. 1

Joystick moves cursor sluggishly. 1

Not very accurate. 1

The cursor wouldn't move. 1

<u>Comments</u>	<u>No. of Responses</u>
The type of controller was very inaccurate and hard to move.	1
Trackball is clearly superior on this concept to joystick.	1
Worse than the trackball. But device is better than Bravo and Charlie.	1
You can't use the right mouse button and joystick at the same time.	1
<u>B</u>	
Easy to use when movements didn't require precision. Dragging was much easier than with the trackball, but if something was missed or overshoot by a short distance, fine tune adjustments were nearly impossible.	1
Not bad, but would have been better if the joystick wasn't so inaccurate.	1
Hard to do cursor work with the joystick.	1
Modify the joystick, especially the speed.	1
It was hard to move the cursor on the object that you wanted to select.	1
Bad design.	1
Device was very hard to do task with.	1
I'm right handed, so having to use my left hand was not the greatest.	1
Since I am right handed, it was difficult to get used to the buttons and trackball being used by my left hand.	1
Need to be able to hold weapon at low ready.	1
Not a totally practical design outside of cover and concealment range. Potential room for user error and injury during employment in live fire scenarios.	1
Very uncomfortable and hard to control or use.	1
<u>C</u>	
Perfect for virtual gaming scenarios. Not exactly practical for live fire engagements.	1
Joystick seemed to have resistance to movement, difficult to quickly move cursor.	1
Once object selected, easy to move in straight lines with cursor.	
I like the one with the balls instead of the joystick.	1
Difficult to move with joystick.	1
Difficult to use due to location on body. Was not integrated with weapon.	1
Had to use two hands for about 50% of tasks just to move quickly enough.	1
Hard to perform task.	1
I did not like this device at all.	1
The two piece concept made it difficult to use effectively.	1
If the device were able to be held in the hand vs. attached to my ACUs, it would be better. The type of controller it had is horrible and is very slow to respond.	1
Not efficient!	1
Too slow.	1

Comments**No. of Responses****D**

The device was difficult for me to use because I am not used to using joysticks or anything similar to this on a daily basis, but I think the overall concept and design is good.	1
This device was the best one out of the ones that I tried. Movement between objectives was easy.	1
All difficulties were due to the joystick, not the Delta configuration.	1
Buttons were in wrong location. Confused with which was the joystick and which was the secondary button.	1
Difficult to move.	2
Had trouble being left handed and using a mouse type device.	1
The device was not that hard to use but the only problem I had was using my left hand because as was mentioned earlier it is rare that I use my left hand.	1
Hard to perform task.	2
The resistance required to move the joystick was too high, leading to imprecise cursor control.	1
The trackball one is better than the joystick one.	1

Trackball**A**

Best thus far!	1
Very good task execution.	1
Wonderful.	1
Good.	1
User friendly.	1
Liked it. Easy to use buttons and comfortable hand position.	1
Much easier with trackball than joystick, movement is easier to control.	1
Did the best on every task using this configuration. Is better than Charlie because the mouse movement plane is the same as if you were using a mouse on a table, whereas with Charlie the plane is inverted and causes some confusion.	1
Again, I don't know why a mouse on a rifle, as battery technology isn't advanced enough to give us hours of power without significant weight. I can't see this being carried by anyone on foot practically; the battery weight would be disgusting.	1
More successful with the use of the mouse as opposed to using the joystick and trackball.	1
Trackball sucks.	1

B

Worked very well.	1
Pretty good.	1
Was easy to adapt to controls, last task was much easier than first. Liked the natural fit around hand stock.	1

<u>Comments</u>	<u>No. of Responses</u>
Much easier to complete the desired tasks.	1
Performed well, but is too big.	1
Buttons possibly too close for thick gloves.	1
The buttons were in the wrong place making it very awkward to use.	1
I would recommend adjusting the buttons more to the right side of the weapon for a more firm grip.	1
Small movement tasks difficult to perform, very inaccurate. Also with buttons forward made grip feel odd, difficult to hold button and then track with trackball.	1
If you are going to use this mechanism on the weapon system I would place on the rear and where it is comfortable to place the fingers.	1
It would probably be a lot easier after two or three more tries.	1
Selection of any task was poor, takes too much time.	1
The right and left click buttons did not respond very well to pressure. I feel like this would be even harder in gloves. Did not like them at all. Already expressed my displeasure with the trackball itself.	1
<u>C</u>	
Performed task well.	1
This was much easier for me to use than the joystick.	1
Much easier than the task 1.	1
Hard to use overall.	1
How embarrassing.	1
Needs to be more versatile.	1
Only issue I had with it was the buttons seemed a bit worn out. I had to really click hard to get it to register on the system.	1
Sometimes I had to look down to see which button to push.	1
The buttons where not very easy to use.	1
The trackball could be more sensitive to movement so that there is less rolling required to move the cursor.	1
The way the device had to be mounted did not allow for the proper use of the trackball.	1
This one is awful. The buttons are not placed in a convenient, much less in an ergonomic manner. It is extremely difficult to maneuver the tracking ball while holding down a button. It is just overall useless.	2
<u>D</u>	
Great performance, but then again this is my 8th try.	1
Much easier to use. Way more accurate.	3
Easy to control.	1
Good performance.	1
Best I have seen.	1

