Bated Breath - Feasibility of a Respiration-based Biofeedback System in Affective Horror Experiences

How is the player experience in the survival horror game Maid of Sker affected by replacing the button-held breathing mechanic used to avoid enemies with real-life breath-holding?

Medialogy Master Thesis, Interaction Specialization

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Abstract:

Inspired by recent findings in Affective Gaming and Recreational Fear, this study investigated the feasibility of using a respiration belt to create an affective horror experience by replacing the button-held breathing mechanic used to avoid the blind, but sound-sensitive enemies in the commercially available survival horror game; Maid of Sker, with real-life breath-holding.
A between-subjects experiment with 20 voluntary participants was conducted with breath controls as independent variables. Players in the control condition held their breath in-game using Z keypress, whereas players in the experimental condition held their breath in real-life, as determined by a binary predictor algorithm fed by a respiration belt. Players navigated a linear level while their GSR response was recorded, then filled out a self-report questionnaire evaluating their playing experience in regard to enjoyment, fear and presence. While the breath-based control interface proved feasible, no significant difference was seen in the player experience factors between groups. Despite this, the future for breath-based biofeedback in commercial horror looks promising, with indications of it being more intuitive than keyboard controls, having a calming effect on fear, ease-of-use issues increasing fear response due to reduced agency, over-sensitized fear resulting in enjoyment, and game familiarity affecting fear response to a lesser extent than horror familiarity.

Preface

This master's thesis has been written to fulfil the graduation requirements of the Medialogy master's education at Aalborg University, Copenhagen campus. The developed software and experiment were produced in collaboration with Thomas Terkildsen from Aarhus University's Recreational Fear Lab.

If I had been told upon starting my bachelor's degree in Medialogy, that I would be doing my thesis on a psychophysiological novel interaction interface for a horror game of all things, then I would have questioned yours, and my own sanity.
Yet here I stand, five and a half years later, despite having two publications under my belt, this paper on that exact unexpected interdisciplinary subject represents my academic magnum opus.
I have poured countless sleepless nights, chocolate-chipped cookies, and energy drinks into understanding the underpinnings of our emotions and the allure of horror...-Two subjects that I previously had absolutely no interest in. - Especially horror, where Mathias Clasen's incredible book Why Horror Seduces helped me understand and, while not fully conquering my fears, has made me more resilient to the psychological effects of my arachno-and-acrophobia.
In this regard, a colossal thank you to Mathias Clasen and Thomas Terkildsen from The Recreational Fear Lab in Aarhus, and their Apex of Fear project, which ignited my passion in horror and, for better or worse, drowned out all other project candidates. I hope that the knowledge contained in this paper can inspire more students and researchers to take a leap of faith into the unknown to explore the daunting, at times scary, but utterly fascinating field of recreational fear.

All appendix material is available in the attached Supplementary folder. The folder's depth-level is structured so that:

A = Game investigations PDF, describing how each investigated game fulfilled the 3 design criteria.
B = Sub-folder containing the two scripts described in section 6.
C = Sub-folder containing evaluation & raw results.
- C.1 = Consent form.
- C.2 = Moderator guide.
- C.3 = Pre-session questionnaire results.
- C.4 = Post-session questionnaire results.
D = Boxplots
E = Statistics (Levene, T-test, Correlations)

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Bated Breath - Feasibility of a Respiration-based Biofeedback System in Affective Horror Experiences

***Index Terms*—Psychophysiology, Horror, Respiration, Biofeedback, Novel Interaction, Enjoyment, Fear, Presence, GSR, Games Research, Thesis**

1. Motivation

As a person suffering from severe arachnophobia and to some degree acrophobia, I have always shunned horror. Because what enjoyment can be found in a media that inherently exploits our deepest fears and triggers negative emotions to scare us, keep us up at night, and at times traumatize us?

By a most peculiar happenstance, I stumbled upon a research study [Recreational Fear Lab, a] shared by a colleague, which investigated just that, in a most curious field called Recreational Fear [Andersen et al., 2020]. This study was conceived to enhance the user experience of virtual reality horror through affective computing, that is creating an adaptive horror simulation tailored to your subjective psychophysiological reactions.

In an almost Lovecraftian manner, I felt drawn to this occult prospect and reached out to the horror researchers behind the study. After an introductory meeting, they invited me to a virtual workshop on recreational fear [Recreational Fear Lab, b], and provided me with a book: *Why Horror Seduces* [Clasen, 2017], which completely changed my view on the subject. Following several lengthy discussions about the state of this new research field that probes the relationships between enjoyment and fear, it was found that very few studies currently exist on this subject.

Seeing an opportunity to investigate this newfound fascination with the underlying mechanisms of fear using the medialogist toolbox, I began research in earnest to find the perfect academic research gap to work with.

2. Introduction

Video games began as a niche hobby in the 1960s, but have since matured into one of the most popular leisure activities of the modern era, grossing over $150 billion [Saucier, 2022], [Ivory, 2015]. Since then, the format has seen numerous paradigm shifts as developers keep pushing the boundaries for what is possible in terms of technological advancements, game design frameworks, and innovative new approaches to digital play [Saucier, 2022], [Ivory, 2015], [Zackariasson and Wilson, 2010], [Robinson, 2022].

