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Gaze-Supported Gaming: MAGIC Techniques for First Person Shooters

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ABSTRACT
MAGIC—Manual And Gaze Input Cascaded—pointing techniques have been proposed as an efficient way in which the eyes can support the mouse input in pointing tasks. MAGIC Sense is one of such techniques in which the cursor speed is modulated by how far it is from the gaze point. In this work, we implemented a continuous and a discrete adaptations of MAGIC Sense for First-Person Shooter input. We evaluated the performance of these techniques in an experiment with 15 participants and found no significant gain in performance, but moderate user preference for the discrete technique.

Author Keywords
Eye tracking, First-Person Shooters, MAGIC pointing, MAGIC sense, gaze-supported interaction

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Digital games are now maturing as a cultural phenomenon. For many, playing video games is not only a hobby, but a full time job. Games that used to gather teenagers at LAN houses are now e-sports that attract audiences in the order of millions. Powered by this environment, a whole industry was born aimed at marketing professional input devices that can give players a competitive edge without cheating. An exciting new trend in this industry is the potential of tracking players' gaze with affordable, off-the-shelf eye trackers [17, 19]. Leveraging the high speed and intuitive natural behaviour of the eyes opens the doors to a plethora of possibilities for creating new mechanics, analysing player behaviour and augmenting existing players' capabilities. However, despite these devices being marketed as ways of increasing game performance, it is still an open question as to whether gaze-based interaction techniques can actually outperform conventional keyboard and mouse in games.

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Figure 1 - Experimental setup. Participants played Battlefield 3 with the mouse and keyboard while their gaze was tracked by a Tobii EyeX tracker mounted below the screen.

Gaze-based interaction suffers from well understood problems, such as inaccuracies due to the natural jittery movements of the eyes; the double-role of the eyes as a sensor for visual observation and as a modality for system control; and the Midas Touch—the unintentional activation of targets due to the continuous tracking or the eyes [16]. To alleviate these problem, gaze is usually combined with other modalities in what is called *gaze-supported interaction* [15]. The most widely studied of such techniques are MAGIC (Manual And Gaze Input Cascaded) pointing techniques, which combine the high speeds of the eyes and the high precision of mouse input. Such techniques stem from the evidence that gaze precedes mouse action and they have been shown to offer significant advantages over simple mouse input in a variety of HCI tasks.

In this work, we adapted MAGIC into two interaction techniques for First-Person Shooters (see Figure 1). Similar to MAGIC Sense [3], the techniques modulate the speed of the cursor depending on its distance to the target. We conducted an experiment with 15 participants in which we compared the gaze-supported techniques to a mouse-only baseline in online *Battlefield 3* sessions and found no significant differences in player performance. We discuss our findings and propose directions for future work.

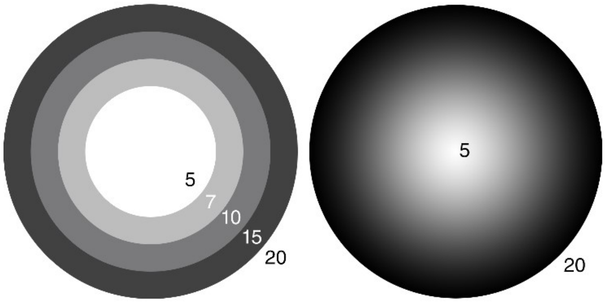

Figure 2 - MAGIC Sense techniques for First-Person Shooters: Discrete (A) and Continuous (B). Numbers indicate the cursor speed in the MS Windows scale (1-minimum, 20-maximum).

RELATED WORK

MAGIC Pointing (Manual and Gaze Input Cascaded Pointing) was first proposed by Zhai et al. to leverage the fact that we look at targets on the screen before selecting them [21]. The principle behind it is to warp the cursor to the vicinity of the target when the user looks at it. They originally implemented two versions of the technique: a *liberal* one, which warps the cursor to every new object the user looks at; and a *conservative* one, which only warps the cursor when the mouse is actuated.

Since then, other authors have adapted their basic idea in a variety of application domains. Drewes and Schmidt used a touch-sensitive mouse to toggle liberal MAGIC on and off in a technique called *MAGIC Touch* [2]. Fares et al. proposed *MAGIC Sense*, a technique that defines four radial zones around the gaze point that determine the speed of the cursor [3]. The further the cursor is from the gaze point, the faster its speed. This technique achieved 18% lower error rates when compared with only the mouse. A similar technique was proposed for the Radiology domain by Tan et al., who achieved an 8% improved performance compared to the mouse-only [18]. Fares et al. also proposed *Animated MAGIC*, a variation that not only modulates the speed of the cursor but also its direction towards the gaze point, achieving an 8.1% higher throughput than with mouse-only [4].