Comments**No. of Responses**

Satisfactory.	1
Completed all tasks.	1
I was able to use it fairly easily; however, the trackball on the joystick was too close to the right click button and my thumb kept hitting it when I was trying to move the mouse. A larger device with more space in between the two might help.	1
The trackball and buttons were easy to use; however, manipulation of certain aspects of powerpoint was slightly difficult due to the small nature of the taskbar.	1
Can't use right mouse button and trackball at the same time. Trackball inaccurate. Moving the cursor occurs in bounds rather than steady motion.	1
Hand tires out on this one too quickly. Need something to grip, there is nothing to hold on to.	1
Too focused on proper manipulation of device instead of end result.	1

4. At any time during this trial, did the WCG device fail to function properly?

	Number of Responses							
	JOYSTICK				TRACKBALL			
	A	B	C	D	A	B	C	D
No	40	40	42	37	44	43	38	42
Yes	6	6	4	6	0	4	7	4
NR	2	2	2	4	4	1	3	2

JOYSTICK**A**

A screen kept popping up.	1
At times the cursor would not push to the right.	1
Controlling cursor and selection of items.	1
I lost a button.	1
The trackball would consistently fail to respond when I tried to move the cursor right. It would either not move at all, or be very slow.	1

B

At times when I would try to move the cursor using the device, the device wouldn't respond.	1
Cursor was difficult to control.	1
Joystick sticky.	1
The right click button fell off.	1
There was no device; device was broken before I started.	1

C

Screen pop-ups from buttons being too small.	1
Several times it would not respond when I was trying to move the cursor.	1
With device attached to clothing, made it hard to control.	1

Comments**No. of Responses****D**

Button had to be held for click operations.	1
Drag and drop feature for drawing lines and other features did not work.	1
It consistently would not go right quickly or at all.	1
Left mouse button wasn't responding well.	1
Other screens pop-up while maneuvering. Buttons did not work on all screens.	1
Unable to effectively control device.	1
Unable to get device to move arrow immediately as needed in any specific direction.	1

Trackball**B**

Holding the button became problematic for the drag and drop feature. It would continually release.	1
If more time was allowed it would have been easier to accomplish.	1
Kept accidentally hitting the red button.	1
The left clicker did not work effectively.	1
The trackball was extremely difficult to work with and broke off after only a few uses.	1

C

Holding contact with button. Use better buttons.	1
Left mouse button didn't seem to work right.	1
Trackball became unseated, left mouse failed.	1
Trackball glitch.	1
Maneuvering cursor in right direction.	1

D

Controlling rolling device.	1
Failed to track properly on "Z".	1
Had to click the red right-click button fairly hard.	1
The left and right mouse buttons failed to recognize pressure applied to them.	1

5. Describe anything you **DISLIKE** about the trackball or joystick.

JOYSTICK**A**

Buttons need to be rearranged.	1
Do not like it because it should be incorporated into the weapon. Would be something else the soldier has to learn if you already use the components of the weapon might make more receptive to accept.	1
Don't like the joystick at all.	3
I dislike the feel.	1
I dislike the joystick for smooth fast movements.	1
I think the joystick is difficult to use.	2

<u>Comments</u>	<u>No. of Responses</u>
It's not that easy to control.	1
It is difficult to pinpoint.	1
Joystick does not respond well to fine mouse pointer movements.	1
Not responsive enough.	1
Joystick doesn't move very quickly.	1
The joystick doesn't move well.	2
Joystick too slow.	5
Hard to use for long periods with the thumb.	1
Joystick was difficult to accurately maneuver with thumb of non-dominate hand.	1
Because I had to use my left hand, it was harder to control.	1
There's a learning curve to become accurate with functions.	1
Hard to do angles with. Would twist in finger which would create movement problems. Not sensitive to light movements.	1
This type of joystick due to the trackball mouse was horrible.	1
Trackball is better.	1
Joystick is not sensitive enough.	1
Use a better joystick or better brand.	1
<u>B</u>	
Joystick hard to move for short distances.	1
Can not control the cursor in an accurate way.	1
Do not like the joystick!	1
Doesn't move well at all.	1
I disliked EVERYTHING about it. Joystick was horrible at responding to me trying to move it.	1
I found the joystick to be ineffective.	1
Joystick and shape/size of device.	1
Joystick can be better type or brand.	1
Joystick is jerky and you can't tell if it will go fast or slow.	1
Joystick terrible compared to trackball. Perhaps make it slightly longer? I prefer a joystick that I can grip with my entire hand for proper control.	1
When trying to click on the corners of objects it became very difficult.	1
Twist in finger, hard to do angle.	1
Too slow.	6
Difficult to select what is needed.	1
The joystick was too rigid.	1
The location was difficult for me.	1
Required too much effort.	1
<u>C</u>	
Overall really good.	1
Do not like the joystick at all. Fix it.	2

