Eye Point of Gaze for object selection and weapon aiming*

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ABSTRACT

This paper provides details and considerations for evaluation of Eye Point Of Gaze technology for object designation and weapon aiming. It lists considerations for equipment, scenarios, measures and variables to be tested. It also describes the Eye Point Of Gaze and scenario presentation equipment in general detail. The results are presented and discussed. In general, Eye Point Of Gaze is proved to be advantageous for speed, and for tracking accuracy for moving objects. Traditional weapon aiming is shown to have higher accuracy levels at the point of object designation.

KEYWORDS

Eye Point of Gaze, Weapon Aiming, Object Selection

Introduction

The task of the infantry soldier is complex, variable, and often time-critical. In modern combat situations battlefield success often depends on the ability of the fighting force to maintain higher tempo than the adversary, and to achieve flexibility in action and movement. A key consideration in any infantry system is to ensure that full system capability is accessible and compatible with the physical and cognitive capabilities of the operator, and that it enhances operational tempo. By implication, the Human Machine Interface (HMI) must be optimised to ensure system usability, while minimising training burden and likelihood of operator error. Simplification of the user interface and matching of system operation to user capabilities will be the key to unlock system capability in the context of battlefield applications. In the long term this will have the benefits of:

- Increasing the tempo at which the dismounted soldier can fight;
- Minimising the training burden and through-life cost of the system, ensuring that Operational Performance Standards are met with minimal training;
- Meeting the personnel/demographic challenge, ensuring that the system is intuitive and usable by the whole target audience.

It is conceivable that a system that reduces the mediation between the user's object detection and the aiming mechanism could reduce the opportunity for error. However, this was not under test in this piece of work.

The technology under consideration here is eye tracking, and it is envisaged that an eye tracking system will be used by the operator to designate objects in the visual scene for future action. Eye tracking would be used to enable the operator to quickly and accurately designate an object prior to action with minimum effort in terms of interaction with the system HMI.

It is proposed that use of these technologies to support object designation will reduce the psychomotor coordination required to aim and conduct target designation with conventional approaches (i.e. aiming along the boresight of a weapon). In conventional aiming a cross hair needs to be placed over the target via a combination of weapon movement and (in some cases) fingertip cursor control. In a battlefield context, where clutter, multiple targets and a short time to respond provide a unique challenge, there is potential to increase system usability and decrease decision to action time. An Eye Point Of Gaze (EPOG) tracking method would make use of the ability of humans to stabilise eye, head and body movements despite large displacement and was expected to result in an improved ability to designate objects.

The objectives of the study were to:

- Demonstrate the utility of Eye Tracking technology in an operational context
- Understand the performance increments achievable in object designation

An illustrative system concept was developed that enabled the investigation of EPOG utility. The concept used was a short-range small-calibre guided weapon (SCGW) (see Figure 1). The system was described to users as personally carried, deployed, targeted, and fired. It required no external sensor feed. Within this concept eye tracking technology was envisioned as a method of object designation before launch of the missile.

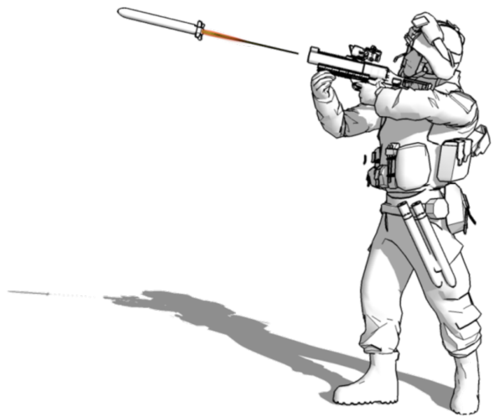

Figure 1 - Concept personal SCGW

Method

Two Separate Virtual Environments were created for this study; one a simple, uncluttered, abstract environment, the other a more realistic, visually busy, representative environment. Both environments were created using the Unity game engine.

EPOG was tracked in the experiment using an integrated binocular tracker within the Virtual Reality (VR) headset. This tracker represents a generic technology and is not proposed necessarily as a solution in itself.

The *abstract* environment consisted of a large room made up of 6 large white panels. A large red cuboid acted as a ‘home’ platform where the user was placed, and from which they designated and engaged objects. In this abstract environment, the objects were black cubes of approximately 2m per side.

