SuperVision: Playing with Gaze Aversion and Peripheral Vision

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ABSTRACT

In this work, we challenge the Gaze interaction paradigm *"What you see is what you get"* to introduce *"playing with peripheral vision"*. We developed the conceptual framework to introduce this novel gaze-aware game dynamic. We illustrated the concept with *SuperVision*, a collection of three games that play with peripheral vision. We propose perceptual and interaction challenges that require players not to look and rely on their periphery. To validate the game dynamic and experience, we conducted a user study with twenty-four participants. Results show how the game concept created an engaging and playful experience playing with peripheral vision. Participants showed proficiency in overcoming the game challenges, developing clear strategies to succeed. Moreover, we found evidence that playing the game can affect our visual skills, with greater peripheral awareness.

CCS CONCEPTS

• **Human-centered computing → Interaction paradigms**; *Interaction techniques*;

KEYWORDS

Peripheral Vision; Gaze Interaction; Games; Play; Interaction Design; Eye Tracking

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1 INTRODUCTION

Gaze input has become a compelling tool for interaction in videogames. Eye trackers are now available as consumer devices at low cost, and mass market videogame franchises have begun to introduce gaze interaction features in their gameplay (e.g., [9, 30, 39, 49]). These include gaze interactions for control of the camera or the characters' movements, aiming at targets and tagging of opponents, just by looking.

Intuitively, gaze input is compelling because we naturally look at objects to interact with. Accordingly, the design of techniques has focused on gaze pointing, for acquisition of targets [24], or implicit indication of objects of interest [45]. In this work, we consider quite the opposite: we propose novel gaze interactions and game dynamics based on *Gaze Aversion*, objects of interest that players must *not* look at, and tasks players must accomplish with *peripheral vision*.

We explore the concept of *playing with peripheral vision* based on three fundamental questions:

- Can Gaze Aversion create game experiences in peripheral vision that are engaging and fun?
- Is it possible to succeed with gameplay in the visual periphery and develop strategies to overcome the challenge?
- What are the benefits of playing with the periphery? Can players experience the development of their visual abilities for object detection?

Our investigation is based on the creation of a conceptual framework for *"playing with peripheral vision"*. We validated it with the design and development of *SuperVision*, a collection of 3 peripheral vision games. The games are inspired by stories of harmful gaze in mythology and popular culture and present the players with game elements they must not look at directly. Each game poses perceptual challenges for assessment of the game situation with peripheral vision and interaction challenges for mouse manipulation of objects without gazing directly at them. The game designs are disruptive in requiring players to rely on peripheral vision for tasks they would normally, and more easily, perform with foveal vision. We posit that this creates an engaging challenge for players to make use of the full potential of their wider field of view.

We conducted a study of SuperVision with 24 users and a follow-up study with 5 users. To evaluate our concept for gameplay we assessed player experience using the Game Experience Questionnaire [20], and player performance and behavior based on game logs and gaze heatmaps. Besides, we evaluated the participants' peripheral visual capabilities before and after playing the games, to test for skill development. The results confirm the high level of challenge involved in playing with peripheral vision, and that this can provide an engaging and enjoyable experience. Participants were able to develop strategies to succeed. We also found a significant improvement in object recognition in the participants' peripheral vision after playing the games.

Our work makes four main contributions. First, the conceptual framework of *playing with peripheral vision*, and novel game dynamic created by elements that players must perceive and manipulate without directly looking at them. Second, the description of 3 games that illustrate the implementation of the concept in playful and engaging experiences. Third, empirical insight into player experience, performance, and behavior in tackling perceptual and interaction challenges with peripheral vision. And fourth, evidence that games such as demonstrated can affect our visual skills.

2 RELATED WORK

Gaze and Games

Gaze has been widely explored as game input [50]. The main thrust has been to adopt gaze for accessibility, to replace or complement the original game controls [21–23, 44]. Other work has embraced gaze as implicit input, for example for gaze-responsive storytelling [45], camera viewpoint control [33, 44] and social interaction with avatars [53]. The underlying principle is to leverage gaze as a pointer and selection mechanism for objects users align with their foveal vision. Our work is in sharp contrast, focusing on peripheral vision and how to engage the wider visual field for play.

The recent emergence of eye trackers in the consumer space has spurred interest in novel creative uses of gaze [48, 50], for instance, based on eye movements other than fixation [10, 54], multi-player gaze [34, 37] and novel multimodal combinations [51]. Some works are proposing to use gaze to make interactions more challenging, for example by adapting the level of difficulty to the player's gaze performance [32]. Compelling examples of gaze interfaces that are challenging by design are Ekman et al.'s *Invisible Eni*, where players are challenged to control game elements with pupil dilation [11], and Vidal et al.'s *Shynosaurs*, where players face a dilemma between staring down monsters and hand-eye coordination [52]. Our work follows in this spirit, in creating a game dynamic that makes interaction inherently more challenging by pushing it into the periphery of the players' visual field, while having the potential to enhance their visual awareness.

Gaze Aversion

Gaze interfaces are usually concerned with where users look, although it can be equally relevant to detect when they are not looking, for instance, to interpret manual input differently depending on whether it concurs with visual attention [36, 43]. In our work, "looking away" is not merely detected but required for successful gameplay.

In psychology and behavioral studies, "not looking" is considered as an action that can be related to social factors such as fear [42], or as a mechanism to manage cognitive load [8]. However, our approach is based on the shift of the visual focus as a perception tool. The proposed dynamic is based on inhibitory control of visual attention, i.e., the fundamental human ability to look away and resist a reflexive urge to look. In psychology, this is related to study paradigms such as the anti-saccade task [31].

There are prior examples of games requiring avoidance of game elements. In the *Slender Man*, though not based on eye tracking, the user needs to turn away when they glimpse the adversary. The *Virus Hunt* [51] is a game idea where gaze spurs the growth of viruses which therefore must not be looked at. A variety of attention training games [6] have been proposed that include inhibition tasks training users' ability to resist "automatic" attention to particular events. In our work, gaze aversion serves the purpose of moving game interaction into the visual periphery. Users must not only avoid looking at certain game elements but are challenged to complete tasks with peripheral vision.

Peripheral Vision

The role of peripheral vision is to process the wider visual field preattentively (i.e., without eye movement) as the basis for directing attention and eye movement to events that draw attention and relate to our goals. Many games involve the inherent challenge of maintaining peripheral awareness of "the bigger picture" while focussing on one object or character at a time. Peripheral awareness is, for instance, an essential skill in many sports, and can be trained [26, 58].

Shynosaurs [52] is a specific example of a game that challenges players' vision in that it presents tasks that are competing for visual attention. At any time, a player can only focus on one of the tasks – either moving *'cuties'* to safety or stopping *'shynosaurs'* by staring them down. While players focus their gaze on one task, they rely on peripheral vision to notice other events (e.g., more *'shynosaurs'* appearing from the woods). In contrast, in the work we present, players must use their peripheral vision not only for awareness but actual manipulation of objects and completion of tasks.

