Effective Use of the Periphery in Game Displays

Kevin Grad, T.C. Nicholas Graham, A. James Stewart
School of Computing
Queen's University
Kingston, Ontario, Canada K7L 3N6
{kevin,graham,stewart}@cs.queensu.ca

ABSTRACT

The human eye can perceive visual information with high acuity within a narrow foveal view; outside the foveal view (in the periphery), vision has progressively less resolution, and ability to perceive colour is reduced. In this paper, we argue that game displays can be improved by accounting for the part of the visual field in which information is displayed. We present two games in which information is visually encoded for presentation in the periphery. We conclude that the use of peripheral displays may be an interesting way of improving the challenge and entertainment of games involving rich informational displays.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—*Screen design*

General Terms

Human Factors

Keywords

Computer games, display design, peripheral display

1. INTRODUCTION

Video games often require players to perceive, process and act on extensive time-sensitive information. For example, in a real-time strategy game, players must simultaneously monitor the state of different locations on a large map, while managing combat, resource gathering and production. In a multiplayer first-person shooter, players must monitor the locations and activities of their teammates and opponents while rapidly moving, aiming and firing. Often, what distinguishes a poor game player from a proficient one is the ability to deal with such a profusion of time-sensitive data. The design of informational displays is therefore an important part of creating a challenging and entertaining experience for players.

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Attributes of the human visual system influence the success of informational displays. For example, it is more difficult to perceive information presented in the periphery of the visual field than in the centre of the visual field (the "fovea"). In a typical real-time strategy game, a player fixating on the centre of the screen may be unable to perceive the contents of a mini-map in the upper-right corner of the display, or a chat window in the lower-left corner.

We propose that game design can be improved by visually encoding information appropriately for its position in the player's visual field. We expect that information encoded for peripheral view can provide a novel twist to information display. Players will be challenged to become expert in the parallel interpretation of data available from numerous sources and unfamiliar formats.

Designing effective peripheral displays is challenging. In this paper, we provide two examples of game display that encode peripheral and foveal information differently, with the goal of improving the performance of expert players. Testing showed the first example to be unsuccessful, and the second to be successful. We use these examples to illustrate both the difficulties and benefits of creating displays intended for viewing in the periphery.

There are two fundamental challenges in creating peripheral displays. First, we must find appropriate ways of encoding information for peripheral view. While experiments done by earlier researchers and knowledge of the physiology of the eye provide hints as to what kinds of encodings may be successful, our own experience is that designing such encodings is highly challenging. Second, we must determine whether requiring players to attend to peripheral displays in addition to their primary foveal display produces a form of information overload, where the additional information fails to improve performance, or even worsens it. Our two example games illustrate these issues.

The paper is organized as follows. We first review the differences between foveal and peripheral vision, and discuss previous research in peripheral displays. We then present *CoOp Tetris* and *City Flyer*, the two games that we have developed for our case studies, and report our findings about the effectiveness of their use of peripheral displays.

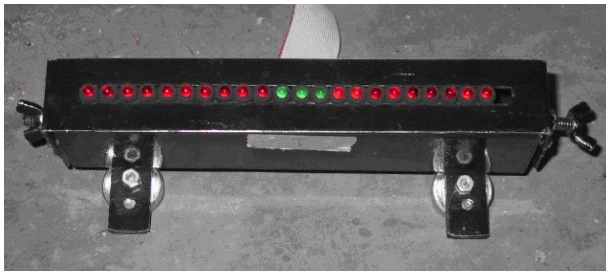

Figure 1: A lightbar is used as a peripheral display in a tractor to show deviance from the tractor's intended path [6]

2. PERIPHERAL VISION AND RELATED WORK

The retina is a light-sensitive layer of photoreceptors at the back of the eye. Photoreceptors are sensitive to photons and are of two types: rods, which are sensitive mainly to intensity, and cones, which are sensitive mainly to colour. Rods also provide more sensitivity to motion detection and to low illumination. The fovea is a small area on the retina that contains only cones and provides an acute, or highly detailed, image of the world within about two degrees of the line of sight. Around the fovea is a greater concentration of rods. This peripheral area of the retina is better at detecting motion and low illumination, but worse at detecting colour [5]. Any information that projects to this periphery may be visually encoded to exploit the properties of the periphery.