<u>Comments</u>	<u>No. of Responses</u>
Everything. Throw it out, get a new idea.	1
Hard to go at an angle with the joystick.	1
Hard to operate with one hand.	1
Inaccurate with point.	1
It does not feel right.	1
Too small and not responsive enough.	1
It was very sluggish and hard to move.	1
The joystick is hard to move accurately.	2
Joystick is terrible.	2
Joystick moves too slowly!	3
Joystick sticky, with gloves would be hard to navigate I think.	1
Needs to be more adaptable to battle specifications, will be hard to use during a firefight.	1
Not smooth in its motion.	1
Mouse movement felt rigid.	1
Slow.	2
The joystick is awful! It needs to be more sensitive to small movements to allow precision. Perhaps you should model the joystick off of gaming systems such as the xbox360, which allow much greater ease of movement, and many soldiers are probably already accustomed to the feel of those joystick designs.	1
<u>D</u>	
Fine movement needs to be improved but still better than the trackball.	1
As a personal preference, I don't like using this type of device at all. Hard for me to coordinate at first, but with practice over time I would adapt.	1
Do not like the joystick at all. Ditch it.	2
Hard to do a diagonal.	1
Hard to move joystick accurately.	1
I just disliked it period.	1
It was hard to use. I did not like anything about it.	1
No accuracy.	1
Seems somewhat ineffective due to delayed response time.	1
The buttons were a bit confusing. I would have liked it better if there was a way that I could control all features with only one mouse instead of using all three.	1
The joystick was difficult to move and control.	2
Arrow never moved or stopped where you want it to.	1
The type of cursor mover it had was horrible. It needs to be thrown away. I could not get it to move right or anything with any type of ease at all.	1
Too complicated.	1

<u>Comments</u>	<u>No. of Responses</u>
Trackball superior.	1
Was slow and awkward.	2
The thumb button is much too easily confused with the joystick!	1
<u>Trackball</u>	
<u>A</u>	
Trackball moves smoother and would work better in gloves.	1
I completely like it.	1
Trackball on this was easier to manipulate than in other arrangements, but still needs to be smaller.	1
Handle could be a little shorter.	1
Hard to steer the cursor and keep the left button down at the same time.	1
The size.	1
Trackball could possible cause discomfort after continuous use.	1
Trackball moves the cursor too fast and erratically.	1
Trigger was too long and loose.	1
Trackball makes the cursor move way too fast.	1
Only the tract is hard to pinpoint.	1
<u>B</u>	
Do not like it being on the left side of device.	1
Felt jittery and a little loose. Did not feel tight and stable like you would want it to be	1
Impossible to use in a real live fire fight.	1
It moves too quickly to keep up.	1
Its location on the WCG.	1
Mouse buttons caused problems with selections, kept having to reselect task.	1
Moves too freely.	1
Needs more work.	1
Once again, I'm not left handed so that would take some getting used to.	1
Hate the trackball.	1
Side to side cursor movement was difficult.	1
Size and shape.	1
The initial direction up, right, left, and down needs to be shifted clockwise to a slight degree. So it is not in conjunction with the weapon but with the holding user.	1
The trackball again is not sensitive enough, requires considerate pressure to move accurately.	1
Trackball is uncomfortable and does not get accuracy moments when in a hurry.	1
Trackball movement needs to be more controlled.	1
The trackball should have a little more friction when moving.	1
<u>C</u>	
Trackball rules!	1

<u>Comments</u>	<u>No. of Responses</u>
Axis needs to be changed or changeable.	1
Buttons too close together.	1
Device not anchored; was subject to moving as a whole unit when attempting to use trackball.	1
Hard to get to in time of need in battle.	1
Having to attach to uniform.	1
I think everything was upside down.	1
Location.	1
The trackball is overly sensitive.	1
Trackball felt loose inside the socket.	1
Trackball not good on this device.	1
Very uncomfortable to use.	1
What do I NOT dislike?	1
<u>D</u>	
All of it.	1
Trackball rules.	1
Cannot point to the desired point.	1
Needs more work.	1
Not precise.	1
The grip of the controls could be longer. Swiveling at that point may cut the hand when turning the control.	1
The shape can be improved a bit.	2
Trackball is too sloppy, although fine movements of cursor were adequate.	1

6. Describe anything you **LIKE** about the trackball or joystick.

JOYSTICK

<u>A</u>	
Easy to use with non-gloved hands.	1
Good access, good size.	1
Good location.	2
Like this slower one.	1
The movement of the cursor was not too fast or too slow.	1
Joystick is not sensitive enough.	1
Nothing.	2
<u>B</u>	
Throw it out!	1
Nothing.	2

<u>Comments</u>	<u>No. of Responses</u>
Trackball is clearly superior.	1
Was easier to drag things for longer distances than the trackball.	1
<u>C</u>	
I don't like the placement of the device on the body, it makes it difficult to use. Better to have something in front of you.	1
I don't like anything about it.	2
Initial reaction is it looks like a button and can trick others who are untrained.	1
Its size.	1
Joystick could make accurate vertical and horizontal movements.	1
Joystick has the potential to be much better than the trackball if above mentioned improvements were made. At the current design levels however, the trackball outperforms the joystick.	1
Light and small.	1
Size.	2
The size of the joystick was big enough for the finger to comfortably fit on.	1
<u>D</u>	
Good device.	1
The joystick is in a good location.	1
Hard to control movement.	1
Nothing.	4
<u>Trackball</u>	
<u>A</u>	
Overall, very comfortable to use. It felt good in the hand.	1
Easy to use.	5
The handle with angle to the trackball made the device easy to use.	1
Good size.	2
It is in a good location.	2
Good access.	1
It moves freely!	2
It was quicker and easier to operate.	2
Looks rugged.	1
Loved the trackball!	1
More effective.	1
Neutral.	1
The speed.	1
Very easy to work with. Flowed very well. Did not have to think too much to use it.	1
It just flowed	
Trackball makes the cursor move way too fast.	1
<u>B</u>	
Accurate.	1
Any trackball is better than almost any joystick.	2

