Breathalising Games: Understanding the Potential of Breath Control in Game Interfaces.

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ABSTRACT
This paper explores the potential for breath control as an interaction medium for gaming. In particular it examines the positioning of breath control within the stack of interface paradigms: As the only control, as a secondary control and as an ancillary or ambient control. It describes a technology developed using specially adapted gas masks to measure breath flow. By describing five simple games (or game modifications), each developed using breath in a somewhat different way, we show some of the possibilities of this unique interface paradigm. Crucially, the paper aims to demonstrate that breathing, though in principle a one dimensional interface medium, is actually a subtle and viable control mechanism that can be used either as a control mechanism in itself, or to enhance a more traditional game interface, ultimately leading to a satisfying and immersive game experience.

Categories and Subject Descriptors
H5.m. Information interfaces and presentation (e.g., HCI)

General Terms
Performance, Design

Keywords
Gas Masks, Breath Control, Biofeedback

1. INTRODUCTION
Breathing is a biological activity with some particularly interesting characteristics: It is both autonomic and in part explicitly and quickly controllable. Control is however mediated by the necessity for breathing to perform its primary function; one cannot voluntarily stop oneself breathing indefinitely. Certain physiological characteristics also limit both the rate and volume which we can breathe.

However, within that space there is much potential in breathing. It is a truly universal characteristic of our everyday lives. In a time where new and exciting interfaces generate much interest in the gaming world, this paper argues that there is a place for breathing as an interaction medium, and demonstrates the various levels in which breathing may be useful.

In particular, for gaming interfaces, breathing offers a kind of control different to that provided by more familiar peripherals, or other forms of biofeedback; while on the surface it seems like a straightforwardly controllable process, in practice, while significant accuracy can be achieved, sustaining any part of the control for anything but the shortest periods of time is all but impossible. These unusual properties make for a new and intriguing approach to game control that can provide a fun, original and engaging experience.

In this paper we present a new peripheral, a gas mask which measures breath flow, and a series of simple games, aimed at demonstrating the potential of both the peripheral itself and the wider idea of breath control as a valid interface paradigm.

2. RELATED WORK
There is within the literature an established body of research into breath as an input mechanism. This falls into two main categories: assistive technologies that adapt user interfaces to specific abilities; and expressive devices that enable dynamic control of creative applications. Assistive interfaces include keyboards for use by individuals with motor impairments such as tetraplegia; simple 'suck-puff' switches allow letters to be selected from an on-screen keyboard, while more recent advances use piezo film sensor arrays to detect flow [5]. Along with more accurate control of screen-based interfaces [3], improved sensitivity and reliability of sensors is now enabling breath to control physical artifacts such as powered wheelchairs [12]. Turning to creative applications, breath controllers have augmented traditional wind and brass musical instruments (e.g., the Yamaha BC3A Breath Controller [11]) and been incorporated into new kinds of instrument [1]. Breath control has been put to other creative uses too: for navigating an immersive virtual world through the metaphor of diving [2]; and for enabling two-way 'gust-based' communication [8]. Mainstream products have also entered the market, for example the Sensawaft breath controlled mouse [9]. Indeed, breath control has already been used in some game interfaces [6] from

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simply blowing out candles on a DS, to Robin Arnott's Propeller award winning sensory deprivation game Deep Sea [15].

The use of biofeedback in games is also not unusual. Such games however tend to be associated with some form of exercise such as those described in [7] and [10]. Other more complex forms of bio feedback based games such as [4] have cumbersome or expensive interfaces requiring extensive calibration.

3. THE GAS MASK INTERFACE

The idea of the gas mask interface emerged from a long term project to develop interactive entertainments using biological sensing. The mask is designed to explore the aesthetics of respiration monitoring as a form of engaging spectacle and gaming interaction. During the development of the mask interface, we carried out an initial pilot study using a crude chest strap breathing monitor to control a bucking bronco ride [16]. This revealed that breath control was feasible, fun and challenging, and also showed how riders became more aware of their own breathing as they struggled to control both the machine and their own bodily response. The fully developed interface described here "ups the ante" with an interface that deliberately heightens these sensations. The gas mask is designed to be used as part of intense experiences that challenge participants to engage with and confront fear, an essential ingredient in thrill rides, horror films and similar experiences. The use of a gas mask appealed due to its striking aesthetic, strong cultural resonances (from wartime horrors to fetish wear), distinctive visceral physicality (affecting sight, touch and smell), and practical ruggedness.