Peripheral vision is generally considered for display of information that can be detected without a priori focus, in games [13] and other areas of HCI, for example, deliver notifications without disrupting the task in focus [25] (e.g., keeping the eyes on the road while driving [18]). Recently, *Luyten et al.* proposed a near-eye display for presentation of peripheral information that is positioned relative to the user's eyes such that it is impossible to focus on it [28]. This relates in an interesting way to our work as it also enforces reliance on peripheral vision.

Peripheral Interaction has also emerged as an area of HCI research concerned with tasks that can be handled in the periphery, in the sense of not requiring much conscious attention [1], and not disrupting a primary task [17]. In contrast, the games we propose involve conscious and prolonged interaction with tasks presented in the visual periphery.

3 CONCEPTUAL FRAMEWORK

We propose *playing with peripheral vision*, to create a new type of game experience. Our concept is based on understanding human peripheral vision to provide a framework for the design of games that challenge peripheral vision.

The human visual field covers approximately 135 degrees vertically and 210 degrees horizontally, of which the foveal region of highest visual acuity is limited to only around 2 degrees at the center (with up to 5 degrees considered as parafoveal) [15]. Outside the foveal region, visual acuity drops sharply, but peripheral vision plays a key role in situational awareness and preattentive attention to features that visually pop out [4, 15, 41]. As peripheral vision has limited acuity, objects seen outside of the foveal region might be perceived smaller, distorted, blurrier, and more compressed [2]. This effect can be experienced even if we know what the object in the periphery is, or see an identical object in our foveal vision [35]. Peripheral vision is also limited to the number of objects that can be perceived without eye movement, and visual crowding can inhibit object detection [57].

Based on these insights, we put forward a framework to guide the design of peripheral vision games. We propose to use *Visual Challenges* to explore vision capabilities, and to create *Tasks* that players must accomplish, thus putting visual perception to the test. A *Rule* is needed to enforce that only peripheral vision is involved during the task-solving, and *Metaphors* are required to explain and forge the *Rule* with each *Task* and *Challenge*. This framework is as follows:

Tasks: Aims or objectives of the game regarding:

- *Decision-making:* Objects need to be assessed in the periphery for later interaction based on different challenges and rules.
- *Interaction:* Objects need to be explicitly manipulated (e.g., mouse clicks or hovers, aim by gaze) either in the periphery or the focus. Inherently, different input modalities other than gaze must be used if interaction occurs in the periphery, which may introduce a challenging hand-eye coordination.

Visual Challenges: Exploiting visual theory and perceptual capabilities to differentiate objects based on:

- *Color.* Objects that have distinct colors (vibrant, obscured, with information overlay).
- *Size.* Objects that can be identified because they are different in size (a large from a small).
- *Focus blindness.* Detection of objects that appear in the focus of our vision when the visual attention is on peripheral vision assessing other objects.

Rule: "Objects must not be looked at". This rule is supported by the use of the Gaze Aversion mechanic. The rule is used to move interaction to the periphery through the following strategies:

- *Reaction:* Moving objects away from the focus to make it mechanically impossible to interact with them (e.g. An object that changes position when it is looked at).
- *Negative effects:* Crowding of the visual area to lower perceptual capabilities (e.g. block object at the scene to make it *"noisy"*).
- *Penalization:* Life losses when objects are looked at.

Metaphors: The narrative technique to frame the rules with the tasks and challenges (e.g., *Looks that turn into stone*, *looks that kill*, *what you look is what you will ever look*, etc.).

4 SUPERVISION

To address the conceptual framework of *playing with peripheral vision*, we designed and developed *SuperVision* with 3 games examples (*Figure* 1). *Metaphors* from literature and pop culture characters represent each game because they experience a gaze challenge (influencing the way they look), and require the use of periphery. Players will assume their gaze hurdles and given tasks.

In each game, players *challenge* is to understand the game objects that appear in the scenario while keeping their eyes away from looking directly at them. Given that our eyes are attracted to objects that pop up, it is difficult for players to keep their gaze away and play the game efficiently. This *rule* creates a challenging experience. Players need to handle the constant stream of game objects that appear. Their *task* is to carefully identify and decide how to manipulate with the mouse the objects, without looking at them and only being able to see them in their peripheral field of view.

The mouse is augmented with the drawing of the tool relevant to each game so that it can be identified in the periphery. The gaze focus is defined in a 90x90 pixels (around 4 degrees of visual angle) box, not visible to the player.

Figure 1: *SuperVision*'s four different game scenes that require using peripheral vision to play. (Top-left) The game main page. (Top-right) The Cyclops' game. (Bottom-left) Medusa's game. (Bottom-right) Narcissus' game.

Introducing SuperVision

In the introductory screen, players are invited to select the game they want to play by gaze pointing (See *Figure* 1, top-left). This interaction aims at demonstrating to the player that the game is gaze aware. Further instructions can be extended by clicking on the plus signs next to each character.

Players need to click on the play button (size: 330x110 pixels) to start the game. When the mouse hovers the button, it is highlighted and has sound feedback. However, if players look at the button, it moves to the other side of the screen (*Rule Reaction*). This way, players need to click on the play button without looking directly at it (*Interaction Task*).

We introduced this interaction challenge being inspired by *Dark Rides* design. A typical dark ride uses light-controlled passages to leave reality behind and transport riders to a different world [56]. Accordingly, we aimed to introduce the games' concept in *SuperVision* before playing them. We intended to break traditional gaze interaction from the start, to teach how to play with the periphery.

For each game, we introduced different interaction modalities with the mouse and visual perception challenges. We wanted to explore how well we can perceive differences between objects in our periphery; how well can we act on them without looking directly; and how well we can control our gaze behavior. Moreover, each game is spanned across 12 levels of ascending difficulty. The level goes up after 10 elements have been correctly assessed. Players are provided with 5 lives that can be lost by making tasks mistakes or when the rule is neglected. If a life is lost, the game carries on until no lives are left.

Color: "*The Cyclops in a Balloons' adventure*"

The Cyclops is a character from pop culture and the X-Men comic books published by Marvel Comics [27]. The Cyclops is a mutant who can release an energy beam from his eyes. In the context of the game, he cannot control his power, causing the destruction of anything he looks at directly (*Metaphor*).

The Cyclops *challenge* is to watch over colored hot air balloons traffic flow (see *Figure* 1 top-right). There are good balloons (*red, blue, green or multi-colored*) and bad balloons (*Pirates*), which can be either *black* or camouflaged as good balloons but with a *skull* symbol (appearing from level 3). Balloons can be affected by air pollution, appearing with fog around them (all of the balloons, except the camouflaged ones, from level 4 onwards). See *Figure* 2, left, for visual details.

The game *task* is to move the balloons (size: 190x290 pixels) by guiding them while they fly from a randomized point on the x-axis, so they enter their color-related gate without staring at them. To move good balloons, players need to push them with the colorful *fan* (on the mouse), moving it towards the desired direction (sideways). Failing to guide the balloons correctly will cause a game life loss.