Mankoff [9] has studied the characteristics of peripheral displays and determined eight heuristics for building a good peripheral or ambient display. The most useful of these include: the display should be designed to convey enough information but not too much; the display should contain only useful and relevant information; the display should keep users continuously informed through appropriate and timely feedback; the display should be unobtrusive unless it requires the userŠs attention; and the display should be should be easy for its users to monitor. Shen [10] also provides three guidelines to a good peripheral display, incuding that the information presented closest to the primary screen should be the most important, and that animation should be either slow or smooth in order to reduce distraction.

Gaze contingent displays (GCDs) degrade the display resolution in peripheral regions in order to reduce computational requirements during image transmission, retrieval, or display [4]. The region near the user's line of sight is rendered in high detail, while the peripheral regions are coarsely rendered. The high resolution region moves with the user's line of sight, which is determined with an eye tracker. Loschy has summarized six separate studies of gaze contingent displays [7].

Most peripheral displays are used to convey alerts, such as the arrival of email or of an instant message [3]. Most such displays rely on animation, which the research cited above tells us can be easily perceived in the periphery. For example, email arrival under Microsoft Windows shows a small, animated alert box in the lower-left corner of the display. The idea behind this kind of display is to inform the user of some event of interest, so that he may turn his attention to a different task [8, 1].

A more difficult case with peripheral displays is to present a stream of information that is pertinent to the user's central task. Here, the system provides a continuous stream of information rather than a simple alert prompting the user to change his focus of attention. An early example of such a display is Dahley *et al.*'s use of pinwheel lights to project a wall display representing current network state; the network speed influences the speed at which the pinwheel display rotates. The user can therefore continuously perceive the state of the network using her peripheral vision [2].

A perhaps more practical novel peripheral display was developed by Ima and Mann [6] for harvester guidance. Large harvesters are difficult to drive and mis-steering can result in missed crops or twice-harvested strips. Ima and Mann's system uses a GPS to track the harvester's position, and uses an LED strip, placed in the driver's peripheral vision, to guide the driver (see figure 1). Ima and Mann experimented with the size of the lightbar and the colours of the LEDs, and found that the use of blue LEDs resulted in significantly less steering error than red LEDs, and that steering improved with the size of the lightbar. In the periphery, icon colour and icon size must be carefully chosen.

2.1 Peripheral Vision and Games

Both the alert-based and streaming-information styles of peripheral displays are widely used in computer games. Figure 2 shows a display from the game *Eve Online*. The left image is what is displayed on the player's screen. Significant information is displayed in the periphery:

- Chat messages appear in the lower-left corner. When a new chat message arrives, the chat tab blinks, providing an alert to the player.
- A column of buttons runs along the left side of the display. As events occur, these buttons flash, indicating, for example, the arrival of mail, the sale of an item in the galactic market, or the completion of training of a skill.
- A box in the upper-right corner of the screen shows a list of all other ships, stations or items in the player's vicinity. When ships with bad "reputation" arrive in sensor range, their line on this display blinks red, alerting the player to a possible dangerous situation.

The right image shows how the eye perceives this display, while fixated on the centre of the image. The centre of the display is in full resolution. Detail progressively decays with distance from the centre. Alerts such as red, flashing text will be visible, but the text itself is not legible unless the player shifts his visual focus.

Analogous peripheral displays can be found in many realtime strategy and first-person shooter games where a minimap is used to display a top-down overview of the vicinity.

Figure 2: A display from CCP's *Eve Online* (left), and what the eye perceives when focusing on the centre of the display (right).

Similarly to figure 2, the contents of mini-maps cannot be seen while the player is fixating on the centre of the display; mini-maps are often used to convey flashing alerts to engage the player's attention.

An interesting entry to the area of peripheral displays for games is Nintendo's DS portable game platform (figure 3.) The DS has two physically separate displays. In the *Mario Kart DS* game, one display shows a third person view, while the other shows a top-down overview. Only one display can be visually processed at a time, so the player must shift attention between them.

We see from these examples that games frequently use displays that appear in the player's periphery. It is therefore important for game developers to understand how such displays are best designed.

2.2 Guidelines for Design of Peripheral Displays

From our knowledge of the physiology of the eye and from the results of earlier researchers, we can propose some simple guidelines for the design of displays intended to be perceived in the periphery.

- *Increase size of visual elements:* As visual elements move further into the periphery, they must be larger to be perceived in the same way [11].

