Applied Ergonomics 40 (2009) 500–508

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Pistol shooting accuracy as dependent on experience, eyes being opened and available viewing time

Ravindra S. Goonetilleke*, Errol R. Hoffmann, Wing Chung Lau

Human Performance Laboratory, Department of Industrial Engineering and Logistics Management, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong

ARTICLE INFO

Article history:
Received 2 July 2007
Accepted 12 September 2008

Keywords:
Shooting
Aiming
Accuracy model
Elite shooter
Novice shooter
Postural balance
Gun alignment
Pistol
Rifle
Stability
Information processing
Visual feedback

ABSTRACT

A study of the shooting accuracy of three groups of pistol shooters is reported. The groups included (i) experienced gas pistol shooters; (ii) persons with experience in video shooting games; and (iii) persons with no shooting experience. The viewing time was varied in the tests. The results showed that experience had a significant effect on the mean and root mean square (RMS) shooting errors at the target. The results also showed that the viewing time does not need to exceed about 2 s for an experienced pistol shooter and about 3 s for a novice shooter to reach the best performance. Two models for the effects of limited viewing time are proposed; both models fit the data well when the viewing time is less than about 2 s. The results indicated that the differences occurring with varying levels of experience are due to postural balance and not due to the aiming or cognitive component of the task.

1. Introduction

Shooting of various forms has both military and police applications as well as being a popular pastime and part of International and Olympic sporting activities (IOC, 2008). These activities take place in events such as rifle shooting, pistol shooting, dart throwing, archery and clay-pigeon shooting (Wikipedia, 2008). A basic characteristic of all these forms of shooting is that the participant aims an object at a target, be it a dart, bullet, shot or an arrow. In all forms of shooting, the winner is that person who obtains the maximum score, this usually being the average error from a target center (Mononen et al., 2003b) or the number of clay targets destroyed.

Many studies have investigated the physical factors that determine the sway or tremor of the participant and ways in which it may be minimized to improve the accuracy of shooting. The effect of experience of the shooter has been extensively studied as well, mainly for rifle shooting, possibly due to its use in the military. Compared to that for rifle shooting, there is very little literature related to pistol shooting. In this work, we investigate pistol shooting and several of the factors that affect the accuracy with which a target may be hit.

The research that has been reported on shooting accuracy and shooter experience has been mainly concerned with the stability of the body/rifle combination at the point of squeezing the trigger. Thus a major consideration of the present research was to investigate the cognitive effects involved in shooting, such as the task of aiming (aligning the pistol sights with the target) and the time that is required to achieve this task.

1.1. The effects of shooter experience

There are some general effects of experience reported in the literature not specifically related to shooting tasks. Annett and Kay (1956) have drawn a distinction between experts and novices by showing that a skilled person has more time to act. Differences in perceptual and cognitive characteristics have been used to differentiate expert (or elite) and novice (or sub-elite) performers (Rose, 1997; Vickers, 1996). Research comparing experts and novices (Abernethy and Russell, 1984, 1987b; Allard and Starkes, 1980; Allard et al., 1980; Bard and Fleury, 1981; Chase and Simon, 1973; French and Thomas, 1987; McPherson and Thomas, 1989; McPherson, 1993) points to the fact that experts are able to search a visual display faster and are also able to extract the necessary information to execute the task.

* Corresponding author. Tel.: +852 2358 7109; fax: +852 2358 0062.
E-mail address: ravindra@ust.hk (R.S. Goonetilleke).

0003-6870/$ – see front matter
doi:10.1016/j.apergo.2008.09.005

In relation to shooting tasks, two types of aiming techniques have been proposed in the literature:

1. Fixing the gaze on the target and bringing the 'weapon' to the direction of the gaze (Raynaud, 1980). Abrams et al. (1990) refer to this type as the position-only hypothesis.
2. Focusing on the weapon and visually assisting its positioning as suggested by Rouquier and Prouzet (1978). This was called the movement-only hypothesis by Abrams et al. (1990).

In a study of expert shooters and pentathletes, Ripoll et al. (1985) found that experts (pistol shooters) adopt a strategy between these two strategies, whereby the gaze is between weapon and target and the weapon is brought towards the target without any visual support. On the contrary, pentathletes, who in general have a lower level of expertise, tend to use the second strategy by using visual support for weapon movement. Due to these differences, Ripoll et al. (1985) found that there is approximately a 0.5 s difference in the final adjustment of gaze onto the target. They explained the difference in time as that needed to attain equilibrium because the head and neck movements affect body posture and movement (Manzoni et al., 1979).