Players need to correctly direct the good balloons while keeping an eye on the bad ones and do not allow them through. If the player looks at the good balloons, they will pop and fall, besides losing a game life (*Rule Penalization*). Players can look at the Pirates balloons to make them pop and fall too, so they do not pass. The balloons gates can change positions every 3 levels and speed increases slightly after every level.

The Cyclops game aims to explore the role of color and color differences in peripheral vision. It uses different colors, and colors with a subtle variation (skull) or colors that are less vivid (polluted). Moreover, players need to push the targets with the mouse without much precision needed. When the fan collides with the balloon, it is moved away from the fan.

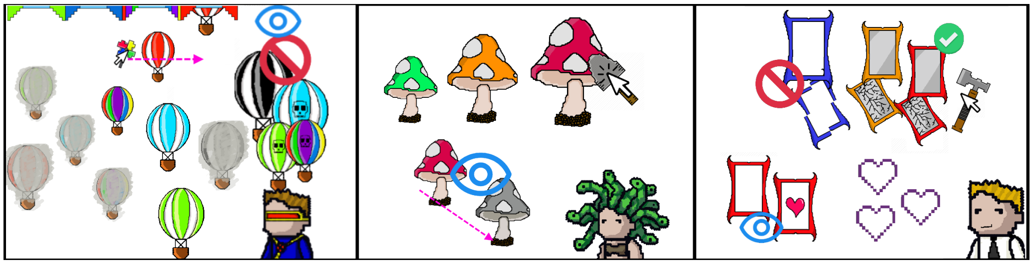

Figure 2: *SuperVision* elements and instructions. (Left) The Cyclops' game. (Center) Medusa's game. (Right) Narcissus' game.

Size: *"Medusa and the mushrooms' attack"*

Medusa is a character from Greek mythology [14]. With a head full of snakes for hair and a half human half serpent body, Medusa was known to be able to turn anything and anyone into stone by just looking at them (*Metaphor*).

Medusa's *task* is to remove mushrooms from a garden (see *Figure* 1 bottom-left). The game *challenge* is to do it without looking at them in descending size order, from the biggest to the smallest one. Failing to perform the task in the correct order will make extra mushrooms appear (1 to 3, chosen randomly) scattered around the parcel (screen). This will modify the size order scenario, as well as causing a life loss (*Rule Penalization*). As a consequence, the screen will get more crowded with mushrooms. Moreover, if the player looks at a mushroom, it turns into stone and cannot be removed, losing a game life, and crowding the screen (*Rule Negative effect*). These require players to concentrate more as it is harder to identify objects in a cluttered scenario (experiencing the *crowding* effect in their peripheral vision [41]).

Medusa's game aims to explore the role of targets' size in the periphery of vision. Every pair or group of mushrooms have a size difference of 50% between them, and it decreases gradually towards 10% difference after each level.

Focus blindness: *"Narcissus and the cursed frames"*

Narcissus is another character from Greek mythology. He was known to be a very handsome man that could make anyone fall in love with him with just a glance from him. The nymph Echo fell for him, but he constantly ignored her, until she *died for love* and turned in what it is known as the echo. As a consequence, the goddess of *Love*, Aphrodite cursed Narcissus with the following warning. If he ever sees his reflection, he will fall in love with himself and be doomed to look at himself for eternity [14] (*Metaphor*).

Narcissus' game is based on the game *Fruit Ninja* [16]. Players need to act as Narcissus and help to control the production of frames. During the game, both frames and mirrors (frames with a defect) are continually thrown in random orbital movements from the bottom of the screen from any position on the x-axis. Only one frame/mirror (size: 145x220 pixels) is released at a time, but the spawning speed increases at every level from 2 seconds to 0.5 seconds. Beyond level 6, 2 elements can be randomly thrown at a time. Frames and mirrors can be either red, blue or orange, and the color is randomized during the gameplay.

The game's *task* is to control that only frames pass. When a mirror appears, players need to break it with the hammer (size: 100x180 pixels, on the mouse) by hovering it. If a frame is accidentally broken, a game life is lost (*Rule Penalization*).

The *challenge* is to classify the frames and the mirrors while trying not to look at any of them. If players look at frames they will fall in love with them and crowd the screen (*Rule Negative effect*), creating a peripheral *crowding* effect [41]. If a mirror is looked at, Aphrodite's curse will become true, and the mirror will be stuck on the player's gaze point, crowding the gaze focus (*Rule Negative effect*). Moreover, while solving the game *task* in the periphery, messages of love from the nymph Echo in the shape of purple hearts (size: 50x40 pixels) will randomly appear around the player's gaze (in a radius of 50 pixels, every 30 to 50 seconds). Players need to click on Echo's hearts to collect them and win extra points. See *Figure* 2 (right), for game elements reference.

Narcissus' game aims to explore what happens to perception in the gaze focus when the attention is on the periphery. We hypothesize that while players are solving the peripheral task (sorting frames and mirrors), there is a *focus blindness*, and anything appearing in focus will be ignored.

Implementation

SuperVision was developed using Unity Game Engine in 2D, custom graphics and creative commons sounds. The game requires the use of an eye-tracker and uses Tobii Gaming SDK for Unity to enable gaze interaction. The calibration of the eye-tracker is needed before playing the game.

5 EVALUATION

We conducted a user study to evaluate the conceptual framework illustrated with *SuperVision* and to measure the game experience of the dynamic. Moreover, we performed visual tests to study the effect of playing the game in visual periphery abilities. Further, we carried out an ad-hoc behavioral

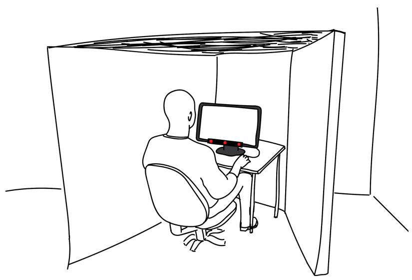

Figure 3: Sketch of the user study set up.

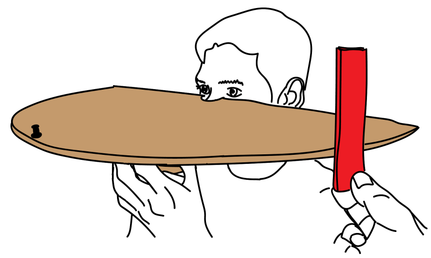

Figure 4: Sketch of the peripheral vision test performed with the DIY cardboard protractor and the colored visual cues.

analysis during gameplay, using gaze heatmaps. Finally, we tested the influence of playing over time in a follow-up study.

Apparatus

To conduct the user studies we used a *Tobii EyeX* eye-tracker under a 27" monitor (Resolution: 1920x1080; Aspect Ratio: 16:9) at 40cm from the user.

Participants played the game sitting in a custom-made booth with a covered ceiling (see *Figure* 3). The booth aimed at blocking the participants' field of view so no visual distractions could happen during the study.