The *representative* environment was designed to be broadly representative of what infantry soldiers might expect in the real world. Buildings and roads were added to an existing model of a town. 'Standalone' spots such as a church and a satellite array were added as points for the user to scan arcs from and potential engagement positions. The terrain was modified by changing elevation in parts and adding textural detail such as wooded areas, open grassland, and rocky areas. General environmental clutter was added including parked vehicles, industrial equipment, and domestic detritus. Within this environment, seven key locations were selected where the user was placed in sequence to fit a generic storyline of advance towards an objective. At each position a predetermined set of objects appeared for the user to designate.

Task

The task in each condition was the same. Participants were required to find an object in the environment, designate that object as a target, and fire the weapon. Participants were provided with a representative physical weapon to hold and point, this was replicated as a virtual representation in the synthetic environment. In the Weapon aiming condition, the designation part of the task was performed using a virtual sight attached to the weapon. Participants moved the weapon until the object was in the crosshairs, then pressed a designation button. In the EPOG condition there was no need to point the weapon, participants were able to look at the desired object, and press the designation button. The weapon was fired using a second button acting as a trigger.

Hypotheses

The following hypotheses were to be tested:

For Object Designation Accuracy:

1. Object Designation Accuracy will be better (distances will be lower) for Static Objects than for Moving Objects.
2. Object Designation Accuracy will show no difference between EPOG and Weapon aiming methods.
3. Object Designation Accuracy will show no compound effect of Object Motion with Aiming Method.

For Object Designation Time:

4. Object Designation Time will be better (times will be lower) for Static Objects than for Moving Objects.
5. Object Designation Time will be better (times will be lower) for EPOG compared to Weapon aiming.
6. Object Designation Time will show a compound effect of Object Motion with Aiming Method, and will be better (times will be lower) for Moving Objects using EPOG than for Moving Objects using Weapon aiming.

For Object Tracking Accuracy:

7. Object Tracking Accuracy will be better (distances will be lower) for EPOG compared to Weapon Aiming.

Variables

The following variables were under consideration.

Dependent Variables:

- Object Designation Accuracy - Angular distance between the centre of the target object and the measured aim point at Time of Designation. Measure: Degrees.
- Object Designation Time - Time from Time of Object Appearance to designation as a target. Measure: Seconds.
- Object Tracking Accuracy - The mean angular distance of aim point from object centre between Time of Object Appearance and Time of Designation. Measure: Degrees.

Independent Variables:

- Scenario - The scenario may be representative or an abstract object designation scenario. 2 Levels – Representative; Abstract.
- Objects - May be representative (virtual representations of realistic objects) or abstract (canonical shapes - cubes). 2 Levels – Representative; Abstract.
- Aiming method - Aiming method may be EPOG or traditional weapon-mounted sight. 2 Levels – EPOG; Weapon.
- Object motion - Objects may be static or moving in relation to the operator. 2 Levels – Static; Moving.

Conditions

The conditions for test are shown in Table 1. The list of possible conditions was cut down in order to make testing practical. It should be noted that this leaves an unbalanced design (in particular, more data are gathered for moving objects than static). However, the high number of data points gathered, and the total number of samples per participant enable a complete analysis to be performed for the variables of interest. Moreover, the *abstract* scenario condition in isolation does provide a balanced design, enabling the option of disposal of *representative* data if it is confounding or poor quality.

Table 1 - Selected Condition Configurations

Scenario	Object	Object Motion	Aiming Method
Abstract	Abstract	Moving	EPOG
Abstract	Abstract	Moving	Weapon
Abstract	Abstract	Static	EPOG
Abstract	Abstract	Static	Weapon
Representative	Representative	Moving	EPOG
Representative	Representative	Moving	Weapon

Comparisons

The following comparisons were made.

Table 2 - Comparisons

Comparisons	
Object Designation Accuracy	Object Motion – Moving vs Static Aiming Method – EPOG vs Weapon Compound Effects - Object Motion vs Aiming Method
Object Designation Time	Object Motion – Moving vs Static Aiming Method – EPOG vs Weapon Compound Effects - Object Motion vs Aiming Method
Object Tracking Accuracy	Aiming Method – EPOG vs Weapon

Participants

Participants were drawn from two populations. The first, representative of the postulated user group, and therefore considered experts, was from the Infantry Trials and Development Unit (ITDU). The second was an opportunity sample from engineers at MBDA(non-experts). A total of 7 personnel from ITDU were involved, and 29 from within MBDA. Note that expert users were included for informed discussion of the technology, and not because any performance differences were hypothesised between expert and non-expert groups.