- *Reduce reliance on colour:* In the periphery, there are fewer cones than in the fovea. As cones are the eye's receptors for colour, peripheral displays should avoid reliance on colour. Ima and Mann found that blue color is better than red in attracting the attention of subjects, and would, therefore, be better in the design of peripheral displays [6]. In general, short wavelength lights are better perceived in the periphery than long wavelength lights.

Figure 3: Nintendo's DS handheld computer offers two displays. When a player focuses on one display, the other is in the periphery.

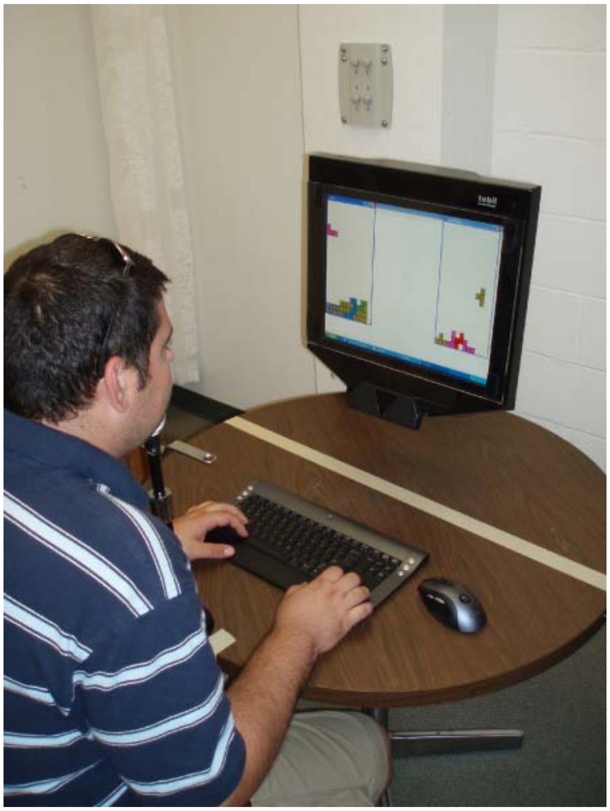

Figure 4: Experimental set-up: a Tobii eye tracker is used to determine where the players are looking during experiments.

- *Use motion:* The periphery has far more rods than cones. Rods are effective at perceiving motion. Therefore, motion may be a useful peripheral indicator.

3. CASE STUDIES

In order to demonstrate how these guidelines can be applied, we have created two example games that visually encode information for viewing in the periphery. Both games attempt to convey streaming information to the player rather than simple alerts. The first, *CoOp Tetris*, was unsuccessful, showing how following the standard design guidelines is insufficient to guarantee a successful peripheral display. The second, *City Flyer*, successfully conveys information in a peripheral display. We first discuss the equipment we used to test the games, then introduce their designs, and finally discuss what these games teach us about the design of peripheral displays.

3.1 Experimental Equipment

We tested both games using a PC equipped with a Tobii eye tracker (figure 4). The eye tracker recorded where the subjects were looking while playing the game, allowing us to determine whether they were accessing information using their peripheral vision, or instead looking directly at the peripheral display. The Tobii eye tracker runs at 50 Hz with an accuracy of 0.5 degrees. This means that when subjects are seated a normal distance from the monitor, the eye tracker records the focus of their gaze within an accuracy about the size of a quarter. The eye tracker works by beaming infrared light at the subject, and triangulating the reflection of this light from the subject's pupils via cameras with infrared filters.

Players were seated 46 cm from a 34" computer display. A chin rest was used to ensure that players' position remained constant with respect to the display.

Both games were instrumented to log where players were looking throughout the game session. Positions were recorded as coordinates relative to the upper-left corner of the display.

3.2 Example: CoOp Tetris

Many computer games involve *cooperative play*, where players must coordinate their activities to be successful. For example, in real-time strategy games, players must be aware of their teammates' movements, resource gathering, and combat. In a World of Warcraft battleground, players must be aware of their teammates' locations, targets and health.

Our first example game explored whether a peripheral display can be used to convey awareness in a computer game. Providing awareness of other players' activities is an ideal application of peripheral displays: the player's foveal view can be reserved for his central game task, while the periphery can be used to represent the state of his teammates.