Moreover, we built a 180° cardboard Visual protractor with a 30 centimeters radius and a center nose hole. A protractor is an instrument for measuring angles, in the form of a flat semicircle (see *Figure* 4), used to test and measure peripheral vision [3, 5]. A visual protractor is traditionally employed in visual perception research to determine where in the users' visual field the stimuli are going to be placed [40, 47].

We aimed to use the DIY protractor to test participants' peripheral vision capabilities before and after playing the game, to check whether visual periphery skills development occurs.

Methodology

To assess the game experience of the game we used the *Game Experience Questionnaire* (GEQ) [20]. We used the short version of the GEQ, comprised of 14 items combining game-related statements that need to be rated on a 5-point Likert scale. GEQ is categorized and averaged into 7 experiential game measures, which are: Competence, Sensory and Imaginative Immersion, Flow, Tension, Challenge, Negative Affect, and Positive Affect.

Competence refers to the ability to do something successfully or efficiently. Immersion can be defined as the extent of deep but effortless involvement and reduced concern for the sense of time [46]. On the other hand, Flow is defined as the state of enjoyment in which players are completely absorbed in the gameplay [46]. Tension is related to the experienced annoyance or frustration. Challenge is attributed to the mental or physical effort needed to succeed in the game. Affect refers to the difference that playing the game made in pleasantness (positive) or boredom (negative).

Positive affect, Competence, Challenge, and Tension are part of the Enjoyment dimension, whereas Negative affect, Flow and Immersion relate to game Engagement [12].

Moreover, in addition to the GEQ, we added 4 extra statements to measure how easy it was to adapt to the proposed dynamic of not looking (Easiness), and how eager they would be to play again (Repeatability). The statements are *"I felt difficult not to look"*, and *"I felt the game was easy"* for Easiness; *"I felt I would like to play this game again"* and *"I enjoyed playing with my eyes"* for Repeatability.

We also used a custom-made questionnaire to ask about participant's game preferences. The questionnaire asks users to choose which game was the easiest; the hardest; the one they enjoyed the most; the one they would like to play again; the game concept they like the most; the game concept they disliked the most; and the game they were not interested in playing again. Answers were closed to: None of them, Cyclops, Medusa, Narcissus or All of them. Finally, the questionnaire asks participants to rate *SuperVision* from 1 to 10, and to provide any comments they would like to share.

In order to perform the visual test, the protractor needs to be held up horizontally to the subject's face with their nose in the nose hole. Participants are asked to keep their gaze on the black push-pin located in front of them at the edge of the protractor. While the participant focuses on the push-pin, the researcher holds a cardboard strip against the outer edge of the protractor on either side (see *Figure*4). Then they will move it slowly and evenly along the curved edge towards the middle. Participants are asked to tell the researcher to stop the movement when they can see the strip in their periphery and guess which color is it or what is it drawn on it. The distance (in degrees) is recorded.

In the periphery visual test, we used different cardboard strips. They could feature 3 different colors (red, green, blue); and drawn in the pieces, 3 possible numbers (1, 2 or 3), 3 letters (A, B or C) or 3 shapes (circle, square, triangle).

During the game playing, we saved the participants' gaze position data on the screen and main game's events.

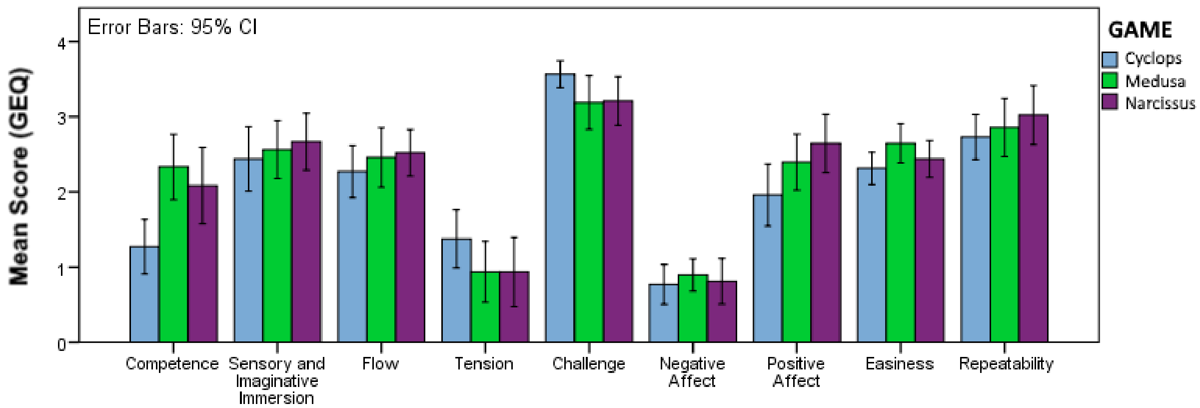

Figure 5: Results for the 7 experiential game measures from the Game Experience Questionnaire (Competence, Immersion, Flow, Tension, Challenge, Negative and Positive affect) and the 2 extra added to measure Easiness and Repeatability.

Procedure

In the user study, we asked the participants to fill in a demographics questionnaire. It included close-ended questions about how frequent they play video games, cycle, drive or play any sports, to understand how trained their vision is.

Then, participants performed the protractor test. The order of colored cardboards and eye side were randomized. For each color and side, every extra feature was asked to participants only once (either letter, number or shape related to one of the colors).

After the visual test, we calibrated the eye tracker for the participant, using Tobii's native application, and controlling the accuracy with the same app, before playing each game for 5 minutes. They played, on average, between 3 and 6 times. Participants were invited to continue playing for longer if they wished. The order of games was counterbalanced. After playing each game, participants were asked to fill in a GEQ. Subsequently, they played the next game.

In the end, we asked participants to rate the games and choose which one they preferred. The session was concluded with the repetition of the visual test, using another randomized order to display the visual cues. Finally, they were invited to share their thoughts about the quality of the games and the concept. The study duration was around 40 minutes.

Participants were invited to a follow-up study. They were required to play the 3 games for at least 15 minutes (5 minutes each) every day for 2 consecutive weeks, excluding weekends. On both Mondays, they were asked to perform the visual protractor test before playing, whereas the test was performed after on Fridays.

Participants

24 volunteer participants took part in the first user study (10 wearing glasses). 13 men, 10 women, and 1 undisclosed gender person participated in individual studies. 9 of them had used an eye tracker before (6 considered themselves experienced).

Players were aged 20-39, with a mean of 27 ± 4 years old. 11 participants indicated being used to play games regularly (between once a week and almost every day) during 2 hours or more, mainly First or Third person shooter, action and Real-Time games for PC. The rest of the participants (13) indicated playing sporadically to puzzle games on their phone.

12 participants indicated playing sports regularly (2 to 5 times a week) for at least 1 hour. Only 2 users reported to cycle or ride a motorbike for less than 1 hour between 2 and 3 times a week. Finally, 7 participants reported driving almost every day for 1 hour or more.