In a gaming context, Leyba and Malcolm compared mouse and eye pointing in a balloon-popping game, achieving a substantially better performance with the mouse. In their implementation, the cursor was warped to the gaze point whenever the user clicked with the mouse, instead of when the mouse was moved, as in the original MAGIC techniques. However, this effectively removed the high precision of mouse pointing combined with the high speed of gaze pointing that MAGIC pointing builds upon [11].

These works showed that in conventional HCI pointing, MAGIC techniques offer significant advantages over the mouse-only baseline. Inspired by the possibility of improving player performance in First-Person Shooters, we set out to adapt these techniques for this scenario.

Other works have also explored gaze-based mechanics for FPS games. Several authors proposed navigation mechanics in which the gaze direction control the camera rotation either by centring the camera at the gaze point [6, 13], rotating the camera when the user looks at the edges of the screen [1, 5, 7], or defining active regions or buttons on the screen that correspond to different camera controls [1, 14, 20]. Further, there are many examples in the literature of gaze aiming and shooting [6, 8, 12]. However, in all of these works either gaze is used as the sole input modality in the game (e.g. for disabled users) or as an independent input modality for a given control (e.g. the mouse controls the camera and gaze aims the weapon [8]). In this work, instead of using the mouse and gaze independently, we modulate the velocity of the mouse with gaze.

MAGIC TECHNIQUES FOR FPS GAMES

In conventional pointing tasks, moving the mouse causes the cursor to move around a largely static viewport. In First-Person Shooters (FPS), moving the mouse causes the viewport to move, while the cursor remains static at the centre of the screen. This imposes certain constraints in adapting gaze-based techniques for gaming.

First, both the original liberal and conservative MAGIC techniques make the cursor jump to the vicinity of the gaze point. In a first-person game, this would make the viewport jump, potentially causing visual fatigue, motion sickness [10] or even making the game unplayable. This led us to adapt MAGIC Sense instead, as this technique allows for a smooth transition as it modulates the cursor's speed rather than its position.

Second, instead of checking the cursor position at every frame to compute the warping, we only compute the distance to the centre of the screen, as the crosshair is fixed there. Mappings where the viewport and the crosshair are decoupled are possible, but uncommon. Kenny et al. recorded players' eye behaviours when playing an FPS game, and found that they spend most of the time looking at the centre of the screen [9]. Our techniques stem from the principle that if the player's gaze moves away from the centre, the viewport will soon follow until the crosshair and the gaze point are, once again, at the same place.

Figure 2 illustrates the two variations of MAGIC Sense we implemented. In the Discrete version, we defined radial regions around the centre of the screen with 100 pixels of thickness. Depending on which region the player's gaze is at, the cursor had a different speed, as indicated in the figure. In the Continuous version, we mapped the speed of the mouse as a linear function of the distance. Both techniques were at their maximum at a distance of 540 pixels (half of the vertical resolution of the screen—the maximum distance in the vertical direction). We implemented the techniques in a C# program that received gaze data through the Tobii API for the EyeX tracker and set the speed of the cursor using the *SystemParametersInfo (User32)* Windows API.