We designed and implemented *CoOp Tetris* to use a peripheral display to represent teammate awareness information. We intended that the use of the peripheral display would increase players' performance in a cooperative task, and that players would prefer the specially-encoded peripheral display to a standard display. This design did not succeed in these goals: performance did not improve when the peripheral display was available (and in some cases actually degraded.) Furthermore, players reported that they preferred the standard display. These results indicate the difficulties involved in designing a peripheral display, and highlight the importance of careful design and experimentation. Our study illustrates that simply providing a peripheral display does not guarantee that either players' performance or enjoyment of the game will improve.

CoOp Tetris is a two-player version of Tetris in which players collaborate to maximize their scores. While there are numerous multiplayer Tetris games, *CoOp Tetris* is the only version of the game of which we are aware where players cooperate rather than compete. The goal in the standard game of Tetris is to position falling blocks of different shapes so as to form solid horizontal lines. Additional points are given for forming multiple solid lines simultaneously. The game ends when the player's game well is filled up so that there is no remaining space for new pieces to occupy.

Our cooperative version extends Tetris by allowing two players to play simultaneously. The score for the game is the sum of both players' scores, and play terminates when one player has lost. Therefore, it is in each player's interest for the other player to play successfully. Play is cooperative in that the score is the sum of the players' scores and that a loss by one player is a loss by both.

Figure 5: CoOp Tetris: The well on the left shows the player's own view; the well on the right shows the well of the player's partner.

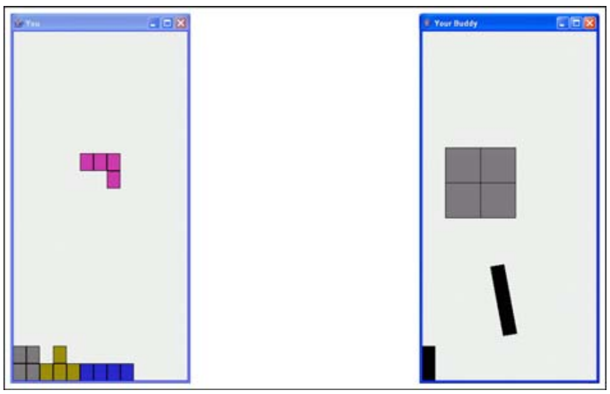

Figure 6: CoOp Tetris where where the display of the partner's well is encoded for viewing in the periphery.

Figure 5 shows *CoOp Tetris*, where both players' game wells are shown side-by-side on the same screen. The player controls the left game well, and the right game well is controlled by the player's partner. The right game well is a form of *awareness display*, allowing the player to see the state of his partner's game. If the player focuses on his own game well, the awareness display will appear in his periphery. The display in figure 5 is the same as the partner's primary display, and is therefore not specially encoded for peripheral view.

As described so far, the game allows two people to play together, but does not allow them to *cooperate*. We further extend the game to allow players to swap pieces as they are falling. Either player can invoke a swap by pressing the space bar. The other player is not given any choice as to whether the swap takes place, but can of course use her own swap key to change the pieces back. Invoking swap causes the two players' falling pieces to be exchanged. The pieces remain in the same orientation. A piece that is swapped is positioned at the same height and horizontal position as the piece that it replaces. The only communication between the two game wells is through swapping.

Swapping introduces interesting dynamics to the game. In Tetris, players frequently wait for a particular piece in order to complete a row or set of rows. If the player's partner receives that piece, swapping can allow the player to make the desired move, increasing his score. To take advantage of this potential for swapping, players must be aware of the other player's current piece.

Since the game is cooperative, it is not sufficient just to know what is the other player's piece. Sometimes, initiating a swap can harm the partner more than it helps the player. Perhaps the partner was waiting for the same piece, or perhaps the swap will confuse the partner, leading her to make a poor move. It is particularly bad to swap when the partner's piece is nearing its destination or when the partner's pile of dropped pieces is high. Therefore, players require more detailed knowledge of the partner's game state, indicating how much a swap will inconvenience the partner, allowing the player to balance the benefit to him against the harm to his partner.

3.2.1 Peripheral Encoding of Awareness Information

The game display of figure 5 provides sufficient information for players to decide whether it is helpful to swap pieces. Since the player sees the entire state of his partner's game well, he can see whether the piece is one of particular use to the partner, how close the piece is to the bottom of the game well, and how much space the partner has left in her well. Therefore, the player has all necessary information to judge the impact of swapping on his partner.