Figure 1. Gas Mask and Respiration Monitor

The core of our device is the gas mask, a British Army S10 Gas Mask and Filter. These standard pieces of equipment are used by military personnel (and are also popular amongst fetish-wear enthusiasts). The Filter (on the right in Figure 1), is a detachable part, which cleans air coming into the mask. In our system, we customise this filter to create a Respiration Monitor, which contains two gas flow sensors, batteries, and an Arduino microprocessor board, with a WIFI extension shield attached to it. For safety reasons, we have modified the front of the gas mask so that air can flow into and out of the front of the mask without obstruction. This means that only a small percentage of the air breathed by the wearer goes through our Respiration Monitor. For our purposes we assume that the percentage of sensed air volume flow rate to actual air volume flow rate is constant, meaning that the total air flow can be assumed to be a constant multiple of the flow measured by the flow sensors. We use two flow sensors, as these are directional, to sense both inhalation and exhalation rates.

The microprocessor records readings from both the flow sensors at 20Hz, and transmits them on a WIFI network using local broadcast. This allows us to obtain accurate and low latency inhalation and exhalation rates, while the wearer can move around freely. These messages can be received and processed by any other device connected to the WIFI network.

4. GAMES

The following subsections use the MDA framework [14] to describe the five games developed to investigate the incorporation of a user's breath as a game mechanic via a gas mask interface. MDA is a formalised method used to describe games in terms of their mechanics, dynamics and aesthetics, which, while something of a syntactical and semantic minefield, in this case refer repectively to the technical behaviour, the run-time behaviour and the users' physical and emotional experience.

4.1 FPS Aim Control - Serious Sam

'Serious Sam HD: The First Encounter' is a traditional first-person shooter game in the style of Doom. The game was adapted so that the position of the aiming reticule on the screen fluctuated vertically with the player's breath.

Figure 2. Player experiencing FPS aim control.

4.1.1 *Mechanics*

A simple minded approach was taken for control of the aiming reticule. By generating 'fake' mouse movements (SetCursorPos) the position of the cross-hairs was perturbed based on the difference between consecutive values of the two (in and out) breath sensors, these values having first been calibrated to a quiescent level using an initial 100 readings of the sensors. A fixed scaling (k) of the range was applied (hence, there was no dynamic adjustment applied for an individual's lung capacity or breathing style, though there was no zero drift since the differential was used). i.e.

$Q_{in/out}$ = the quiescent levels of the two sensors

$S_{in/out,\,t}$ = the value of the sensors at time t

So, the 'breath value' at time t is given by:

$$B_t = (S_{in,\,t} – Q_{in}) – (S_{out,\,t} – Q_{out})$$

and, perturbation in the vertical direction, is:

$$P_t = (B_t – B_{t-1}) * k$$

4.1.2 Dynamics

The game was controlled by the player in the regular manner, by using the keyboard to move, and the mouse to aim and shoot. Because the 'fake' mouse movements were 'added' to the existing control mechanisms, play was identical to the original game with the exception that the cross hair would move up and down as the played breathed in and out.

4.1.3 Aesthetics

From the small group of play testers (seven regular game playing males aged between 19 and 25) feedback was broadly positive with all seven reporting that they enjoyed the experience. There was some general consensus about the breath control dynamic, with all but one player reporting that having to hold your breath to steady your aim was an enjoyable aspect.

"[it was] ...cool how you had to balance it out. It took a while to work it out but once I figured it out, how it reacted to what you were doing, it was good."

Unsurprisingly, a large part of the feedback centered on the novelty of wearing a gas mask while playing a game; this received a less favorable reaction, with six of the seven participants highlighting issues with the physical mechanics. Problems outlined included the mask being too heavy, too big (which limited the amount of the screen that could be seen), too hot, and a little bit uncomfortable. Two participants claimed that the mask fogged up slightly, despite the use of an anti-fogging spray, although one of these two thought that this actually enhanced the experience. Contextualization was flagged as an important consideration with one participant saying they would feel more immersed if,

"[wearing the mask] was relevant to the context of the game, like say you're in a toxic environment and your character is wearing a gas mask"

Interestingly the majority of players claimed that their breathing was not affected by the action in the game (the expectation had been that players may exhibit a sharp intake of breath in response to a surprise encounter with an attacker). Assuming this is not merely a memory artifact (which is not supported by the recordings of the players) there are several factors that could explain this flattened affect. The players in the study were all regular gamers and may have habituated to this type of stimuli, indeed a lack of emotional or strong physiological response maybe beneficial while playing these games. There is of course, a great deal of debate in this particular area but that is beyond the scope of this paper. Alternatively it could simply be that game is just not that shocking, or that the brightly lit lab environment in which is was played, was not conducive to the production of a fear response, or that the players felt inhibited in some other way. Indeed one player did comment that,

"if it was night time, and I was on my own and playing something genuinely scary, then maybe"

There was also mention that simply moving the aiming crosshairs based on breath may not have incorporated this aspect as fully as would be been require to have more of an impact.