<u>Comments</u>	<u>No. of Responses</u>
Easy to use.	2
Normally trackballs are done on a table surface, so rotating the imaginary surface 90 degrees to operate took some getting used to. However, once mastered was easy to use.	1
Fit well into palm of hand.	1
Helps with the accuracy of the device.	1
Its technology, so that is good, but I still hate the trackball with a passion.	1
Liked the location where device mounts. Like how trackball moved.	1
The fact that a mouse is on a weapon and were are taking the next step in future weapons	1
The location on the device.	1
It was in exactly the right place to use with one hand while maneuvering to the fight.	1
The size is good.	1
Trackball easy to move but not accurate. Quick movement of cursor with trackball a definite plus.	1
Type.	
<u>C</u>	
Accurate.	1
Better to use than joystick.	1
Easier to handle.	1
Easy to select object.	1
Good concept, needs more work.	1
Neat concept.	1
I felt that this was much easier for me to be accurate.	1
Movement.	1
Prefer a trackball over a joystick hands down.	1
Trackball itself.	1
<u>D</u>	
Ease of control.	2
I like how the trackball can be used with the thumb making it easier to control.	1
Easy to maneuver and accurate.	2
Easy to pick up on the more you train with it.	1
I like the fact that the ball is easy to use as tracking the objects you select.	1
Flow easily and easy to direct.	1
Good location.	2
I liked the overall concept, just too small.	1
Like to use the trackball. Do not like the joystick at all.	1
Love the trackball much better.	1
This model was much easier to use and felt more natural.	1
Trackball fine movements are better than the joystick.	1

<u>Comments</u>	<u>No. of Responses</u>
Trackball is definitely better than joystick, allows easier and more precise movement.	1
Very easy to use, smooth.	1
Very good size.	1

7. Describe anything you **DISLIKE** about the buttons or switches.

JOYSTICK

<u>A</u>	
Buttons excellent location, feel.	1
Do not like it because it should be incorporated into the weapon; would be something else the Soldier has to learn if you already use the components of the weapon might be more acceptable.	1
Not responsive enough.	1
The joystick, prefer the trackball.	1
The right click button was too small and oddly positioned.	1
The right mouse button was too small.	1
<u>B</u>	
The buttons were OK this time.	1
Buttons and joystick positioned oddly, better for use in a prone position than a standing position.	1
Buttons are too small and stiff.	3
Buttons on this concept too close together. Thick gloves could possibly cause the user to accidentally press two buttons at once.	1
The buttons are too far apart... left and right click.	1
Cursor moves too slow.	1
Hard buttons. Relocate the buttons for a better grip on weapon.	1
Positioning was bad.	2
<u>C</u>	
They were ok. No real opinion.	1
Buttons too small and confusing because it is upside down in terms of how one would use a normal mouse device. It would be easier if the device could be placed somewhere else on the body like mid ACU top or upper ACU bottom in order to use it.	1
The buttons respond to very light touch. This makes it difficult to perform tasks.	1
Too small and was difficult to push buttons quickly.	1
Do not like it attached to my uniform.	1
Hard to pinpoint a target.	1
Have both buttons where index finger could reach. As configured had to move thumb off joystick to press right click button.	1

<u>Comments</u>	<u>No. of Responses</u>
Needs to be more adaptable to battle specifications, will be hard to use during a firefight.	1
Seemed small to use and would not work well with gloves.	1
The location.	1
Too small, positioned poorly.	2
<u>D</u>	
The left click had to be held for click operations.	1
You can't right click and use the joystick at the same time.	1
The location for the primary button is ok. The secondary button needs to be separated from the joystick by placing it on a different side or below the primary button.	1
The thumb button is much too easily confused with the joystick!	1
Too small.	2
Too small, won't be able to find them with gloves, confused that they were on opposite sides of the device.	1
Did not always work.	1
<u>Trackball</u>	
<u>A</u>	
Location of switches.	1
One of the thumb buttons did nothing, this was confusing.	1
Right mouse button and trackball are both operated by left thumb and thus cannot be used at the same time.	1
The right click button was hard to reach at times.	1
The buttons are hard to maintain consistent pressure on. Should look into modeling the buttons after those found on game systems, for ease of use and familiarity with the operator.	1
The green button may need to be closer to the red button.	1
<u>B</u>	
Buttons do not respond well.	1
Buttons felt somewhat clumsy.	1
Buttons forward were difficult to use.	1
Buttons too close together for gloves.	1
Buttons were too far away from the trackball, which forced me to spread my hand too far.	1
Buttons were bad.	1
Compatibility with gloves.	1
I disliked the placement of the buttons.	1
Location.	1
Needs more work.	1