1.2. The effects of postural balance

There are numerous references on the effects of postural balance (Era et al., 1996; Mononen et al., 2007) and weapon stability during the aiming phase of shooting (Mason et al., 1990; Zatsiorsky and Aktov, 1990; Konttinen et al., 1998; Ball et al., 2003; Mononen et al., 2003a; Yuan and Lee, 1997). Ball et al. (2003) found that postural balance affects rifle stability. Postural balance and rifle stability tend to be different for novices or inexperienced shooters for whom disturbances to postural balance cause increases in gun movement (Mononen et al., 2007). Elite shooters are more capable of keeping their rifles more stable during the aiming period compared to novices (Viitasalo et al., 1999; Konttinen et al., 2000; Mononen et al., 2003a) as their body oscillations are much smaller (Era et al., 1996). Even then, Yuan and Lee (1997) manipulated rifle weight and handling length and found that aiming stability is related to shooting performance even in experienced marksmen. Mason et al. (1990) and Viitasalo et al. (1999) argued that postural balance and gun stability are independent among elite shooters; in other words, they are able to control them separately. Experienced shooters rely less on visual information to stabilize their posture compared to inexperienced shooters. Viitasalo et al. (1997) showed that the body's center of pressure movement is less than 1 mm in the last 2–4 s before firing a shot. Experienced shooters can stabilize their postures quite well during the last 1.5 s preceding a shot and are thereby quite different from their inexperienced counterparts (Era et al., 1996). This result possibly indicates that elite performers shift from achieving postural balance to holding and aiming the weapon to the center of the target within the last 1.5 s. This could possibly be the reason that some researchers have found postural balance and rifle stability to be independent of each other (Mason et al., 1990; Viitasalo et al., 1999) whereas both balance and rifle stability influence the performance of novice shooters. Plaster (2006) reckons that the most stable shot is the one taken within the 2 s period between exhaling and inhaling, known as the natural respiratory pause. Hence, good timing in relation to the breathing cycle can play an important role in the stability and accuracy of a shot.

1.3. Cognitive aspects of the aiming task

The aiming task consists essentially of two components: bringing the pistol up to the approximate position where the gun sights and target center are aligned and then homing-in and discriminating the error between the line of the sights and the target center. One way of viewing this process is through the task of arm movement with an initial large movement to the region of the target and a second fine movement for alignment to the target center. Research of this form of body movement has been widely documented.

Woodworth (1899) identified two types of sub-movements in limb movement, such as those that may occur during aiming a gun. The first of these is a rapid movement of the limb to an approximate position of the target. This movement is carried out in a ballistic, preprogrammed manner and does not have close accuracy constraints. The second phase is the homing-in on the target location where the movement of the gun is under close visual control and the gun sights are aligned with the target center. These sub-movements in the aiming process are similar to those used for any visually controlled movement, where the two phases are called the 'distance-covering' and 'homing-in' phases, respectively (Woodworth, 1899; Keele, 1968; Welford, 1968; Meyer et al., 1988). Alternatively, these phases may be called the primary sub-movement and the secondary sub-movement. The homing-in phase requires control in that the deviation between the target center and the sight alignment has to be monitored and an attempt has to be made to minimize the error between the two locations.

Abrams and Pratt (1993) have shown that duration of the secondary movements reduces while that of the primary movements remains constant or increases with practice. Other research has shown that practice reduces the duration of the primary sub-movement (Gottlieb et al., 1988) and also reduces the standard deviation of the primary sub-movement's end points (Darling and Cooke, 1987; Georgopoulos, et al., 1981).

Aiming (alignment of the gaze, weapon and target) tasks in many sports involve the same two types of sub-movements. Stubbs (1976) has argued that seeing the target is more important for aiming accuracy than seeing the hand, since the hand position is generally known from proprioceptive sources. Visual feedback-control models (e.g., Keele, 1968) propose that the distance between the hand and the target is monitored visually and the resulting error is used for corrective adjustments. Experiments performed under vision and no-vision conditions have assumed that decrements in performance under no-vision conditions are due to a lack of visual error information (Carlton, 1981).

Performance evaluations of differing aiming times have been scarce. The available time is important as time is required to process visual error information. The visual feedback processing time involves identifying, deciding, and initiating corrective action based on visual feedback. Visual processing time estimates have been controversial. Beggs and Howarth (1970) and Keele and Posner (1968) proposed a visual feedback processing time between 190 and 290 ms. Zelaznik et al. (1983) found that the time is much less than these values and they agree with the Smith and Bowen's (1980) estimation that visual processing time can be as low as 100 ms. A movement demanding high accuracy will require a number of sub-movements in order to align the sights and the target center. The important fact for shooting of any form is that, if the time available for aiming is limited and is less than that for optimal aiming, it can be expected that the accuracy of aiming will be reduced.

1.4. Research objective

Most past research has focused on the kinematic or physical factors and little on the visual aspects of shooting. The objective of this study was to evaluate the effect of viewing time on the performance of pistol shooters of differing expertise levels, as Mason et al. (1990) has found that shooting accuracy improves with