"[it] would be good if it detected when you made a loud noise [breath] that would alert enemies."

4.1.4 Discussion

As a general mechanism for retrofitting breath control to an existing game, perturbation of the cursor is an effective and easily implemented adjustment. There was general enjoyment of breath as an aspect of the play although there are clearly some practical and physical issues that need addressing. Finally, breath clearly offers more scope than simply making aiming harder, and players indicated that they would like to see developments in that area.

4.2 Sneak'em-up Alert Area Control

The sneak'em-up game design pattern is a traditional play motif that prefers sneaking past enemies rather than engaging them in combat (or, at least to gain an advantage). It is often used as a break between more confrontational sections game narrative to provide contrast (e.g. virtually all versions of the classic Nintendo series Zelda have at least one section where Link, the protagonist, must sneak undetected past guards of one sort or another to gain access to something important). Other games lean more heavily on the dynamic, for example the popular *Thief* and *Splinter Cell* series are almost entirely stealth based. The implementation described here strips this pattern down to its bare essentials.

Figure 3 – Player of Sneak-Em-Up

4.2.1 Mechanics

There is a circular area surrounding the game character the radius of which is governed by the player's breath. A slightly more sophisticated, adaptive, approach for mapping the breath data onto the game mechanics was attempted for this implementation. A list of the most recent previous breath values (calculated as for B_t in the previous game) was kept over a specific time period (in practice 30 seconds) and sorted with respect to magnitude. This allowed an average of the top 10% (T) and bottom 10% (B) of breath values to be rapidly calculated, and the current breath value (C) to be normalized with respect to this, scaled (k), and the magnitude taken to give the radius (R) – in practice this was clamped to a maximum value to allow the games difficulty to be adjusted.

$$R = \min(\mathrm{abs}(C / (T - B)) * k , \max)$$

The circle was clearly displayed around the player's avatar as a black circle and a player was 'Detected' when one of the green guard dots fell within this area (see figure 4).

4.2.2 Dynamics

The position of the small avatar was controlled by the player using a keyboard, and a top down view of the maze was presented as shown in the figure 3. There were three levels of progressively increasing difficulty and length. The player had to navigate each level from beginning to end without alerting the guards to progress to the next.

The effect of the buffered breath calculation was two fold. Firstly it allowed automatic calibration for each player. By breathing normally for 30 seconds before the game started, a full scale deflection would be achieved; the radius of the circle would go from maximum to minimum for each natural breath. However, if players attempted to overly control their breathing (by holding their breath for an entire level for example) then the system would adapt and become more sensitive, making the game much harder. The player is encouraged by the design to control their breathing only in areas of maximum benefit, or risk over-sensitizing the calibration to the point where the level is impossible.

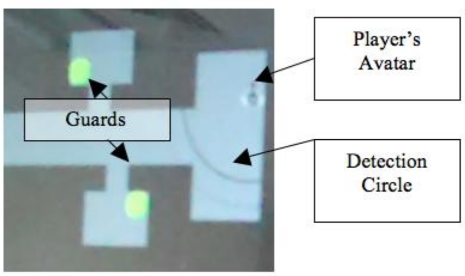

Figure 4: Close-up Player View

4.2.3 Aesthetics

A different group of play testers (six males and one female aged between 19 and 25 and of various degrees of familiarity with gaming) took part in the test. Again there was broad agreement that the breath based game mechanic was fun and an enjoyable aspect of the experience. The more complicated calibration procedure seemed to negatively affect the experience and caused some confusion.

"There were sometimes when I thought I was breathing quite lightly and then it suddenly just spiked and got quite large."

"when I first started using it, it only seemed to really register when I exhaled."

"I wasn't quite sure what it was trying to monitor."

Perhaps this was due to the way the system continually adjusted its sensitivity, so the same action by the player could produce different levels of effect in the game (i.e. the same breath input could produce different sized circles depending upon a player's previous breathing activity).

Fogging of the lenses was again common, although one participant suggested that the fogging of the lenses added a slight sense of urgency as it got progressively harder to see! Contextualization was again seen as important to the experience, with many participants suggesting that possible genres in which a similar mechanic could be more effectively deployed included survival horror games and first-person shooter games.