<u>Comments</u>	<u>No. of Responses</u>
Since I am left handed, the right and left click buttons were switched when the device was set-up. This made it difficult to use the correct buttons. Also, the small size may make it difficult to use when wearing gloves.	1
The buttons stick out too far, and so to maintain pressure while moving or dragging items are difficult.	1
The red and green buttons are too close to each other.	1
The right click button is hidden and difficult to locate.	1
The left click button needed to be a little more sensitive.	1
<u>C</u>	
Buttons are too small.	4
Buttons didn't respond well.	1
Buttons on this one weren't sensitive at all. Had to click and hold with a lot of pressure.	1
Could be helpful if buttons made more of a clicking sound when pressed.	1
Hard to use buttons when mounted on chest.	1
I think everything was upside down.	1
I wish it more resembled a mouse with a trackball in that the two buttons would be side by side.	1
I wouldn't be able to feel them through my gloves.	1
Poor location.	1
The button push is too long; button sensitivity is too sensitive when releasing the button.	1
The left mouse button didn't click when pressed.	1
Too low on the device. Adjust for thumb and other fingers.	1
<u>D</u>	
Buttons not shaped well. Perhaps buttons that more closely resemble those on gaming systems.	1
Left click seemed to stick.	1
Not sensitive but moves quickly.	1
Right click and left click sometimes confusing to determine which was which.	1
Too small.	3

8. Describe anything you **LIKE** about the buttons or switches.

JOYSTICK

<u>A</u>	
Good location	3
Represent left and right mouse buttons well.	1
Not much.	1
<u>B</u>	
Good.	1
Buttons are good quality thus far.	1

<u>Comments</u>	<u>No. of Responses</u>
Buttons work wonderfully.	1
Buttons (the left and right click) were not so bad, but using my left hand for them took some getting used to.	1
Not much.	1
Throw it away.	1
<u>C</u>	
In good location.	1
They were slightly easier to push than past devices.	1
<u>D</u>	
Good location.	2
I liked the left click button being by my pointer finger.	1
Accurate.	1
Nothing except placement.	1
<u>Trackball</u>	
<u>A</u>	
Buttons were located in an excellent position to make it easy to hit while controlling the device.	1
Buttons were well placed and easy to identify.	1
Good location.	4
Liked having my index finger on the left click button.	2
Switches were fine.	1
Nice and contoured for extended usage.	1
Once you get used to the location of the button and the idea that this is only for functionality, it becomes easier to use.	1
Respond quickly.	1
Roller was very nice.	1
The size.	1
<u>B</u>	
Good location.	2
The buttons are the best feature of the device, easy to use.	1
The smoothness and contour of the buttons.	1
<u>C</u>	
Good concept, needs more work.	1
Manageable.	1
Smooth and contoured.	1
The button locations were great, easy to figure out.	1
Too flimsy.	1

Comments**No. of Responses****D**

Easy to feel and push with your fingers. Would make it easy for when gloves are used.	1
Good location	5
Light.	1
Smooth and contoured for fingers.	1
The buttons are located in a good spot making it easy to push.	1

9. What changes would you recommend to improve this WCG device?

JOYSTICK**A**

Buttons need to be rearranged.	1
Move right mouse button to front, so that use can use joystick and button at the same time.	1
Change to a trackball and it would be much better.	2
Device rotates too easy, would rotate if conducting very physical operations.	1
Do not use joystick.	1
Remove joystick or loosen joystick.	1
I think that the mounting device is a bit bulky and could be made smaller or more ergonomical to the hand.	1
More training.	1
To move faster.	2
Use the components of the weapon system also makes it less detectible by the enemy.	1
Using a remote device not connected with weapon.	1

B

A little smaller.	1
Do not use the joystick.	1
Make it a trackball.	2
Use something else completely.	1
Grip location and shape.	2
I would make the joystick move quicker.	1
Perhaps making the right click button nearer to natural location of the thumb so as to use the thumb instead of the index finger for clicking? That might help with glove problem.	1
Redesign the joystick, as you are not going to be able to use with combat gloves.	2
Speed up the pointer and use software to add in the auto selection of objects as pointer passes over an object.	1

Comments**No. of Responses****C**

Change the design of the grip.	2
Don't pick this model! What's the point if I have to put my weapon down?	1
Ditch it.	2
I would not locate the device on the chest.	1
Increase length of joystick.	1
Larger buttons and use of two hands.	1
Make the device easier to make angle adjustments.	1
Needs more work in order to be used in the battlefield, will be hard to work with during a firefight.	1
The device is too small; the chest is a poor position due to problems with being in the prone. Gloves would make the joystick very hard to use. Buttons poorly placed for glove use.	1
Try taking the analog joystick from the play station or xbox to get better motion for the controls.	1
Improve the diagonal movements of the device.	1

D

Different grip.	1
Make the device larger and do not use the type of cursor mover.	1
Move the right mouse button to the front, underneath the left mouse button, activated by the middle finger.	1
Place buttons or maneuvering switches by the hand guards for maximum effectiveness and ease of use.	1
Remove joystick.	3
Replace joystick with a trackball would be a huge improvement.	1
The buttons and joystick are hard to use.	1
The thumb button is much too easily confused with the joystick!	1
Larger buttons.	1

Trackball**A**

Can't think of anything right now.	1
Change the design of the grip.	1
More grip for the buttons.	1
Eliminate any buttons that don't perform any type of function.	1
Everything.	1
Alter shape of buttons to reflect that of a gaming system.	1
Make the ball smaller and put it on the handgrip.	1
Make the device slightly smaller or more ergonomic.	1
Shortening the handle an inch or so.	1
Slow down cursor speed.	1
The green button may need to be closer to the red button.	1

