On the Validity of Using First-Person Shooters for Fitts' Law Studies

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3D first-person shooter games provide highly polished, compelling and entertaining environments that far out-strip the refinement of most research systems. Many also provide extensive support for tailoring the environment, allowing researchers to adapt them to specific research agendas. This paper examines using 3D first-person shooter game environments for motivating participants in Fitts' Law studies. In particular, we examine whether the first-person metaphor for target acquisition, which involves rotating the world to pan the target to the screen-centre, is accurately modelled by Fitts' Law, and whether the resultant Fitts' metrics are representative of traditional cursor-based acquisition. Results show excellent Fitts' modelling, with metrics that are similar to traditional pointing.

Fitts' Law, 3D Games, empirical studies, target acquisition.

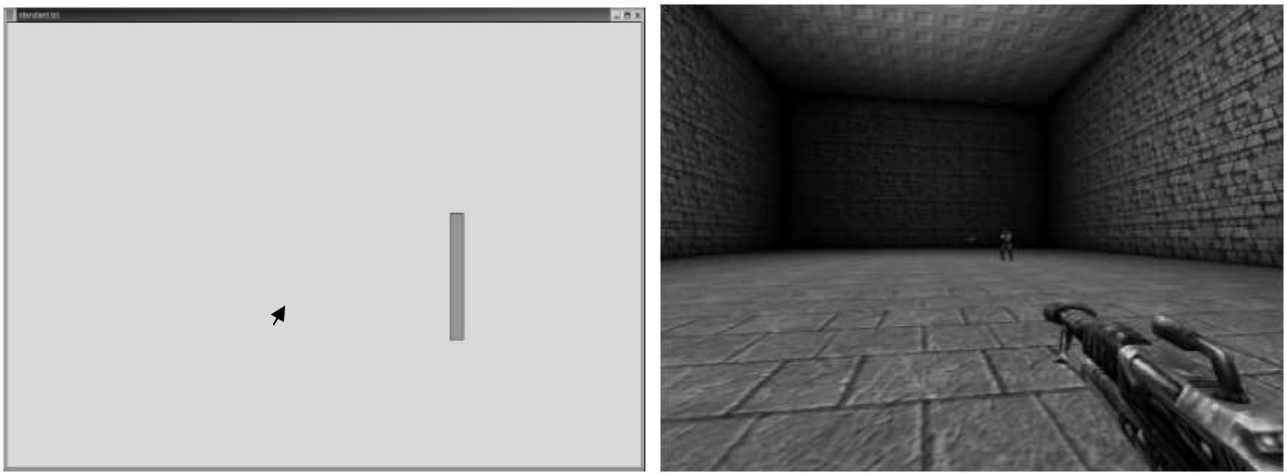
1. INTRODUCTION

Almost all contemporary computer-based user interfaces are designed around direct manipulation of graphical components, with a pointing device being used to move the cursor to items, and to click, drag or manipulate them. The accuracy and efficiency of pointing is therefore extremely important to the overall effectiveness of computer use. Many researchers and hardware/software vendors have developed technologies to improve pointing, including isometric input devices such as the IBM Trackpoint, configurable control-display gain to accelerate mouse movement [7], and interface components that expand [8] or are 'sticky' [2]. Although heavily researched, moving the cursor to the target is not only method of target acquisition. It is also possible to move the target to the pointer by panning the information space. This style of acquisition is common in first-person 'shooter' computer games (see Figure 1), in which the user aims by bringing the target to a cross-hair at the screen-centre—dragging the mouse rightwards rotates the user's view rightwards as through they had turned their head in that direction.

Fitts' Law [3] is the standard empirical tool for assessing and comparing the efficiency of pointing techniques. Fitts' robust model shows that the time to select an item is proportional to the logarithm of the distance to the target divided by the target size. During a Fitts' Law study, participants will typically sit in front of a computer screen, looking at a circle of blobs, moving the cursor as quickly as possible to the next illuminated blob. It is intensely tedious. While participants can be recruited for single-session studies through small incentives, it can be hard to find willing participants for longitudinal studies that demand multiple sessions in order to study skill development.

This paper examines pan-based target acquisition in 3D first-person computer games. The aim is two-fold: first, to verify that Fitts' Law accurately models this type of target selection; and second, to compare user performance with traditional pointing and pan-based pointing. If there is little difference between traditional and pan-based pointing, there is an argument supporting the use of 3D game environments for motivating participants in longitudinal Fitts' Law studies.

FIGURE 1: A typical first-person shooter game.



(a) Traditional targeting. **(b)** 3D pan-based targeting.

FIGURE 2: The experimental interfaces.