Results

Comparisons were carried out using t-tests between applicable conditions. Interaction effects were investigated using a two-way ANOVA.

Object Designation Accuracy

There was a significant difference in the scores for Moving ($\bar{x}$=0.73, σ=0.4) and Static ($\bar{x}$=0.67, σ=0.37) conditions; t(4323)=4.45, p=.001.

There was a significant difference in the scores for EPOG ($\bar{x}$=0.87, σ=0.38) and Weapon ($\bar{x}$=0.54, σ=0.33) conditions; t(4323)=30.38, p=.001.

No significant interaction effects were found.

Figure 2 - Object Designation Accuracy results (means)

The results indicate that accuracy at the time of object designation was worse for moving objects than for static objects. It is also indicated that accuracy was worse while using the EPOG aiming technique than when aiming using the weapon sight.

There is no indication that either aiming condition confers better accuracy performance on either object movement type.

Object Designation Time

There was a significant difference in the scores for Moving ($\bar{x}$=3.75, σ=3.51) and Static ($\bar{x}$=2.03, σ=1.19) conditions; t(4121)=23.7, p=.001.

There was a significant difference in the scores for EPOG ($\bar{x}$=2.92, σ=2.96) and Weapon ($\bar{x}$=3.41, σ=2.68) conditions; t(4232)=-5.63, p=.001.

No significant interaction effects were found.

Figure 3 - Object Designation Time results (means)

The results indicate that time taken to designate the object was greater (worse) for moving objects than for static objects. It is also indicated that time taken to designate was worse while using the weapon sight than when aiming using the EPOG aiming technique.

There is no indication that either aiming condition confers better response time performance on either object movement type.

Object Tracking Accuracy

There was a significant difference in the scores for EPOG ($\bar{x}$=8.05, σ=4.98) and Weapon ($\bar{x}$=10.75, σ=6.14) conditions; t(2826)=-13.65, p=.001

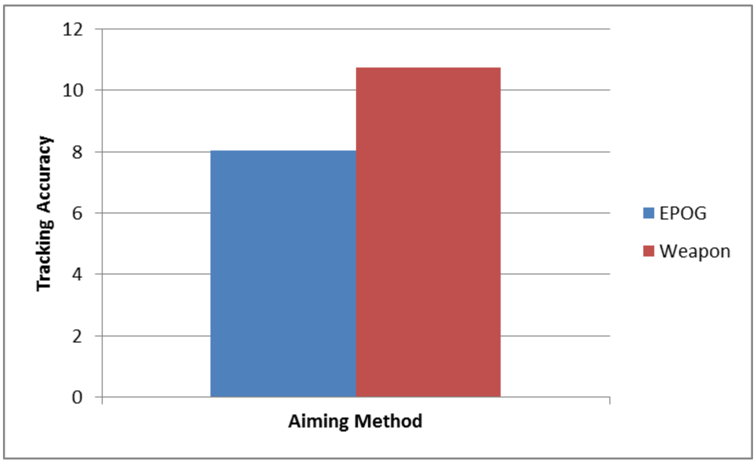

Figure 4 - Object Tracking Accuracy results (means)

The results indicate that accuracy of tracking a moving object was better using the EPOG aiming technique than when aiming using the weapon sight.

Discussion

For Object Designation Accuracy

1. Object Designation Accuracy will be better (distances will be lower) for Static Objects than for Moving Objects.

This hypothesis is supported by the results obtained. It is not surprising that static objects enable higher accuracy to be obtained than when the user is aiming at a moving object. The aim point is continually adjusted for moving objects while it can be continually refined onto a static object. At the time of designation, then, it is more likely in the moving object condition that the aim point will be further from the centre of the object than in the static condition.

2. Object Designation Accuracy will show no difference between EPOG and Weapon aiming methods.

This hypothesis was not supported by the results; instead it was found that accuracy at the time of designation was worse in the EPOG condition than in the Weapon aiming condition. This is initially contrary to what might be expected, but two factors should be considered. Firstly, in the weapon aiming condition, users were provided with an aiming graticule, enabling them to be very precise with the aim point, while in the EPOG condition they were provided with no aimpoint feedback. Secondly, the natural motion of the eyes is to move in saccades and not to remain static on a fixed point. It is plausible that this effect is down to the user ‘scanning’ the whole object of interest rather than fixating on the centroid. It is worth noting that this measure was a single snapshot of the point of aim (or gaze) only at the point in time when the object was designated, and will therefore not capture any general accuracy in the time period prior to designation (compare to results for Tracking Accuracy).