<u>Comments</u>	<u>No. of Responses</u>
Too easy to rotate. It makes me wonder if it would turn on its own while conducting operations which required lots of movement.	1
Use something other than the trackball type mouse.	1
<u>B</u>	
Move the trackball.	1
Get rid of the trackball.	2
Use something other than a trackball.	1
Make the trackball right-handed.	1
Make trackball easier to use and adjust sensitivity so it will not move 20 inches instead of the amount you need.	1
I would make the trackball more sensitive to movement and the buttons easier to depress.	1
Is there any way to move trackball to thumb side of pistol grip? (behind and a little lower than fire selector) than place buttons on barrel left side for thumb to use?	1
Move the buttons a little more to the side of the device. Could make for easier push of button.	1
Somehow make this smaller and not get in the way of gripping your barrel.	1
Trackball sticks out the furthest in this design, it could be hit if dropped or bumped on that side. Sand in trackball if laid down in dirt.	1
Wouldn't use it in a real fire fight.	1
<u>C</u>	
Awkward body placement. Arm was uncomfortable.	1
Larger buttons.	2
Find somewhere to attach it too, except ACU.	1
Design so that the ball rolls easier.	1
Ditch it.	1
Explain before using equipment both hands can be used. Location of buttons may cause difficulty in using.	1
If the device as a whole could be a little smaller, that would be great.	1
Improve the overall concept because during battle it might be hard to get to your trackball and use it properly in order to call in help for any simulation.	1
Make the buttons shorter.	1
Making the ball stiffer.	2
Scrap it.	2
Try for different location that's more practical.	
<u>D</u>	
Better ergonomics.	1
I would make the device longer so there is more to hold on to. This would make it more comfortable.	1
In addition to being able to swivel clockwise and counterclockwise, should be able to angle and rotate around the barrel for maximum ergonomic ease.	1

Comments**No. of Responses**

Make the trackball and right click button further away from each other.	2
Making the handle a little bigger.	2
More comfortable grip.	1
Need to improve the sensitivity.	1
The shape.	1
Move the right-click button further away from the trackball, it may be triggered when gloves are worn.	1
Put the ball behind the trigger guard.	1

10. Using the scale below, what is your OVERALL rating of the WCG device you used.

1	2	3	4	5	6	7
Extremely bad	Very bad	Bad	Neutral	Good	Very good	Extremely good

MEAN RESPONSE							
JOYSTICK				TRACKBALL			
A	B	C	D	A	B	C	D
3.80	3.42	2.89	3.57	5.64	4.59	3.70	5.30

JOYSTICK

<u>A</u>	
Good concept but more for ergonomics than functionality.	1
Good device.	4
Can improve with more thought.	1
Did not like the trackball type mouse.	1
Thumb joystick set too slow, hard to manipulate.	1
Too hard to maneuver.	1
Was a very comfortable device but was hard to use when it came to accuracy.	1
Why a mouse on a rifle? Maybe this can find use in vehicle, which is very cramped.	1
Again, battery weight will be disgusting.	

<u>B</u>	
Good system.	1
If something like this was taken out into the field it would be difficult to use.	1
Not a totally practical design outside of cover and concealment range. Potential room for user error and injury during employment in live fire scenarios	1
Poor shape and size because it places uncomfortable strain on the wrist. Cannot change orientation of device to suit different ways of holding the weapon.	1
The glove issue, plus it feels a bit awkward. Not as much for the hand to hold on to.	1

<u>Comments</u>	<u>No. of Responses</u>
This device stinks.	2
Recycle it.	1
WCG may fair better with another movement device.	1
Will interfere with weapon safety.	1
Could not complete the tasks due to the difficulty of the trackball.	1
<u>C</u>	
I like this one; I just don't like the joystick.	1
Bad, others are better.	1
I don't think this should be used.	1
No real world applicability, uncomfortable, confusing.	1
Not easy to use whatsoever. It stinks.	1
Trackball is better.	1
<u>D</u>	
Not a bad design, but with a trackball would be much better.	1
Device is still uncomfortable, but the joystick is easier to use on the weapon than by itself.	1
Prototypes- work in progress.	1
The joystick version is bad.	1
Concept A with the joystick is the best but joystick responsiveness needs to be improved with fine cursor movements.	1
Not recommended.	1
<u>Trackball</u>	
<u>A</u>	
The best device overall.	1
Good.	3
I like this system of trackball.	2
More effective behind cover and concealment, not in direct live fire engagements.	1
Size and buttons good; ball bad.	1
<u>B</u>	
Surprisingly decent device.	1
Best so far.	1
Clumsy to work with.	1
Good concept but difficult to use, perhaps with training would get easier.	1
Good, but can be improved upon.	1
Place the buttons in an easier place to access.	1
Poor design, uncomfortable.	1
Perhaps move right click button to be used by thumb to avoid problems with gloves?	1

Comments**No. of Responses****C**

Very good.	1
Difficult to work with. Was not integrated with the weapon. Difficult to constantly look down and back at the screen to complete the mission	1
I don't like this equipment at all when placed on the uniform.	1
I have to get used to playing with it for me to get the hang of using the mouse.	1
It does the job, but I believe that it could be improved to be more effective.	1
Stinks.	1
The worst design of all 4. Poor real world applicability, uncomfortable, confusing interface.	1

D

Good device.	2
Tracker ball much easier to use than joystick.	1
I was able to complete virtually all the tasks. Fairly easy to use.	1
The only device that doesn't stink.	1
Very easy to use, really liked it.	1
Very good concept.	1
Very good performance.	1

Appendix D. End of Experiment

This appendix appears in its original form, without editorial change.