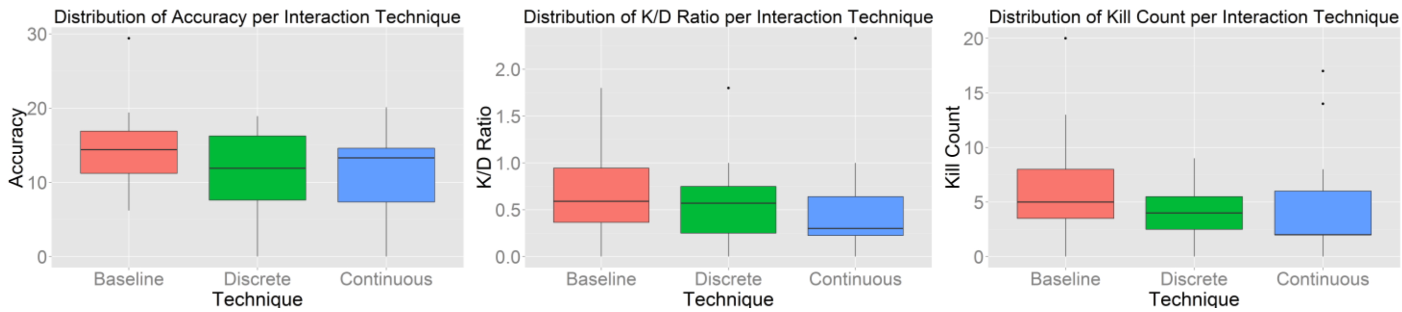

Figure 3 - Experiment results: (A) Accuracy, (B) K/D Ratio, (C) Kill Count

USER STUDY

Based on the performance improvement achieved with MAGIC techniques for conventional pointing, we hypothesised that both the Discrete and Continuous versions of MAGIC Sense would yield higher game performance metrics (accuracy, kill/death ratio and kill count) than the mouse-only baseline. Unlike previous works that prioritised internal validity, rather than implementing a controlled task, we chose a more ecologically valid task. Participants played a popular FPS game, in an online setting, against other actual players.

Participants

We recruited fifteen participants (13M/2F), aged between 18 and 21 years (median = 20), with an email sent to our University's students and staff. Two wore contact lenses and two wore glasses. All participants were regular computer users. Eight of them played two hours or less of video games per week, and seven played three or more, with two of them playing more than six weekly hours. Seven of them had never played Battlefield 3 and five played it for 20 hours or more. None of them had used an eye tracker before the study.

Experimental Setup

Figure 1 shows our experimental setup. We conducted the experiment in a quiet environment, with only the participant and the experimenter. Participants played the first-person shooter *Battlefield 3* (Electronic Arts, 2011) on a desktop PC equipped with an Intel i7-2600 3.5GHz processor, 8 GB of RAM, and an Nvidia GeForce GTX 760 graphics card. We recorded participants' faces and voice with a webcam mounted above the screen. We tracked users gaze with a Tobii EyeX eye tracker, with an average gaze estimation error of 0.4 degrees of visual angle, mounted below the display. Questionnaire data was recorded in a separate laptop.

Procedure

Upon arrival, participants completed a consent form and a demographics questionnaire. We calibrated the eye tracker using the manufacturer's default 9-point procedure. Participants then played three rounds of *Battlefield 3* in *Team Deathmatch* mode. In this game mode, players are split into two teams and the goal of each team is to accumulate 100 points by killing the players in the other team. When players are killed, they respawn after a few seconds. To minimize the variation between different playthroughs, due to this being a multiplayer online game, we always connected to the same server, with players of average ability (i.e. filtered by 'Normal' difficulty in the server search feature) and a maximum of 32 simultaneous players, and a minimum of 28.

In each round of the study, participants used one of three techniques: Baseline (no gaze support); Discrete MAGIC sense and Continuous MAGIC sense. The order of the conditions was counter-balanced across users. After each playthrough we recorded participants' Accuracy (number of hits divided by total number of shots), Kill/Death (KD) ratio, Number of kills, and how easy it was to use the technique on a 5-point scale. These are all standard performance metrics that several games provide. Game statistics were obtained with *Battlelog*, a social platform connected to Battlefield 3 that provides messaging, voice communication, server selection and game statistics. Each round lasted between 5 and 8 minutes. After all rounds were completed, participants filled in a post-experiment questionnaire, in which we asked the how noticeable was the gaze-based speed modulation, how useful was the gaze-based speed modulation, the perceived difference in performance with the eye tracker, how distracting were the gaze-based techniques and their preference ranking amongst the techniques. We also conducted an unstructured interview on their impressions about the techniques.

Results

We compared the mean Accuracy, K/D Ratio, and Kill Count between each technique and tested the effects of the technique on the dependent variables with a one-way repeated-measures ANOVA, Greenhouse-Geisser corrected in case Mauchly's test revealed a violation of sphericity.

The mean Accuracy (see Figure 3a) was higher in the Baseline condition (14.52%) than in the Discrete (10.95%) and Continuous MAGIC sense (11.38%), but this difference was not statistically significant ($F_{1.4,19.6} = 2.10, p = 0.16, GG\varepsilon = 0.57$). The K/D Ratio (see Figure 3b) was also higher in the Baseline condition (0.65) than in the Discrete (0.57) and Continuous (0.52), but this difference was not statistically significant ($F_{2,28} = 1.31, p = 0.29$).

We found similar results for the Kill Count (see Figure 3c), with the Baseline yielding the highest (6.33), followed by the

Continuous (4.67) and Discrete MAGIC Sense (4.07), and once again, this difference was not statistically significant ($F_{1.44,20.2} = 1.66, p = 0.21, GG\varepsilon = 0.72$).