5 participants took part in the follow-up study. 4 men and 1 woman, with a mean age of 27 ± 4 years old.

6 RESULTS

Player Experience

The player experience was measured using 7 scales from the Game Experience Questionnaire (GEQ) and 2 custom made. They measured the enjoyment, the engagement, the repeatability, and the easiness of the game concept.

Figure 5 indicates that participants found the games enjoyable. They reported feeling slightly to moderately successful and competent, and fairly to extremely challenged. All of the games were considered to be slightly frustrating (slight tension) due to the unnaturalness of the dynamic, but pleasant and enjoyable. The Cyclops' game was informed to be the most challenging and frustrating, scoring lesser pleasantness and the feeling of success.

Participants reported the concept to be engaging. The game story made them feel involved and absorbed, with moderate to fair flow and immersion. Although none of the games were considered to have a negative affect, Medusa's game was indicated to be less engaging than the others.

Overall, participants indicated that the games were moderate to fairly easy to play and that they would like to play again. Narcissus' game was rated to be the game with more interest; the Cyclops' one, the least; and Medusa's game qualified to be the easiest to play.

During the post-game discussion, participant 14 (P14) described the game as an *"anti-game"*, referring that it is like a normal game, but you are mostly not allowed to look at the main action. They added that you have to force yourself not to look, something that is unusual to other games. P8 said *"you have to trick yourself not to look, and then get frustrated when you look and don't even notice! That's quite funny!"*.

Player Performance and Preferences

We analyzed the game data logs for each participant to measure success in each game. Gameplay logs show how the Cyclops' game was the most difficult to succeed. The maximum level achieved by players was level 5, from 12 levels of difficulty (M = 2.88 ± 2.253). Medusa and Narcissus' game show more players' success. They were able to reach level 10 (Medusa: M = 4.58 ± 2.28; Narcissus: M = 4.7 ± 2.279). Players completed more than 80% of the levels of difficulty for at least Medusa and Narcissus' games.

Participants with gaming experience reached higher proficiency in all the games, getting to higher levels of gameplay. However, using a One-way ANOVA, we did not find a statistically significant difference for gameplay performance between players exposed to activities that demand peripheral awareness (cycling, driving, playing sports or gaming).

Moreover, we extracted from Narcissus' game logs the ratio of success on noticing and collecting Echo's hearts. It measured the influence the peripheral task had on the gaze focus attention. Players were able to collect the bonus objects a mean of 36.91% ± 3.6% of the times.

Further, 13 players thought none of the games were easy, with the Cyclops' game chosen to be the hardest (by 14 participants). 10 users described Narcissus's game as the most enjoyable, whereas 10 other participants preferred the Cyclops' game, and 4 could not decide between the three. Moreover, 21 participants indicated they liked the concept. Only 1 participant reported they would not like to play again. During the post-game discussions, P24 pointed out that *"it was really hard, but because it was so frustrating I really wanted to play again"*. Participants rated the game concept with a mean score of 8.66 ± 1.10 out of 10.

On the other hand, results from the follow up study using a Wilcoxon signed-rank test show that playing *SuperVision* every day elicited a statistically significant improvement in performance, in the Cyclops' game (Z = -2.023, p = 0.043) with mean 273.40 points ± 42.027 points the first day, and mean 637.20 points ± 254.986 points the last day; and Narcissus' Game (Z = -2.023, p = 0.043) with mean 2421.60 points ± 1508.404 points the first day, and mean 7354.40 points ± 4049.867 points the last day. No statistically significant difference was found in Medusa's game performance. These results illustrate how players developed proficiency in overcoming all the perceptual challenges the more they played.

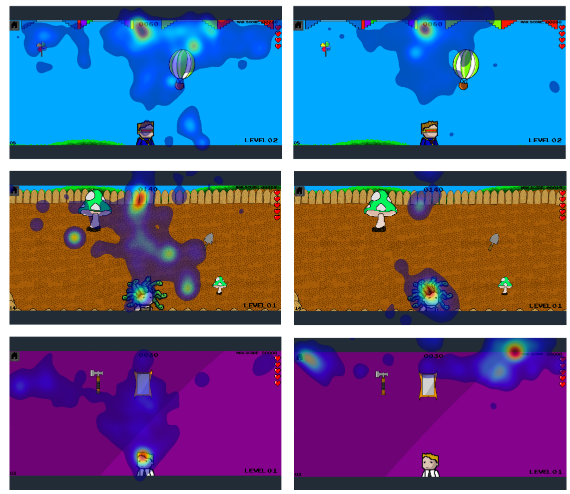

Figure 6: Gaze Heatmaps for First-time and proficient playing for each game.

Gameplay Behavior and Strategies

To analyze players behavior during gameplay we used all the logged gaze data, to create a series of gaze heatmaps for each of the games.

We divided the gaze data into two different groups according to players' behaviors and success during the game:

- *First time*: Corresponds to the first played levels in which players are not familiar enough with the game to fully succeed.
- *Proficient*: Corresponds to the last played levels, showing the players' success. We considered the last level played (maximum reached for each game) and the two previous ones (according to standard deviation).

We produced a gaze heatmap for each behavior group and game. We decided to use the game data from levels 1 and 2 in each game for the First time playing behavior. Levels 8, 9 and 10 logs were used for the Proficient player behavior for Medusa and Narcissus' game, whereas level 3, 4 and 5 logs were used for the Cyclops.

Figure 6 shows the different heatmaps generated for each game and behavior using all gaze data point from all participants. We can observe how novice players (*Figure* 6, left) display greater screen dispersion of gaze points (areas in blue). During the user study, P12 remarked that they did not know where to look as their eyes wanted to go to the item

Table 1: Visual results before and after playing *SuperVision.*

CUE	*Pre-game*	*Post-game*		
	Mean ± SD	*Mean ± SD*	*Z*	*p*
Color	**80.14° ± 6.33°**	**82.75° ± 4.83°**	**-5.232**	**< 0.0005**
Drawn	**40.85° ± 14.08°**	**47.78° ± 12.70°**	**-5.722**	**< 0.0005**

that popped up on the screen. Accordingly, there is evidence that players gaze was in motion rather than staying in a fixed point (green, yellow and red areas).

On the other hand, proficient players (*Figure* 6, right) show fewer focus points and less movement around the screen. *Figure* 6 (left) show how participants' gaze turned more static towards the end of the game, once a strategy was adopted. The Cyclops' game (top) presents a strong focal point on the top-center of the screen, common to all players. Medusa's game (middle) indicates how different users chose between two distinct focal points. The majority of players focused on the characters' head. Finally, during Narcissus' game, players focused all around the top of the screen.

During the user study, 3 participants complained about objects moving towards their gaze focus rather than them looking at them on purpose. They reported their strategy was to be concentrated looking at a fixed point. P15 pointed out: *"I was too focused on thinking where not to look that I forgot at times to move the mouse"*. Evidence shown in *Figure* 6 (right) indicates that most players decided to keep their gaze point fixed in the same location while playing.