2. BACKGROUND

2.1 Fitts' Law

Fitts' Law [3] models the time taken to acquire targets in graphical user interfaces. Linear regression is used to determine the line of best fit between movement time *MT* and the Index of Difficulty (IoD): $MT = a + b \times IoD$, where $IoD = \log_2(A/W + 1)$. *A* is the movement 'amplitude' or distance to the target, and *W* is the target width. The reciprocal of the slope constant *b* provides a useful estimate of hand-eye coordination using the targeting method, called the "Index of Performance" (*IoP*) and measured in bits per second. Although almost exclusively used to examine cursor movement to on-screen targets, recent work has shown that Fitts' Law also models scroll-based target acquisition where the target lies outside the initial view [5]. Fitts' Law also remains a robust model for off-screen target acquisition when zooming is used [9][4]. Guiard et al [9] distinguish between two types of pointing involved in multi-scale (zoomable) off-screen target acquisition: *view-pointing* in which the user moves their view until the target is visible; and *cursor-pointing* in which the user moves the cursor over the final target. Our study essentially examines *view-pointing* for the entire acquisition process.

2.2 3D Game Environments

Gaming is one of the main uses of computer systems, with over 60% of all Americans playing video games [1]. "First-person shooters" are a game-genre in which the player is immersed in a virtual-reality environment viewed from the first-person perspective. To reduce the cost and complexity of game development many games are typically built from the same core code component, called the 'game engine'. The game engine supports fundamental game features such as graphics rendering, physics modeling, and lighting.

Many game engines also provide facilities that allow users to tailor and edit the game content. For example, the game 'Unreal Tournament'[1] supports an integrated scripting language called UnrealScript. We used UnrealScript to support our investigation of pan-based target acquisition.

First-person shooter games are extremely violent, raising obvious ethical questions about their use in HCI research. Most game engines, however, allow some or all of the violent content to be removed.

3 EXPERIMENT

The purpose of the experiment is to determine whether Fitts' Law accurately models pan-based target acquisition in 3D game environments and, assuming it does, to compare the resultant models of traditional and pan-based target acquisition. If the Fitts' Law models are similar and accurate, then 3D game environments may be usable as substitutes for traditional pointing in Fitts' Law analyses.

The traditional and 3D-game interfaces were designed to make equitable targeting demands, except for the essential differences between targeting through cursor movement (traditional) and through panning (3D game). Performance data was recorded in log files generated automatically by the programs. Participants briefly practiced with each interface prior to completing 100 logged tasks with each interface.

The traditional system, shown in Figure 2a, consisted of one 20x200pixel green target displayed within a 1000x700 window. The users' tasks involved selecting the green bar as quickly as possible; with each selection causing the target to move to a new x-coordinate (the bar was displayed at a constant y-coordinate, half way down

[1] EpicGames, 1998. www.unrealtournament.com

the window). The target positions were selected randomly from a set of seven positions. Mouse acceleration was disabled, with a constant control-display gain of 1:1 [7].

The 3D game-based interface, shown in Figure 2b, was implemented using UnrealScript, and was displayed in full-screen mode on a 1024x768 monitor. The targets were 'aliens' and target acquisition involved shooting the aliens with a 'blaster'. Like the traditional interface, only one target was displayed at a time, and successfully 'blasting' an alien (by clicking on it) caused another one to appear at one of seven randomly selected locations on the x-axis. The target aliens had a cylindrical collision volume, meaning that although they appeared to be alien-shaped, they actually presented a rectangular target to the user. The aliens did not move, and the user's movement within the 3D world was restricted to rotation (panning) around a fixed point. The game's sound and explosion effects were maintained. Mouse acceleration was disabled, with a 1:1 control-display gain, and a low in-game mouse sensitivity setting was used.

All eleven participants (9 males and 2 females) studied or worked in a university Computer Science department, and while eight of them regularly played computer games, three did not play games at all. After completing their tasks with each interface type the participants responded to several questions assessing their enjoyment of the environment and about their perception of the violent content in the 3D environment.

3.1 Amplitude and Width Measurements

Measurements of amplitude (distance to target) and target-width are required for Fitts' Law calculations. Direct pixel values are used with the traditional interface, but pixel measurements are complicated in 3D environments, requiring angular measures to be used instead. The amplitude is the angle through which the user must rotate to bring the target to the screen-centre, and the width is the portion of the user's field of view that the target occupies. Bearing in mind that targets are presented along a single dimension, the player's rotation refers only to the player's yaw. A field of view of 90° was used throughout the experiment.

4 RESULTS

The tasks were completed quickly, with high levels of concentration, and with low error rates, as is normal for Fitts' Law studies. It was clear that the participants enjoyed using the 3D-game environment much more, with several participants smiling and making verbal utterance such as "kapow!" and "gotcha" throughout their 3D tasks.

The overall mean selection time was faster with traditional targeting (mean 0.86secs, standard deviation 0.24) than with the 3D game environment (mean 1.09secs, s.d. 0.24), but this comparison is unimportant due to differences between the task Index of Difficulty values with the two interfaces.

We inspected whether the non-gamers produced outlier slow values in game-based selections, but found no evidence of slow performance; indeed, one of the non-game players produced the lowest mean selection time with both interfaces.