In terms of qualitative feedback, participants found the Baseline and Discrete conditions the easiest to use, with an median score of 3, followed by the Continuous condition with a median score of 4, on a 5-point scale ranging from 1-Very Easy to 5-Very Difficult. When asked to rank the three techniques, seven participants ranked Discrete MAGIC pointing first and five ranked the Baseline first. Twelve participants ranked Continuous MAGIC sense last.

DISCUSSION

Our results suggest that the gaze-supported techniques we evaluated show no significant performance advantage over the baseline. Indeed, in all performance metrics, the baseline showed on average a slight advantage over the gaze-supported techniques. However, participants' qualitative responses suggest some potential for them, in particular for the Discrete version. Despite achieving slightly worse performances with this technique, seven participants ranked it as their preferred one. Whereas the observer-expectancy effect could offer an explanation for this contradiction, the fact that twelve participants felt comfortable to rank the Continuous technique as the worst one, leads us to discard this possibility. We found more insightful explanations in the unstructured interviews after the gameplay sessions.

When discussing the techniques, participants claimed that when making turns, the increased speed became too fast, leading to confusion. They reported that sudden turns would lead them to overshoot and waste time to course-correct (and get shot in the meantime). However, some participants praised the increased speed in some circumstances, suggesting that more conservative mappings could offer a potential advantage. More experienced participants claimed to keep their gaze at the centre of the screen at all times, and therefore stated that they did not see a benefit of using gaze outside this area.

In general, we believe that the reason for the lack of difference in performance of the gaze techniques boils down to the visual patterns of players. We observed that, in the baseline case, players spent most of the time gazing at the centre of the screen (50% of the gaze points fall within a 204px distance to the centre), but often scanned the areas away from the crosshair searching for enemies. In the cases where there are no threats or reasons to change direction, the increased speed of the cursor actually caused confusion. In these cases, the gaze point does not work well as a predictor for speeding up the cursor. Searching behaviours are not a problem for gaze-supported techniques in conventional pointing, because the mouse is only actuated when the user is actually moving towards the target. In FPS games, the mouse is constantly being actuated to navigate the environment, so the increased cursor acceleration is often triggered when scanning for threats.

In this work, we only evaluated the techniques in a single session, so it is still unclear whether these techniques could yield better performance with practice. However, one of the main claims of gaze-supported techniques is that they leverage the natural behaviour of the eyes to augment the interaction, suggesting that prior experience should not be expected.

To evaluate our techniques we opted for a task that resembles real-life use as much as possible. Several other works have explored MAGIC techniques in a controlled setting [2, 3, 21], prioritising internal validity. In this work, we showed that in an ecologically valid setting, such techniques do not significantly improve game performance. Not only this highlights the specific needs of interaction techniques for gaming, but also the necessity for more ecologically valid evaluations of interaction techniques in general.

CONCLUSION AND FUTURE WORK

In this paper, we described two variations of MAGIC Sense for First-Person Shooter games. We hypothesized that increasing the speed of the cursor when players looked away from the centre of the screen would incur in increased game performance as compared to the mouse-only baseline. Our results showed a slightly inferior performance in the gaze-supported techniques, though not statistically significant. Amongst the two techniques we implemented, discrete MAGIC sense was generally preferred.

These results do not discourage the use of eye tracking for gaming. Previous works have shown a wide variety of inspiring and novel game mechanics that employ the eyes. They do, however, highlight three important findings. First, the not all gaze techniques that have been shown to be efficient in abstract pointing tasks in HCI studies can be directly ported for game control. The original MAGIC Pointing techniques cause the cursor to warp, which in FPS games would cause jumps in the camera that could lead to motion sickness. Second, performance results from gaze-based techniques in conventional HCI do not directly translate for games. Whereas in conventional pointing, the gaze point works well as a predictor for future cursor positions, the same does not happen in FPS games. Third, when designing gaze-supported techniques for games, it is important to carefully consider players' natural eye behaviours. Visually scanning the environment combined with constant mouse actuation caused the increased cursor speed to overshoot and confuse players.

Directions for future work include evaluating different mappings of gaze points to speed, such as polynomial mappings, multivariate functions or even discrete regions of different shapes. Another direction is to use machine learning techniques to differentiate scanning behaviours from target pursuits in order to trigger gaze assistance only in the latter case. Finally, a longitudinal study over more sessions could give us more insights on how these techniques evolve with practice.

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