Results indicate how players developed a strategy to succeed in the games the more they played. P18 said during a post-game discussion: *"It was hard to find a strategy not to look at the start of the games, but playing them for at least once helped to decide on the strategy and become more successful"*.

Peripheral Vision Skills

We measured participants' ability to detect and identify cues in their peripheral vision with a visual test using a protractor.

We wanted to determine whether the test results prior and after playing were significantly different. *Table* 1 shows the mean position in degrees in the peripheral visual field where the 24 participants were able to identify the different color and drawn cues. We performed a Wilcoxon signed-rank test for both cues. Results indicate that playing *SuperVision* elicited a statistically significant change (improvement) in the detection of color and drawn cues in peripheral vision. Moreover, we did not find a statistically significant difference between the test results for either eye; color cues (red, green and blue); or drawings (letters, numbers, and shapes); nor in the results from participants with or without visual correction (wearing glasses).

Accordingly, with our follow-up study, we wanted to know whether there would be a visual skills improvement over time by playing the games. *Figure* 7 shows the visual test mean

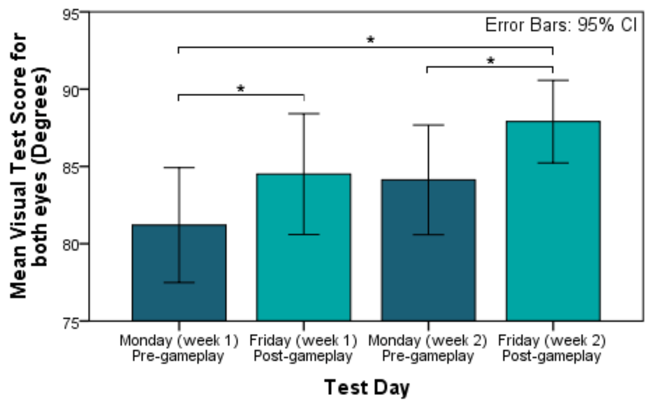

Figure 7: Visual tests results during the 2 weeks follow-up user study performed every first and last day of the week.

scores during the study for the 5 participants. Results from a Wilcoxon signed-rank test indicate that playing *SuperVision* every day during 2 weeks elicited a statistically significant change in detection of color cues in peripheral vision during the first week, Monday to Friday, ($Z = -3.222$, $p = 0.001$) with mean 81.20° ± 4.08° (Monday) and 84.50° ± 4.32° (Friday); during the second week, Monday to Friday, ($Z = -4.240$, $p < 0.0005$) with mean 84.13° ± 3.73° (Monday) and 87.90° ± 2.73° (Friday); and during the 2 weeks, first Monday to second Friday, ($Z = -4.593$, $p < 0.0005$). No statistically significant difference was found in the visual results due to not playing the game during the weekend ($p = 0.521$).

7 DISCUSSION

Playing with Peripheral Vision

The goal of our work is to challenge gaze-focus based design and to propose leveraging the capabilities of the wider vision. We provided a conceptual framework to *"play with periphery"*, illustrated by three games examples. It is very unusual to demand users not to look to assess elements that will only be in their visual periphery, when they could do it easily by looking directly at them. Using this dynamic creates not only a challenge but also a task with high cognitive demand.

Results from the GEQ suggest that playing *SuperVision* was very challenging with a high perceived cognitive load. The perceived frustration when failing to overcome the perceptual challenges made players want to play more and try to succeed, and they rated the gameplay as a pleasant experience.

These results demonstrate how the presented concept created a playful and engaging experience that made people want to play again. However, although the participants seemed keen to keep playing the games because they felt motivated to improve on the peripheral challenges, we do not have enough evidence to guarantee that the experience engagement can be sustained in the long term.

Challenges and Strategies

We also wanted to know if playing in the periphery was feasible and whether players could overcome the perceptual challenges by developing clear strategies. Our results show that differentiating different elements in the periphery is possible. Objects with bright colors, with color variations (skulls for Pirate balloons in the Cyclops' game), less vividness, with a difference of more than a 10% in size from their counterpart, can be differentiated in the periphery.

On the other hand, designing for the periphery poses different questions on how to effectively use color saliency, contrast, size, shape, interaction modes and feedback for the detection of visual cues in the periphery.

Overall, the players showed proficiency in overcoming the perceptual tasks by developing a clear strategy to find a space where they could *"park"* their gaze. This effect might limit the experience when designing the graphics of the game. When gaze remains static, there could be no reason to create *"beautiful"* graphics or too elaborate game objects and stories, as they would only be seen in the periphery.

Nevertheless, our results suggest how the use of metaphors for gaze interaction might have affected the perceived experience of immersion. Further, the proposed challenges may be of interest for entirely different types of games (e.g. serious games to train peripheral vision awareness, or for behavioral training for inhibitory control).

Visual Skills Development

Moreover, we wanted to know if playing games that happen in the periphery could influence the development of players' visual abilities. Although we do not have visual skill development data from a baseline group which did not play the games, our results suggest that playing *SuperVision* could improve visual awareness, as peripheral vision can be trained [59]. This poses our games' conceptual framework as a potential peripheral vision awareness training tool.

Playing with Peripheral Vision opens up opportunities that could have implications for the processing of peripheral notifications, that could be picked up without looking at them; the creation of serious games to train athletes, dancers or industrial workers; and the design of serious games for psychology assessment or behavioral training for cognitive stimulation based on inhibitory control.

Playful Inhibition

Given that human attention gets attracted to elements that pop out in the scene [15], players found hard not look, as they would do naturally.

The proposed "not looking" dynamic is related to a process of inhibitory control of the visual focus, which in *SuperVision* becomes an engaging and playful challenge. Players need to be aware of the Gaze Aversion game rule which goes against their natural behavior. They attempt to control and resist this reflexive impulse to look, while there is additional stress from trying to solve the peripheral task.

During our user study, players reported struggling at first to control the impulse to look. This can be illustrated by Edgar Allan Poe's *The imp of the perverse* [38]. In Poe's work, he reasons why people act against their self-interest (tempted by the symbol of *the imp*), only because they feel they should not. In our work, "looking" becomes *the perverse* action that needs to be controlled. Players could do just fine suppressing the impulse, but they cannot stop thinking about it. This compromises the inhibitory control, that can weaken further when an overload or stress is added [55].

In this way, players know they should not look, but the tasks in the periphery lower their control and make them indulge the reflex of looking, failing at the game. This forces them to train themselves to inhibit the impulse if they want to succeed. Moreover, our results (*Figure* 6) show how participants overcame this challenge and were able to focus on the peripheral task, adopting a static gaze focus strategy.

In behavioral studies, inhibition is closely related to the Working Memory and can be trained [29], for example by showing negative cues (go/no-go test) [19] next to the impulse that wants to be controlled . In our work, given the evolution of the players' success, our mechanisms to support the game rule (e.g., penalization plus sound feedback) served as negative cues to train the inhibitory control.