4.2.4 Discussion

The theme here was to build a rudimentary stealth based game linking breath control to detectability. Similar concerns were highlighted by participants regarding the physical practicalities of the gas mask; although this did not seem to spoil the fun, it is doubtful whether long term use (of more than a few minutes) could be envisaged with the current equipment. The automatic calibration process as implemented seemed to disconnect the user from feeling in control of the on-screen activity, more work is required to design an algorithm that can seamlessly calibrate a system whilst not interfering with the locus of control.

4.3 PerPing

PerPing is a breath controlled version of the classic video game pong. It allows two gas masked players to control the paddles in a basic tennis like simulation. Unlike the previous examples, in PerPing breath is the only control interface used. Players are required to accurately manipulate their paddles at increasing speed in order to successfully score points. Players see a representational chart of their breathing (or more accurately their paddle position) displayed continuously on their side of the screen.

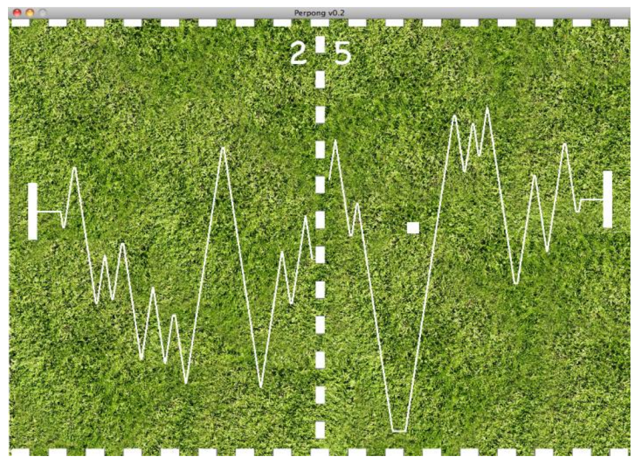

Figure 5: PerPing's game interface

4.3.1 Mechanics and Dynamics

At its most basic level, PerPing makes use of a direct mapping from paddle movement to breath flow volume, that is if a player is breathing in their paddle is moving up, if they are breathing out their paddle is moving down and if they hold their breath, the paddle should remain fixed. The speed of the paddle is mapped to the flow rate measured by the gas mask canister, thus breathing hard will move the paddle faster.

The game calibrates itself during each point based on the player's maximum measured in and out flow, thus if a player achieves a maximum flow of four hundred, they will have to match that value to get the paddle to move as fast again. This improved our previous automatic calibration system and helped the game to adapt more fairly to players with uneven flow capacities. The calibration is reset every point to prevent achieving maximum speed becoming increasingly difficult as the game goes on, since one huge exhalation after holding one's breath can then seriously limit a player's ability to achieve maximum downward velocity until it is recalibrated.

As breath is the only dynamic involved in the interface, a second mechanic is applied based on breath frequency rather than flow volume. Players' paddles change in size based on that frequency.

If a player breathes slowly, the paddle slowly decreases in size (deflates), while breathing quickly causes the paddle to increase in size (inflates) within a fixed range 5%-20% of the screen height. In order to make this more visually accessible, the game displays a chart of each player's breathing (strictly their paddle motion) across their side of the screen, giving a visual representation of the breath frequency.

Breath frequency is represented graphically to support the final game mechanic. If a player reaches a particular breath frequency (default 400 breaths per minute) the ball will split into two parts, bringing a second ball into play and making the game significantly more challenging. To keep this dynamic fresh, the player has to judge visually when they are approaching that frequency, as if the ball happens to be traveling towards them when the second ball comes into play they are quite likely to lose a point, especially as it takes considerable effort to reach 400 breaths per minute, and that exertion seriously diminishes one's ability to engage in fine control.

Breath frequency is determined in a rolling window the size of which is mediated by the screen resolution. The window, and subsequently the frequency value is determined by the number of samples and flow values being shown on the chart, and as each pixel represents a sample. Thus at a standard resolution of 1024x768, 480 samples are represented (allowing a border for the paddle position). A sample rate of 24Hz, matching the 24fps frame rate yields a rolling window of 20 seconds.