While all necessary information is present, however, the problem is that it may not be easy for player to take advantage of it. The partner's well falls within his peripheral vision and therefore, the player has to move his focus from his own well to the partner's well to decide whether to swap. His lack of attention to his own well in the meantime may negatively impact his performance. We therefore created a new version of the partner's well intended for view in the periphery. The goal is that players should be able to fixate on their own well at all times, while gaining awareness information through their peripheral vision. The peripheral encoding is a simplified presentation of the normal game well. It does not add new information and does not synthesize views from multiple sources of existing information. Figure 6 shows the encoded version of the game.

We encode three things that are critical to deciding when to swap pieces: the shape of the partner's falling piece; the height of the partner's pile of dropped pieces; and the distance of the partner's falling piece to its destination directly below.

Three "peripheral icons" are used, following the guidelines listed in section 2.2. The partner's falling piece is enlarged, since larger items are detected more easily in the periphery. A spinning rod is used to show the distance of the partner's piece to its destination below; as the distance increases, the rod spins faster. This takes advantage of the fact that motion is easily detected in the periphery. Finally, a vertical thermometer-like gauge is used to show the height of the partner's pile of dropped pieces.

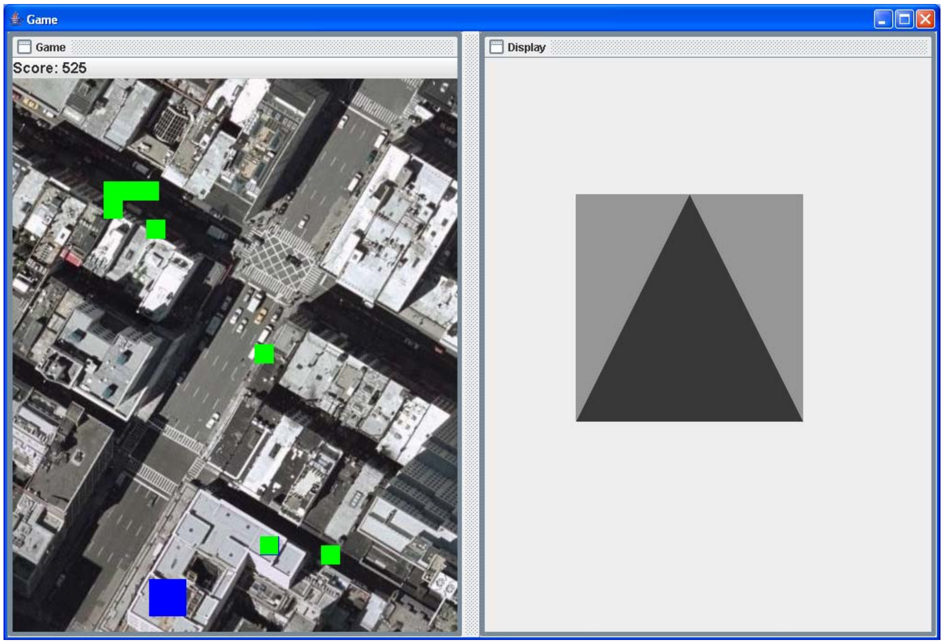

Figure 7: City Flyer: Players attempt to fly over a city while avoiding bombs. When a square appears in the peripheral display, pressing the space bar gives a brief speed boost.

3.2.2 CoOp Tetris: Results

Results of experimenting with *CoOp Tetris* were disappointing. We found no significant difference in players' scores between the detailed and encoded versions. When surveyed, players indicated no clear preference between the detailed and encoded versions. Worse, we found that players using the encoded display attained lower scores than in our control case of a single-player version of the game. That is, use of the peripheral display actually *lowered* players' scores.

A survey of Co-Op Tetris players indicated that most did not use the vertical bar (representing the height of the partner's pile of dropped pieces.) Most reported that, while they could sense the spinning bar (representing the distance of the partner's piece to it's destination), they did not use it. Subjects principally used the large version of the partner's piece to decide when to swap, taking no account of whether this would harm the partner's gameplay.

CoOp Tetris' display was successful in that players could correctly perceive the information it showed. However, in the heat of gameplay, they did not use this information beyond the most simple use of the large symbol showing the partner's current piece. We believe that this problem hinged on the limit of players' attention. Just to manage their own well, players need to keep track of the current falling piece, determine where best to put it, and maneuver it appropriately. As the game speeds up, this consumes all of the player's attention. Even though players can in theory keep track of the state of their partner's well, in practice they do not have sufficient cognitive capacity to do so without sacrificing the quality of play in their own game well.