We can find similar dynamics in psychology studies using the anti-saccades test [7, 31], or products to stimulate cognitively people living with ADHD or OCD [6]. In this way, even though our contribution is focused on presenting playing with periphery as an uncommon mechanic, it could become a potential tool to improve the design of gamified tests for psychology and cognitive assessment and serious games for behavioral change based on inhibitory control. Designing game challenges like in *SuperVision* can offer a promising way to lower the stress for psychology patients and make these tests more engaging and enjoyable.

8 CONCLUSION

We presented the concept of *playing with peripheral vision* as a novel game dynamic that leverages the capabilities of the broader vision. We developed with *SuperVision* three games examples that explore different perceptual and interactive challenges in visual periphery using our conceptual framework. Results show we created an engaging and playful experience utilizing Gaze Aversion to push interaction to the periphery. Players developed strategies to overcome the perceptual and manipulation tasks and they experienced an improvement in visual periphery awareness after playing the games.

REFERENCES

[1] Saskia Bakker, Elise van den Hoven, and Berry Eggen. 2010. Design for the Periphery. *EuroHaptics 2010* 71 (2010).

[2] Joseph Baldwin, Alistair Burleigh, Robert Pepperell, and Nicole Ruta. 2016. The Perceived Size and Shape of Objects in Peripheral Vision. *i-Perception* 7, 4 (2016), 2041669516661900.

[3] Bernell. 2019. Bernell Vision Disk. https://www.bernell.com/product/HS6015/807. Accessed: 2019-01-07.

[4] Jeremy Birnholtz, Lindsay Reynolds, Eli Luxenberg, Carl Gutwin, and Maryam Mustafa. 2010. Awareness beyond the desktop: exploring attention and distraction with a projected peripheral-vision display. In *Proceedings of Graphics Interface 2010*. Canadian Information Processing Society, 55–62.

[5] Science Buddies. 2016. Put Your Peripheral Vision to the Test. https://www.scientificamerican.com/article/put-your-peripheral-vision-to-the-test/

[6] CogniFit. [n. d.]. Inhibition or inhibitory Control - Cognitive Ability. https://www.cognifit.com/science/cognitive-skills/inhibition

[7] Trevor J Crawford and Steve Higham. 2016. Distinguishing between impairments of working memory and inhibitory control in cases of early dementia. *Neuropsychologia* 81 (2016), 61–67.

[8] Gwyneth Doherty-Sneddon and Fiona G Phelps. 2005. Gaze aversion: A response to cognitive or social difficulty? *Memory & cognition* 33, 4 (2005), 727–733.

[9] Crystal Dynamics. 2015. *Rise of the Tomb Raider*. Game [Xbox].

[10] Inger Ekman, Antti Poikola, Meeri Mäkäräinen, Tapio Takala, and Perttu Hämäläinen. 2008. Voluntary Pupil Size Change As Control in Eyes Only Interaction. In *Proceedings of the 2008 Symposium on Eye Tracking Research Applications (ETRA '08)*. ACM, New York, NY, USA, 115–118. https://doi.org/10.1145/1344471.1344501

[11] Inger M Ekman, Antti W Poikola, and Meeri K Mäkäräinen. 2008. Invisible eni: using gaze and pupil size to control a game. In *CHI'08 extended abstracts on Human factors in computing systems*. ACM, 3135–3140.

[12] Brian J Gajadhar, Henk Herman Nap, Yvonne AW de Kort, and Wijnand A IJsselsteijn. 2010. Out of sight, out of mind: co-player effects on seniors' player experience. In *Proceedings of the 3rd International Conference on Fun and Games*. ACM, 74–83.

[13] Kevin Grad, TC Graham, and A James Stewart. 2007. Effective use of the periphery in game displays. In *Proceedings of the 2007 conference on Future Play*. ACM, 69–76.

[14] Robert Graves. 2017. *The Greek Myths: The complete and definitive edition*. Penguin UK.

[15] Carl Gutwin, Andy Cockburn, and Ashley Coveney. 2017. Peripheral Popout: The Influence of Visual Angle and Stimulus Intensity on Popout Effects. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. ACM, 208–219.

[16] Halfbrick. 2010. *Fruit Ninja*. Game [iOS][Android][Windows Phone].

[17] Doris Hausen. 2012. Peripheral interaction: facilitating interaction with secondary tasks. In *Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction*. ACM, 387–388.

[18] Renate Häuslschmid, Sven Osterwald, Marcus Lang, and Andreas Butz. 2015. Augmenting the Driver's View with Peripheral Information on a Windshield Display. In *Proceedings of the 20th International Conference on Intelligent User Interfaces*. ACM, 311–321.

[19] Katrijn Houben and Anita Jansen. 2015. Chocolate equals stop. Chocolate-specific inhibition training reduces chocolate intake and go associations with chocolate. *Appetite* 87 (2015), 318–323.

[20] WA IJsselsteijn, YAW de Kort, and K Karolien Poels. 2013. The Game Experience Questionnaire. (2013).

[21] Poika Isokoski, Markus Joos, Oleg Spakov, and Benoît Martin. 2009. Gaze controlled games. *Universal Access in the Information Society* 8, 4 (2009), 323–337.

[22] Poika Isokoski and Benot Martin. 2006. Eye tracker input in first person shooter games. In *Proceedings of the 2nd Conference on Communication by Gaze Interaction: Communication by Gaze Interaction-COGAIN 2006: Gazing into the Future*. 78–81.

[23] Howell Istance, Aulikki Hyrskykari, Stephen Vickers, and Thiago Chaves. 2009. For your eyes only: Controlling 3d online games by eye-gaze. In *Human-Computer Interaction–INTERACT 2009*. Springer, 314–327.

[24] Robert J. K. Jacob. 1990. What you look at is what you get: eye movement-based interaction techniques. In *Proceedings of the SIGCHI conference on Human factors in computing systems: Empowering people (CHI '90)*. ACM, New York, NY, USA, 11–18. https://doi.org/10.1145/97243.97246

[25] Lee Jones, John McClelland, Phonesavanh Thongsouksanoumane, and Audrey Girouard. 2017. Ambient Notifications with Shape Changing Circuits in Peripheral Locations. In *Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces*. ACM, 405–408.

[26] Safal Khanal. 2015. Impact of visual skills training on sports performance: Current and future perspectives. (2015).

[27] Stan Lee and Jack Kirby. 1963. The X-Men# 1. *Marvel Comics Google Scholar* (1963).

[28] Kris Luyten, Donald Degraen, Gustavo Rovelo Ruiz, Sven Coppers, and Davy Vanacken. 2016. Hidden in plain sight: an exploration of a visual language for near-eye out-of-focus displays in the peripheral view. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. ACM, 487–497.

[29] Maria J Maraver, M Teresa Bajo, and Carlos J Gomez-Ariza. 2016. Training on working memory and inhibitory control in young adults. *Frontiers in human neuroscience* 10 (2016), 588.

[30] Ubisoft Massive. 2016. *Tom Clancy's The Division*. Game [Microsoft Windows].