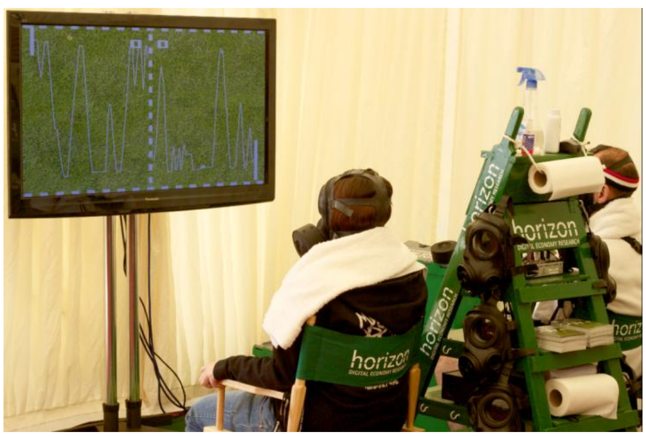

Figure 6: Perpring on display at the Cheltenham Science Festival in the UK

4.3.2 Aesthetics

PerPing has been quite extensively play tested; in part because at the time of writing it is on public display as part of a major UK public understanding of science event. Players' reactions have been universally positive, citing the responsiveness of the system and transparency of the interface:

"It [the game]'s easier to play than I expected."

Because the game was themed on a well known source (Pong) there was no challenge associated with explaining the purpose of the game to players. Players reported that it had a 'pick-up-and-play' appeal, regardless of their current interest in modern video games.

As with the other games, it has been the gas masks as much as the game itself that have come in for commentary. Players find them somewhat uncomfortable, even disconcerting. In the previous games discussed (Serious Sam and Sneak-Em-Up), the gas mask has to some extent fitted into the 'feel' of the game. With PerPing this is not the case: there is no obvious thematic connection between playing tennis and wearing a gas mask. This gives the interface a slightly disconnected feel with the visuals of the game.

"I feel pretty weird wearing this [the mask] though. It'd be hard to play real tennis in!"

Lens fogging has again been cited as an issue, though as with the other games, it has been seen as an aspect of the gameplay, rather than a specific external problem. Breathing too fast, while offering the benefits of a larger paddle does tend to fog up the mask, making the game more difficult. There is a fine line to consider between where the specific faults of the interface overtake the playability of the game.

4.3.3 Discussion

As a comparison, the game was tested without modifying the speed based on flow rate, so simply breathing in or out would move the paddle at a constant speed. This mechanic actually more closely matches the original pong gameplay where the paddles moved at a fixed speed, but play testers found this to be both frustrating and counter-intuitive:

"I keep loosing because my bat's too slow. I'm breathing out as hard as I can"

It appears that there is an expectation that breathing harder should make the paddle move faster. This is somewhat mapped in normal gameplay where players will push a button or joystick harder to try and speed up an action, even though they know it is a digital output so that will have no effect. This is a well recognized behaviour within the games industry, as reflected in the introduction of controllers with analogue buttons in the last generation of home consoles.

PerPing was an attempt to create a game that is sufficiently complex to be enjoyable and tactical, but still based on a single dimensional, albeit analogue, control mechanism. In that respect it appears to have been successful, showing very positive feedback. In principal players seemed to 'get' the point of the game.

4.4 Tunnel Run

Tunnel run is a simple two player game, where one player makes a landscape and the other attempts to fly a ship through it. The game evolved by looking at the breath graphs from PerPing, and noticing a similarity to the landscapes of classic side scrolling games like defender. The result is an interactive and challenging proto-game experience that essentially requires one player to match the breathing patterns of their opponent, while the other attempts to create a pattern that is difficult to match.

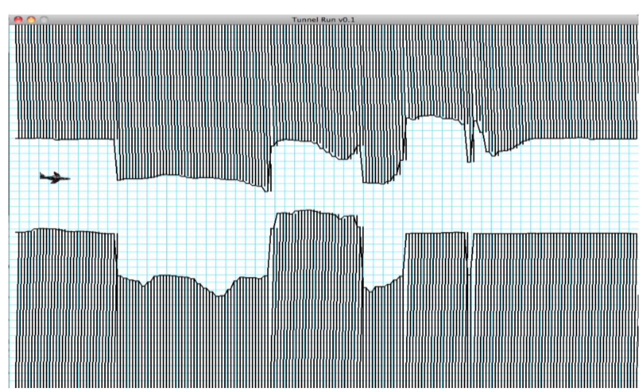

Figure 7: The Tunnel Run Interface is designed to look as if it is drawn on graph paper.

4.4.1 Mechanics and Dynamics

The game mechanic of tunnel run is deceptively simple, masking a surprisingly challenging experience. One player takes on the role of creator, the other of pilot. The creator's breath is measured and a chart of that breath is drawn starting one third of the way up the screen. Above that, and starting one third of the way down the screen is a second chart. The area below the bottom chart and above the top chart represents solid ground, while the area between the charts is the eponymous tunnel.