3. Object Designation Accuracy will show no compound effect of Object Motion with Aiming Method.

As an instantaneous measure, this Object Designation Accuracy largely removed any likely effect of the object motion in combination with the aiming method. The users were able to decide for themselves when the aimpoint was adequately aligned with the object, thereby largely nullifying the effect of object motion in the comparison. It may be that higher object speeds or increased manoeuvrability would lead to an emergent effect in this comparison as the difficulty of establishing an aimpoint on the object increased.

For Object Designation Time

4. Object Designation Time will be better (times will be lower) for Static Objects than for Moving Objects.

This hypothesis is supported by the results. As for Designation Accuracy, it is not a surprising result to find that users took less time to designate static objects than they did moving objects as moving objects exhibit a higher degree of action complexity.

5. Object Designation Time will better (times will be lower) for EPOG compared to Weapon aiming.

This hypothesis is supported by the results. The EPOG technology enabled users to designate objects significantly more quickly than the Weapon aiming condition. There are likely several reasons for this. The EPOG condition is simpler, and more natural, than the Weapon aiming condition. The EPOG technology enabled exploitation of the psychophysiological capabilities of users to detect, focus, and track objects in the visual scene. Moreover, the Weapon condition introduces mediation between visual detection and object tracking; the innate processes are therefore interrupted and may be less efficient. Finally, the Weapon condition introduces a gross psychomotor task to the designation activity, namely holding, moving, and aiming the weapon device. It is to be expected then, that the unmediated technique confers better time performance in this condition.

6. Object Designation Time will show a compound effect of Object Motion with Aiming Method, and will be better (times will be lower) for Moving Objects using EPOG than for Moving Objects using Weapon aiming.

This hypothesis was not supported by the results. It was expected that EPOG advantages over Weapon aiming would be more apparent in the Moving object conditions than for the Static conditions. However, it appears that the EPOG designation time effect is not differentiated across object movement types. It may be that higher speeds or higher manoeuvrability of objects would elicit a result along these lines when the Weapon becomes more unwieldy and device inertia has a greater effect on aiming action.

For Object Tracking Accuracy

7. Object Tracking Accuracy will be better (distances will be lower) for EPOG compared to Weapon Aiming.

This hypothesis was supported by the results. The EPOG condition showed significantly better Tracking Accuracy than the Weapon condition. The Weapon condition introduces both gross physical and psychomotor tasks to the overall action of tracking the aimpoint onto a moving object. In the condition where the user is only required to track an object using their eyes, they employ an innate ability, but in the Weapon condition they are required to first acquire an object with their eyes, bring the weapon to bear, align the graticule with their detected object, then physically move the weapon to track that object in space.

Conclusion

This investigation has provided an assessment of the utility of the EPOG technology for use in object designation. It has done this in the context of a SCGW system and has included representative users where possible.

The results indicate that the technology shows significant promise in such an application (though attention should be paid to the static target designation accuracy results where traditional aiming methods appear better). In particular, the times taken to designate objects were improved in the EPOG conditions, as was tracking performance for moving objects. Overall, the technology has been robust and well-received by users, though at this stage it has several routes for improvement and development. Anecdotal reports from the experienced group indicated a generally high level of support for the technology.

In general, the EPOG technology appears very powerful in terms of freeing the infantry soldier to conduct battlefield missions (rather than manage a Weapon System). It is evident that a user of such a system has potential to remain 'in the battle' and to engage objects at a high tempo. It would be interesting to examine how much of a performance advantage is conferred if the user is moving around the battlefield. There are two main routes for development that are apparent:

1. Develop EPOG as a dedicated designation system for integration into SCGW.
2. Develop EPOG as a generic technology to support Infantry soldiers (in particular) in maintenance of mobility on the battlefield while maintaining awareness. For example, integrating EPOG into binoculars or eye shields.

The EPOG technology has been proved worthwhile, and is at a high technology readiness level (TRL); the EPOG equipment is commercially available and is in use in consumer products. It is relatively cheap and reliable and as such would seem ripe for exploitation in specific applications.

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