[31] Douglas P. Munoz and Stefan Everling. 2004. Look away: the anti-saccade task and the voluntary control of eye movement. *Nature Reviews Neuroscience* 5 (01 03 2004), 218 EP –. http://dx.doi.org/10.1038/nrn1345

[32] Jorge Munoz, Georgios N Yannakakis, Fiona Mulvey, Dan Witzner Hansen, German Gutierrez, and Araceli Sanchis. 2011. Towards gaze-controlled platform games. In *Computational Intelligence and Games (CIG), 2011 IEEE Conference on*. IEEE, 47–54.

[33] Lennart E Nacke, Sophie Stellmach, Dennis Sasse, and Craig A Lindley. 2010. Gameplay experience in a gaze interaction game. *arXiv preprint arXiv:1004.0259* (2010).

[34] Joshua Newn, Eduardo Velloso, Fraser Allison, Yomna Abdelrahman, and Frank Vetere. 2017. Evaluating Real-Time Gaze Representations to Infer Intentions in Competitive Turn-Based Strategy Games. In *Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '17)*. ACM, New York, NY, USA, 541–552. https://doi.org/10.1145/3116595.3116624

[35] Robert Pepperell. 2012. The perception of art and the science of perception. SPIE-IS&T.

[36] Ken Pfeuffer, Jason Alexander, Ming Ki Chong, Yanxia Zhang, and Hans Gellersen. 2015. Gaze-Shifting: Direct-Indirect Input with Pen and Touch Modulated by Gaze. In *Proceedings of the 28th Annual ACM Symposium on User Interface Software & Technology (UIST '15)*. ACM, New York, NY, USA, 373–383. https://doi.org/10.1145/2807442.2807460

[37] Ken Pfeuffer, Jason Alexander, and Hans Gellersen. 2016. GazeArchers: Playing with Individual and Shared Attention in a Two-player Look&Shoot Tabletop Game. In *Proceedings of the 15th International*

Conference on Mobile and Ubiquitous Multimedia (MUM '16). ACM, New York, NY, USA, 213–216. https://doi.org/10.1145/3012709.3012717
[38] Edgar Allan Poe. 2015. *The imp of the perverse.* Edgar Allan Poe.
[39] Ubisoft Quebec. 2015. *Assassin's Creed Syndicate.* Game [Microsoft Windows].
[40] Luisa Jesús Quevedo Junyent, Fernando Palomar Mascaró, and José Antonio Aznar-Casanova. 2017. Effective Visual Field Rehabilitation in Homonymous Hemianopia by Attaching Binocular Prisms to Lenses. *American Research Journal of Ophthalmology and Optometry* 1, 1 (2017), 1–11.
[41] Ruth Rosenholtz. 2016. Capabilities and limitations of peripheral vision. *Annual Review of Vision Science* 2 (2016), 437–457.
[42] Franklin R Schneier, Thomas L Rodebaugh, Carlos Blanco, Hillary Lewin, and Michael R Liebowitz. 2011. Fear and avoidance of eye contact in social anxiety disorder. *Comprehensive Psychiatry* 52, 1 (2011), 81–87.
[43] Baris Serim and Giulio Jacucci. 2016. Pointing While Looking Elsewhere: Designing for Varying Degrees of Visual Guidance During Manual Input. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 5789–5800. https://doi.org/10.1145/2858036.2858480
[44] J David Smith and TC Graham. 2006. Use of eye movements for video game control. In *Proceedings of the 2006 ACM SIGCHI international conference on Advances in computer entertainment technology*. ACM, 20.
[45] India Starker and Richard A. Bolt. 1990. A Gaze-responsive Self-disclosing Display. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '90)*. ACM, New York, NY, USA, 3–10. https://doi.org/10.1145/97243.97245
[46] Penelope Sweetser and Peta Wyeth. 2005. GameFlow: A Model for Evaluating Player Enjoyment in Games. *Comput. Entertain.* 3, 3 (July 2005), 3–3. https://doi.org/10.1145/1077246.1077253
[47] MPS To, BC Regan, Dora Wood, and JD Mollon. 2011. Vision out of the corner of the eye. *Vision Research* 51, 1 (2011), 203–214.
[48] Jayson Turner, Eduardo Velloso, Hans Gellersen, and Veronica Sundstedt. 2014. EyePlay: applications for gaze in games. In *Proceedings of the first ACM SIGCHI annual symposium on Computer-human interaction in play*. ACM, 465–468.
[49] Ubisoft Montreal and Ubisoft Toronto. 2018. *Far Cry 5.* Game [Xbox][Windows][PlayStation].
[50] Eduardo Velloso and Marcus Carter. 2016. The Emergence of EyePlay: A Survey of Eye Interaction in Games. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '16)*. ACM, New York, NY, USA, 171–185. https://doi.org/10.1145/2967934.2968084
[51] Eduardo Velloso, Carl Oechsner, Katharina Sachmann, Markus Wirth, and Hans Gellersen. 2015. Arcade+: A Platform for Public Deployment and Evaluation of Multi-Modal Games. In *Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play (CHI PLAY '15)*. ACM, New York, NY, USA, 271–275. https://doi.org/10.1145/2793107.2793145
[52] Melodie Vidal. 2014. Shynosaurs: A Game of Attention Dilemma. In *Proceedings of the First ACM SIGCHI Annual Symposium on Computer-human Interaction in Play (CHI PLAY '14)*. ACM, New York, NY, USA, 391–394. https://doi.org/10.1145/2658537.2662979
[53] Melodie Vidal, Remi Bismuth, Andreas Bulling, and Hans Gellersen. 2015. The Royal Corgi: Exploring Social Gaze Interaction for Immersive Gameplay. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 115–124. https://doi.org/10.1145/2702123.2702163
[54] Mélodie Vidal, Andreas Bulling, and Hans Gellersen. 2013. Pursuits: Spontaneous Interaction with Displays Based on Smooth Pursuit Eye Movement and Moving Targets. In *Proceedings of the 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '13)*. ACM, New York, NY, USA, 439–448. https://doi.org/10.1145/2493432.2493477
[55] Daniel M Wegner. 2009. How to think, say, or do precisely the worst thing for any occasion. *Science* 325, 5936 (2009), 48–50.
[56] Denise Chapman Weston. 2004. Interactive dark ride. US Patent 6,796,908.
[57] David Whitney and Dennis M Levi. 2011. Visual crowding: A fundamental limit on conscious perception and object recognition. *Trends in cognitive sciences* 15, 4 (2011), 160–168.
[58] Jean M Williams and Joel Thirer. 1975. Vertical and horizontal peripheral vision in male and female athletes and nonathletes. *Research Quarterly. American Alliance for Health, Physical Education and Recreation* 46, 2 (1975), 200–205.
[59] Deyue Yu, Gordon E Legge, Heejung Park, Emily Gage, and Susana TL Chung. 2010. Development of a training protocol to improve reading performance in peripheral vision. *Vision research* 50, 1 (2010), 36–45.