The pilot's task is to fly safely through the tunnel for as long as possible. The pilot's ship is controlled by breathing in to move up and down to move out, using the same mechanics as the paddles from PerPing. To add an extra dimension to the pilot's experience, the frequency of his breath determines the speed of his ship, actually represented by how far forward on the screen he is positioned. Flying too quickly thus means one must react more quickly to the changing landscape, while flying more slowly gives one time to see the forthcoming landscape, but requires a smoother style of control.

One of the main challenges with the construction of this game was getting the width of the tunnel correct to allow a ship to be able to fly through it at all. Sudden dramatic breaths make for very tight spaces in the tunnel, indeed when simply duplicating the lower chart, the upper chart would often cross the lower, making an impenetrable barrier. To counteract this, the upper chart is actually a somewhat delayed duplicate of the lower, and a constant minimum distance is maintained between any two upper and lower data points, which somewhat deforms the top chart. This makes for a tunnel which is always flyable, though potentially very challenging. To prevent the creator character simply taking fast deep breaths, a second frequency mechanic is used, this time for the creator, which varies the minimum distance between the charts based on the creator's breath frequency. If they breath fast then the tunnel gets wider, slowly and it gets narrower, within a specified range; the tunnel can never be narrower than the width of the ship plus a small amount of padding, and can never be wider than a third of the screen.

Although the game in itself proved entertaining and lead to an element of competition, sustained play required a specific competition mechanic. Ultimately it was determined that creator and pilot roles would have to be swapped in line with an 'innings' and points would only be scored by the player taking the role of pilot - an 'innings' would consist of a fixed number of lives with the score simply a number of milliseconds of 'flying time' divided by the number of lives expended.

4.4.2 Aesthetics

Tunnel run has been quite well received by its play-testers, a group of eight players of both genders with age ranges from 19-53. The majority of players were males aged 21-30, few had extensive gaming experience beyond childhood. Players reported that the interplay between the creator and pilot was interesting from both sides, but both also provided opportunity for frustration:

"It's like being god, but I wish I could just hit [pilot] with a lightning bolt. He's too good! It gets boring after a while when he doesn't crash!"

"It's really hard to control the ship after a while. Who'd have thought breathing was so hard!"

The term creator was actually chosen as a direct result of the first of these quotes. Most participants commented in some way about how hard it was to fly for any great length of time. The key point it seemed was that because there was always a floor, no matter how wide the tunnel might be, this meant that a complete and deep exhalation was at no point feasible while playing the pilot as it would inevitably lead to a crash. This fact left some players and one in particular with a feeling of intense anxiety – one of the physical effects of sustained shallow breathing.

It was determined through play testing that a paradigm of lives was required rather than switching every time players crashed as the switchover tended to cause some initial disorientation. A game could consist of just one innings each, but the optimal number seemed to be three each. More and players became bored, less made them feel like they hadn't really had a chance to excel.

4.4.3 Discussion

The challenge of tunnel run, particularly for pilots is sustained control. It turns out that maintaining accurate control over one's breathing is actually very challenging. In PerPing accuracy was required, but one had a chance while the ball was traveling to the other side of the court to rest briefly, similarly in Serious Sam and Sneak-Em-Up. With tunnel run, no 'rest breaks' were available, instead the pilot needs to be fully focused on their breathing 100% of the time. Similarly the need for shallow controlled breathing has a physical effect on the body that makes sustained play as the pilot difficult, hence the regular role switching.

As most of the playtesters of this game were already familiar with the gas masks and had played PerPing, the novelty of the masks themselves was somewhat less for this game. As such, somewhat fewer comments were made about the masks themselves and their relationship with the game. This does suggest to some extent that the physical interface can fade out of the experience once it becomes more familiar.

4.5 Hyperventilation Sports

In principle hyperventilation sports (HVS) is the simplest of the five games. It was inspired by old arcade athletics games like Konami's seminal *Track and Field* and *Hypersports*. The game mechanic of those games was a button-mashing tap as fast as you can race, which was enormously satisfying to play – possibly because of the raw physicality of the interface. HVS takes essentially the same approach and pitches players in a race against each other where they must breathe as fast as possible.