This indicates a significant limitation in presenting streaming information in a peripheral display. Players attending to a primary task must have sufficient cognitive resources to be able to attend to the information presented in this peripheral display in addition to their primary task.

The following section shows an example of a successful game where the demands of the peripheral display have been designed to be considerably lower.

3.3 Example: City Flyer

Figure 7 shows *City Flyer*, our second attempt at a game in which streaming peripheral information is used. In *City Flyer*, players attempt to navigate a city landscape without being destroyed. Players' scores are based on the distance they traverse before being hit with a bomb. The player controls a "ship" represented as a box at the bottom of the display. Arrow keys are used to move the ship left and right. The city landscape scrolls vertically, giving the player the sense of travelling. The player must avoid bombs of different shapes, sizes and speeds as they cascade down the screen. As the game progresses, its difficulty increases by presenting more and faster bombs.

A "shape" display shows a set of shapes (circles, triangles and squares) that continuously morph from one to another. Figure 7 shows a triangle that is in the process of morphing into a square. The ordering of shapes is randomized so that players cannot predict when a particular shape will next appear. When the display shows a square, if the player presses the space bar, he receives a brief speed boost, thereby allowing him to travel more distance and consequently increase his score. If the player makes a mistake and presses the space bar when the second display is *not* showing a square, his speed is briefly slowed, reducing his score. Therefore, it is to the player's advantage to attend to the information in the shape display. However, the brief speed boost is not worth risking being hit by a bomb, so players must retain their attention on the primary display.

In testing *City Flyer*, we found that

- Based on eye tracking information, players do use the second display as a peripheral display. They retain their visual focus on the main display, and make decisions about the content of the shape display without directly looking at it.
- Players accuracy with the shape display is close to 100%. That is, players rarely press the space bar at a time when there is no square in the second display.
- At easier levels, players tend to correctly identify and use all squares that appear in the shape display. As the game progresses and becomes more difficult, however, players cease using the information in the shape display. That is, they allow squares to come and go in the shape display without reacting to them.

We consider these observations to indicate that the shape display is a successful peripheral display. Players are able to use the shape display without directly looking at it. At lower levels, players are able to process the information from the shape display. However, as the game progresses, all of their attention is required to simply stay alive, and so information from the shape display is no longer processed.

3.4 Discussion

We have proposed that game information should be encoded according to its position in the fovea or periphery. Our case studies show that players find it challenging to process information presented in the periphery when the game's central task is consuming all available cognitive resources.

In the design of peripheral displays, care should be taken to follow the design guidelines presented in section 2.2. As was seen in figure 2, most visual information appearing at the edges of displays cannot be perceived if the player is viewing the centre of the display. If the designer's goal is simply to alert players to important events and draw their attention to another part of the display, then it is sufficient to provide flashing or animated alerts. The more difficult (and more interesting) case is where the designer wishes to provide streaming information that the player will continuously perceive in the periphery without diverting attention from the central task. Our guidelines suggest that using techniques such as increasing size of information and using motion help a great deal.

However, as illustrated by our *CoOp Tetris* game, these techniques alone are not sufficient. Players' attention is limited. If games provide an overload of information, they will not have sufficient cognitive power to process it, even if the player can correctly interpret the display. Our *City Flyer* game allowed us to see that this cognitive overload is progressive – as players advance in level, they become so busy with the central task of avoiding bombs that they cease to be able to use the information in the peripheral display. It is important for designers to understand the benefits that peripheral encoding can bring while recognizing peoples' limits in how much information they can process and react to.

4. CONCLUSION

We have discussed the importance of designing game displays to take account of the capabilities of the human visual system. Much information shown in game displays cannot be seen in full resolution by game players who are focused on their central game task. We have discussed the design of two games. The first, *CoOp Tetris*, showed that despite following the standard rules for design of peripheral displays, players could not process information better than using a fully detailed display. The second, *City Flyer*, showed that it is possible to design peripheral displays that are effective up to the point that the player's cognitive resources are consumed. From this we conclude that it is profitable to encode information in the extremes of the display in forms that are suitable for viewing in peripheral vision, but that designers must perform considerable experimentation to ensure that such designs are effective.

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