Linear regression between movement time and Index of Difficulty showed excellent Fitts' models for both traditional and pan-based targeting. Figure 3 shows the data-points and linear lines of best fit for the two interface types. For traditional pointing, the Fitts' Law model is, as expected, highly accurate, with *MT=0.18xIoD+0.19, R^2=0.94*, p<0.01, giving an *IoP* value of 5.5 bits/second (in-line with MacKenzie's [6] studies showing mouse-based IoP values of 5.6). The Fitts' model of 3D pan-based pointing is also accurate, with *MT=0.19xIoD+0.46, R^2=0.93*, p<0.01, giving a similar *IoP* value of 5.3 bits/second. The two important IoP measures are therefore within 4% of one another, indicating that user performance with the two pointing mechanisms degrades at a similar rate as the distance to the target increases.

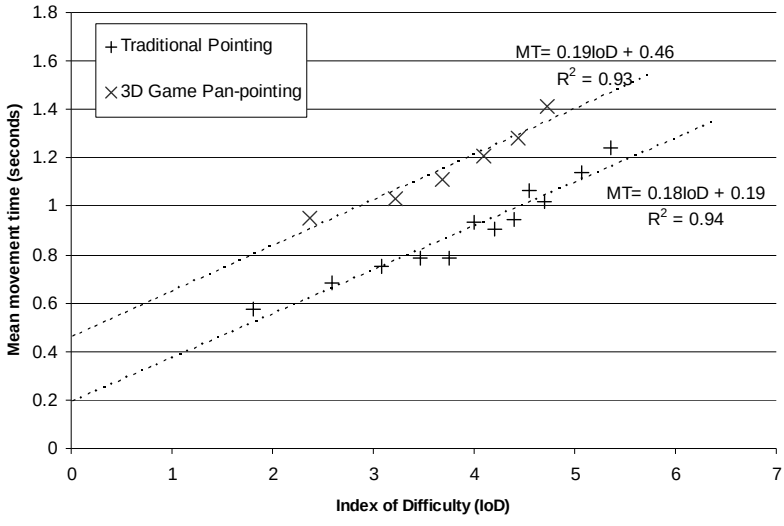


FIGURE 3: Mean movement times plotted against Index of Difficulty, with Fitts' Models determined through linear regression.

Questionnaire responses supported our casual observations of higher enjoyment with the 3D interface. Mean responses to a semantic-differential scale of enjoyment (1="not enjoyable", 5="very enjoyable") were a low 1.9 (s.d. 0.5) with traditional targeting, but a high 4.3 (s.d. 0.5) with the 3D game environment (p<0.01, Wilcoxon). All eleven

participants stated that they preferred using the game environment.

We also asked questions regarding the violent content of the game (the aliens exploded when successfully acquired), with participants checking boxes when they agreed that the violence was “disturbing”, “irrelevant”, “entertaining” and “motivating”. Worryingly, 18% of the participants agreed that the violence was “disturbing”; yet they all would prefer to use the game. 55% rated the violence as “irrelevant”, probably because they have been inured to it in their everyday game-play. 72% checked the box to state that the violence was entertaining, and 46% agreed that it was motivating.

5 DISCUSSION

The results show that Fitts’ Law accurately models 3D pan-based target acquisition, and that the important Index of Performance measures resulting from Fitts’ Law analysis are very similar for traditional and pan-based pointing.

The main difference between the two Fitts’ models is in the value of the constant *a*, or the intercept of the linear model at *IoD=0*. With traditional pointing *a=0.19secs*, but with pan-based game pointing *a=0.46secs*. This constant is often characterised as the cognitive and motor preparation time that precedes movement towards the target. Without further research it is risky to hypothesise about the cause of the difference. It could be that the different lighting effects in the 3D environment (the target is more subtly illuminated within the 3D scene) slowed the initial perception of the target, or it could be that the final stages of acquisition are slower by a constant amount (independent of Index of Difficulty) in pan-based acquisition. Further research is needed to explain this constant cost effect in pan-based 3D acquisition.

6 CONCLUSIONS

3D games are graphically and aurally rich environments that are built to entertain people. They are highly refined, and many offer sophisticated tailoring capabilities that allow researchers to adapt them to their needs. The popular first-person-shooter game genre uses an unusual metaphor for target acquisition in which the user pans the environment (through a strong metaphor of bodily rotation) to bring the target to the centre of their view, rather than the traditional approach of placing the cursor over the target.

This paper has shown that Fitts’ Law accurately models pan-based target acquisition in 3D gaming environments, that target acquisition in these environments is dramatically more entertaining than traditional target acquisition, and that there is little difference between the important Fitts’ Law Index of Performance measure when using the same mouse input device for traditional and 3D pan-based acquisition. 3D gaming environments therefore appear to be a viable tool for researchers wishing to compare different input devices, particularly in longitudinal studies when participant recruitment for ‘tedious’ tasks is difficult.

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