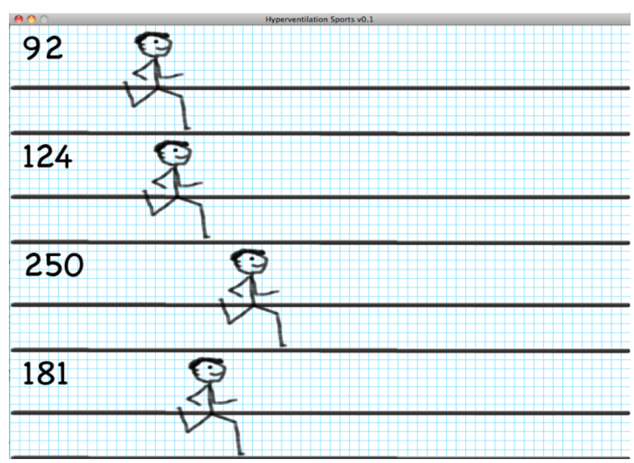

Figure 8: The hyperventilation sports game in action. Like tunnel run, it is designed to have a hand drawn look and feel.

4.5.1 Mechanics and Dynamics

While the game mechanic is really very simple here (breath as fast as you can and the winner is the one who breathes the fastest) there are at least three potential models. The first was pure breath frequency where one breath equates to one step of a race, thus the person who breathes a requisite times first wins. The next approach considered regarded flow volume. Since the gas masks measure flow rate, then total volume of flow could be used as a target, thus the person who breathed the required liters of air first wins, allowing a strategy of slower and deeper, breaths or faster and shallow. A third mechanism combines both rate and flow.

Returning to the source material showed that those games provided a "power meter" and the level of the power meter determined how fast the player was running and was itself derived from the speed and rhythmic nature of the tapping. Replicating this helped to map more accurate times for the distances involved and thus present a more satisfying race experience. Power then is determined by a combination of both breath frequency and flow volume, this combined value is shown on the power meter and that determines how fast the sprite runs.

Unlike both PerPing and tunnel run which had a naturally two player dynamic, and Serious Sam and Sneak-Em-Up, which are single player experiences, HVS provided us with an opportunity to play with as many players as it was practical to equip (five, as we have five gas masks, though the game could clearly support more). The game simply dynamically adapts to support as many gas masks as are connected to the local network, splitting the screen horizontally as necessary. As the player 'runs' it is actually the track that moves, with distance markers passing to show how far along the race a player is. Player position shifts a little to show who is ahead in the race, giving a visual ranking of the current places. The system is quite recognizable from many modern athletics games, most of which are indeed based on the same visual mechanism.

4.5.2 Aesthetics

Like tunnel run, users of HVS were mostly already familiar with the gas masks, and indeed with both those games. In total, 12 participants played HVS (with the maximum five players competing simultaneously). Most races took place between just two or three players, it is even possible to play the game as a single player and try to beat one's own records. Unlike the other games, HVS used a high score system akin to those of old arcade games, because we wanted to have that feel of 'record holding' that is common to both real athletics and nostalgic arcade games.

HVS is without a doubt the most physical of the games we have developed. It is perhaps appropriately named. We had to be careful with durations of races to ensure players did not actually start to hyperventilate, though we were aware that people are unlikely to do so, tending to break off from breathing fast as soon as they start to feel light headed. A sense of physical discomfort is common to all three of the games controlled exclusively by breath, but players of HSV showed this more than in others:

"I feel like I really have just run 100 meters!"

- a sentiment echoed by many of the players.

The power meter proved something of a stumbling block. It was challenging to explain to players the way the score was calculated from both volume and frequency.

"I know I'm breathing faster than [player] - why does he keep winning?"

It was frustrating to the players that something with a particular affordance: faster breathing = faster running, should actually not map in that way.

4.5.3 Discussion

HVS is a very different type of game to the others described here. It is very fast paced, explosively energetic and physically tiring. The trials served to highlight an issue with players' mental mapping of the interface, and though the power meter helped to mediate the race times there remains some question about whether it would have been more appropriate to simply determine the power level from frequency. It does appear however that while some people are able to breathe significantly faster and shallower than others, the addition of volume to the mix seems to be something of an equalizer, which leads to more exciting races. This of course leads to the question if a physical ability should allow a player to excel in a simulation game, in the same way some people excel in the actual sport because of physicality.

5. DISCUSSION

Through the construction and deployment of the five proto games discussed, this paper has demonstrated several levels at which breathing can form an interface, or part of an interface to a game experience. In the case of PerPing, Tunnel Run and Hyperventilation Sports the breathing forms an exclusive control mechanism. In Sneak-Em-Up, the breathing forms a secondary interface along with the primary keyboard controls, while in Serious Sam, the breathing forms an ancillary or ambient interface: not directly required to control the game, but adding to the experience by making the central character respond to a player's own physical state. Each of these levels creates a different and experience for a player. The ancillary interface in particular forms an interesting relationship between the player and their character, increasing the sense of involvement in the game and helping to reduce gaming detachment.