APPENDIX D

END OF EXPERIMENT

SAMPLE SIZE = 48

1. Using the scale below, please rate the degree of acceptability (like or dislike) of the four systems.

1	2	3	4	5	6	7
Extremely unacceptable	Very unacceptable	Unacceptable	Neutral	Acceptable	Very acceptable	Extremely acceptable

	MEAN RESPONSE
	SYSTEM A
Wireless Graphic Controller (WGC) integrated into forward handgrip	5.58
Linear toggle switch mounted to the weapon	5.05
30 degree rotational feature	5.52
Overall concept	5.72
	SYSTEM B
WGC integrated into hand guard	4.17
Rotary toggle switch and integrated PTT button	3.98
Overall concept	4.17
	SYSTEM C
Split design concept	3.00
Rotary toggle switch and integrated PTT button mounted to the weapon	3.28
Allowing user to customize equipment position	3.73
Overall concept	3.33
	SYSTEM D
Split design concept	4.93
Rotary toggle switch and integrated PTT button mounted to the weapon	4.84
Allowing user to customize equipment position	5.29
Overall concept	5.10

2. Overall, did you prefer using the joystick or the trackball?

	No. of Responses
Joystick	3
Trackball	42
No preference	3

<u>Comments</u>	<u>No. of Responses</u>
Both devices have their ups and there downs.	1
I like the speed and accuracy of the trackball but the comfort of the joystick, if you could somehow combine the two ideas, then it would be almost perfect.	1
Needs more work in order to be feasible for both to work successfully in the long run.	1
<u>Joystick</u>	
Better use dependent of range of manual dexterity.	1
Joystick is a little more accurate on horizontal and vertical lines.	1
Joystick is easy to pinpoint object.	1
Joystick was better for Concept B.	1
A joystick is slow but can better weather the elements.	1
If the joystick moved faster, it would have been the better of the two.	1
Sensitivity on joystick another issue.	1
The joystick is not as responsive as the trackball.	3
Joystick harder to control in selection of equipment except for when the trackball was on the joystick.	1
Joystick is moving the cursor too fast.	2
With a little refinement of the fine cursor movements, the joystick would be the better design.	1
Difficult to put the cursor on corners of objects.	1
Joystick is terrible. If the joystick was more sensitive, it would be much better.	1
Joystick was far less accurate.	2
Joystick was too rigid and slow.	3
Joystick too stiff.	1
The joystick was hard for me to use, especially when using my non-dominant hand. I found it to be slow to react and maneuver in "tight" directions.	1
The joystick is extremely hard to maneuver.	1
The joystick was absolutely horrible. It was poor to respond and definitely affected performance. While normally I don't like the trackball, it is the lesser of two evils.	1
Joystick unable to move to desired location with ease.	1
Joystick required too much force to work.	1
The joystick would be better with gloves, but does not approach the ease of use of the trackball.	1
Joystick is too short, cannot be used with one thumb very effectively. Joysticks best with entire hand, not one thumb.	1
The joystick is sluggish, needs a better angle for thumb placement, but is designed for more rough conditions.	1
Resistance and calibration for joystick needs to be adjusted.	1
Do not use joystick.	1
<u>Trackball</u>	
Trackball kicks butt; no ifs, ands, or buts about it.	1
Trackball was better for Concept A.	1

Comments**No. of Responses**

More accurate.	1
Trackball easier to use.	5
Trackball is easier to control.	1
Trackball is worlds easier to manipulate.	1
The trackball outperforms joystick in almost every way simply because the joystick is not sensitive enough to allow accurate and precise movements. Should model joystick after those of X-box controls. Also, Bravo did not perform as well because the trackball/joystick was being manipulated by a finger rather than a thumb, which gives less dexterity.	1
Trackball may get dirty or pop out during use, but is very accurate and fast.	1
The trackball to me is better than the joystick because I have more control of the features.	1
Speed is crucial, so is the ability to use thick gloves or the palm of your hand. The joystick suffers compared to the trackball.	1
Trackball able to move quickly and on target.	1
Trackball was much faster.	1
A trackball is susceptible to dirt, oil, and water but it is accurate and moves faster.	1
Less jerky.	1
Trackball is quicker, and draws zig zag lines better.	1
Much better to work this than the joystick.	1
The trackball was too loose but was easier to use than the joystick.	1
Trackball is more efficient.	1
More erratic and has better fine cursor movements.	1
I wonder how maintenance intensive this would be.	1
Trackball needs improvement.	1

3. Please rank order each system on the dimensions given below (with “1” being the LEAST preferred system and “8” being the BEST system).

Rank order by compatibility with weapon, equipment, and mission:

System	Joystick	Trackball
A	4.9	6.6
B	3.0	4.9
C	2.6	4.4
D	3.9	6.2

Rank order by location of WCG components, i.e., on the body, on the weapon, etc:

System	Joystick	Trackball
A	4.6	6.4
B	3.6	4.9
C	2.8	4.3
D	4.2	5.9

Rank order by location of components within the WCG device, i.e., button separation, distance from button to joystick or trackball, vertical vs. horizontal mounting, etc.