In Sneak-Em-Up, the breathing takes on an equivalent control level to the more traditional keyboard controls. This mixing of new and old control paradigms is familiar to anybody playing the current crop of gesture based games such as those on the Nintendo Wii or Playstation Move, both of which use a relatively new form of interaction (gesture) coupled with more familiar button/joystick based controls. Breathing however, unlike gesture is not something over which we have complete and perfect control, since we must all breathe at some stage, even if we are controlling our breathing as part of a game, we may inadvertently lose control of it in stressful situations, something which is more explicitly demonstrated by the remaining three games.

In the cases where breathing is the only control mechanism, we see both the benefits of breath for control and the limitations. The very fact there is a game to play implies an inability to maintain perfect control over our breathing, otherwise games would run indefinitely. This is fundamentally similar to any other game interface: players by necessity cannot perfectly control any system or games would prevent no challenge. Breathing is no different in this respect, however the effect is somewhat exaggerated. Tunnel run in particular demonstrated just how challenging it is to perfectly control one's breathing for any sustained period. HVS highlighted another associated issue: the pure physicality and indeed the physical limits of breathing. To breathe competitively for any sustained period causes the body to respond uncomfortably, indeed playing such an intense breathing controlled game for anything longer than a few seconds could actually be physically harmful. The optimal level of control vs sustained high speed breathing, at least as far as the games explored here are concerned is probably demonstrated in PerPing, in which players do have to be accurate (to hit the ball) and as the game increases in pace, have to react and thus breathe quickly. It also provides for the physical excitement of fast breathing (demonstrated in HVS) with the ball-splitting mechanic.

One might consider breathing, prima facie, to be a one dimensional interface. Like a digital button it is either on or off. Actually it may be more like a three way switch (breathing in, breathing out, and holding breath). If we then add the fact that it is analogue, based on breath flow we may consider it to be like a slider – many positions in which it can be along a one dimensional line but ultimately a single value at sample time. However we have demonstrated in these games that breath can provide an additional dimension of control based on frequency. Of course frequency is fundamentally intertwined with the other values, so it cannot be simply thought of like a more familiar two dimensional input such as a joystick. Similarly, the input value cannot stay in one place for very long – we cannot maintain the process of breathing in/out or holding our breath for any more than very short periods of time. All this makes for an intriguing and somewhat unique input dimension. In the games described, we have shown some ways in which this unique controller can be applied, but it is reasonable to assume there may be many more.

The gas masks as a gaming peripheral have proved an interesting experience in their own right, quite apart from the actual process of breath measurement. It is fairly obvious that wearing a gas mask is a somewhat cumbersome addition to a player's gaming set up. Though in some cases, such as Sneak-Em-Up and Serious Sam, the players engaged with the gas masks as a part of the overall experience, in the same way most people do not dress up to play their games, this is unlikely to be suitable for anything other than public events. While the gas masks provide an extremely accurate breath flow reading, it is possible to achieve similar results with more lightweight techniques. Chest expansion systems can give fairly accurate breathing information, and are a less intrusive peripheral, similarly a head mounted microphone, such as those popular with regular players of multiplayer online games can be used to track breathing information. Like most technology, the principle is demonstrated using effective but somewhat cumbersome approaches, and then may be simplified to make a feasible and affordable consumer peripheral. Breath control need not stay the exclusive province of research and public events in much the same way as gesture control has become increasingly available to mainstream consumers.

6. CONCLUSION

This paper has demonstrated that breathing is a viable, interesting and fun control method for gaming. The aesthetics and sensing functionality of our gas mask-based gaming peripheral combine to make a striking and challenging input device. Even some fundamental concerns with the interface such as eye pieces fogging up can be seen as part of the 'game experience', particularly if the context of the game supports them (such as the race against time that fogging encouraged in 'Sneak em up').

The five games described here demonstrate that breathing may be used at several levels of an interface – both as an exclusive control method (PerPing, Tunnel Run, HVS), and in combination with traditional interfaces as either a key part of the game control (Sneak-em-up), or as an additional 'ambient' element linking the player's physical state to the game (Serious Sam).

These games demonstrate the challenges of using breath control as a medium: breathing does not map directly as a replacement for any other control type. It is however, a new and exciting addition to the growing arsenal of interfaces available to modern games designers.

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