System	Joystick	Trackball
A	4.7	6.7
B	3.3	4.7
C	2.9	4.0
D	4.1	6.1

Rank order by form factor, i.e., size, weight, balance, etc:

System	Joystick	Trackball
A	5.2	6.4
B	3.6	4.6
C	3.1	4.3
D	4.5	5.8

Rank order by overall ease of use:

System	Joystick	Trackball
A	4.5	6.4
B	3.3	4.8
C	2.8	4.5
D	4.2	6.1

4. Where on an ideal WCG device would the trackball or joystick be mounted?

	No. of Responses
To the weapon	39
To the chest area	2
Hand-held	4
Other (specify below)	2
No response	1

<u>Comments</u>	<u>No. of Responses</u>
Trackball easy to use.	1
Trackball works better.	1
If mounted on the weapon, that is one less item to lose in the field. For the infantry this is very important.	1
Place near pistol grip, thumb side.	2
Adjust to the thumb. Users have an angle with placement to the weapon. Go for the majority.	1
Get rid of the joysticks!	1
I would make one that attaches to the weapon but can detach and be hand held.	1
Weapon is a bad place to put it. Weapon vibrations, blows to device, getting in sand, mud, etc., getting hit by hostile environment. I would make the device a hand held pocket piece because it will only be used when the area is reasonably secure, so you can take it out. Also, keeping it in a box prevents many ruggedization issues, e.g., what happens if I hit someone with my rifle with device attached.	1
If it has to be mounted to the weapon, the ability to take it off quickly and easily would be nice.	1
It would be preferable to mount to the side of the weapon rather than the bottom so as no not interfere with other devices	1
The trackball is the most ideal for me. Also, if both of the buttons are kept together on the other side, maybe at an angle, so as to resemble a computer mouse, would help to eliminate some of the co-ordination and confusion.	1
Make the mouse more realistic with the soldier being able to fire the weapon accurately in a moments notice when trying to use the weapon.	1
Mounted under a flap on the top side of a firing glove.	1
They should add to the stability of the weapon while firing	1
Trackball should be on left for right handed shooter.	1

5. Where on the ideal WCG device would the buttons be mounted?

	<u>No. of Responses</u>
To the weapon	36
To the chest area	1
Hand-held	5
Other (specify below)	3
No response	3

Buttons should be placed for better grip of the weapon. It should not hinder user's primary use, shooting. The buttons could injure fingers or hands if they stick out too far because of recoil.	1
I think it would be ideal to keep the buttons together like a regular mouse.	1

Comments**No. of Responses**

Keep buttons away from trackball/joystick in such a way as they will not be constantly bumped or selected by mistake. 1

Make sure they are far enough away from the buttons. 1

On the device. 1

On the glove or the weapon. 1

Place near pistol grip, next to magazine release button. 2

Red button should not be near trackball/joystick, because requires you to shift hand position. Should be placed opposite, near black button. 1

This is good; just ensure there is enough room for someone wearing thick gloves to prevent hitting two buttons at once, like in concept C. 1

Would best be positioned so that only the thumb and forefinger are used to push them, the less fingers, the less confusing it will be. 1

6. How would the ideal WCG device be controlled?

	No. of Responses
Buttons	12
Scroll wheel	12
Touch screen	15
Voice	6
Other (specify below)	2
No response	1

A combination of the best technology. Voice first. 1

A touch screen with a stylus, similar to your everyday I-phone is the best idea I can think of. This device will always be somewhat cumbersome IMO in a battle environment where eyes are constantly focused on local security, not the screen. 2

Buttons or touch screen would be effective. 1

Eye. 1

Put an I-phone on the topside of my firing glove. 1

7. How would the ideal WCG device alert you to new information or status (e.g., battery)?

	No. of Responses
Audio (sound)	8
Visual (display lights)	15
Tactile (vibration)	24
No response	1

Comments**No. of Responses**

A silent vibration.	1
Allowing the user to adjust the settings would be best.	1
Combination.	2
In the field, audio would probably not be heard and vibrations not felt.	1
IR light.	1
Lights or sound?! NEVER. Tactile rules the day; no light or sound. Light and noise discipline a must.	1
Unless audio was integrated into an ear piece, would not be beneficial in a field environment, i.e., giving away your position.	1

8. Using the scale below, please rate each of the following characteristics in terms of importance.

1	2	3	4	5	6	7
Extremely	Very	Low	Neutral	High	Very high	Extremely
Low priority	Low priority	priority		priority	priority	high priority

	MEAN RESPONSE
Small size	5.80
Light weight	6.04
Compatible with equipment	6.41
Precision cursor control	6.40
Waterproof	6.50
Rugged	6.38
Quick operation	6.26
Use while walking	5.77
Emergency 911 shortcut (call for medic)	5.85
Wireless	6.43
Use while running	5.37
Use while standing	6.09
Use in kneeling position	5.89
Use in prone position	6.02
Use while wearing gloves	6.04
Noise security	6.22
Dedicated zero button that destroys software if WCG device is compromised	5.91

9. Are there any other features or functions that you would like to see on an ideal WCG?

GPS/range finder built in so rapid target acquisition.	1
Integrate with other systems to quickly place distance and degrees for call for fire.	1
Laser/GPS designator for fire missions.	1

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