One such advancement was Virtual Reality (VR), which enabled full visual, auditory, and to some degree, haptic stimulation, providing users with a new standard of immersion [Robinson, 2022], [Suh and Prophet, 2018]. With virtual experiences now capable of stimulating our senses to an extent where we can hardly tell the difference between real and virtual [Suh and Prophet, 2018], researchers and developers look toward Affective Gaming (AG) [Robinson, 2022], [Gilleade et al., 2005], [Gilleade and Dix, 2004].

In AG, physiological self-tracking technologies are integrated into digital games to adapt the experience to the individual's emotional state in order to create more dynamic and personalized experiences. Examples include; using the physiological data as a control input, projecting it back to the player as visual or auditory feedback, and mapping it to player actions or game mechanics. According to a recent literature review on the subject [Robinson, 2022], AG research that utilizes physiological sensors to modify how we interact with a given game, is still in its infancy. The review found 162 valid scientific papers, with very few formal evaluations or attempts at replication and a lack of established research frameworks.

It concluded that when implemented properly, AG enhances the play experience by significantly increasing player engagement and immersion [Robinson, 2022], which aligns with previous research [Navarro et al., 2021].

From literature searches in Google Scholar [Google, b], Scopus [Elsevier,], and Aalborg University Library [Aalborg University,], combined with sources from the aforementioned literature review [Robinson, 2022], it was discovered that both the horror genre and physiological sensing of breath were popular topics in affective research. Horror, likely owing to its aptitude for provoking intense emotional responses [Potter and Bolls, 2012], [Clasen, 2017].

Breathing in particular was used in 48 of the 162 included studies [Robinson, 2022]. Mostly for making rehabilitation more enjoyable, such as controlling a plane or fish during breathing exercises [Lange et al., 2009], [Sonne et al., 2017], but also when mapped to aiming fluctuations in a shooting game [Tennent et al., 2011]. Despite their popularity, not a single study was found that investigated breath in the paradoxically enjoyable but vulnerable setting of horror.

As to why we should not neglect the horror genre in this transition toward affective media, research shows that it has positive effects on our mental health in that it provides an outlet for negative emotions, helps us cope with psychological distress and makes us more resilient in extreme situations like the COVID-19 pandemic [Scrivner et al., 2022], [Scrivner and Christensen, 2021], [Scrivner et al., 2021]. Games and in particular VR games immerse us in the experience, leading to more efficient treatment opportunities like exposure therapy against anxiety [NinjaTheory,], [Lacey et al., 2022].

With this in mind, 7 horror games were investigated to determine the feasibility of integrating a breath-based control interface [Flying Mollusk,], [Gattai Games,], [Frictional Games,], [Red Barrels,], [Kojima Productions,], [Feral Interactive,], [Wales Interactive,] and the survival horror title *Maid of Sker* (MoS) was chosen.

In MoS, players are required to hold their breath in-game to avoid capture by the blind, but sound-sensitive monsters inhabiting the game world, which intuitively reflects the real-world action of holding your breath [Wales Interactive,], [IndieGameReviewer,], [JumpDashRoll,], [Nacke et al., 2011]. Hence this paper raises the following research question:

"How is the player experience in the survival horror game Maid of Sker affected by replacing the button-held breathing mechanic used to avoid enemies with real-life breath holding?"

The original contributions of this work can be summarized as follows:

- Insight into how breath-controlled physiological input can be used to create an affective horror experience and how it affects player enjoyment, fear, and presence.
- Novel Python application for detecting and mapping breathing thresholds to hotkeys.

The remainder of this paper is as follows: First, research leading up to the study is presented in section 3, including a definition of recreational fear, why negative stimulation emotionally draws us to horror media, the underlying processes of emotion, and how we can measure player experience factors. The methodological considerations for the experimental design are presented in section 4. Software and hardware decisions in section 5 and technical decisions in section 6. The experiment is described in section 7, with results presented in section 8. Key findings are outlined in section 9 and discussed in section 10. Future works are presented in section 11 and the study is summarized in section 12.

3. BACKGROUND

To probe the research question, we require a fundamental understanding of the connection between the negative emotions of fear and the enjoyable multimedia experience of horror.

A. *Recreational Fear*

From the comfort of our relatively safe everyday life, we primarily experience fear by actively seeking it out. Be it in the movie theatre, in front of the TV or computer monitor, inside a haunted carnival attraction, or when reading horror fiction. These examples can be categorized as recreational fear activities, since they were created by humans to provide enjoyment by stimulating negatively valenced emotions related to fear [Clasen, 2017]. Two studies on horror preference [Johansen, 2013], [Clasen et al., 2017], both saw indications that people enjoy being scared by fiction. This is further supported by how horror is advertised, with the fear factor frequently used as an explicit selling point and stamp of approval.

For example, the trailer for Paranormal Activity [Peli,], had shots alternating between scenes from the film and audience reactions showing visible fear responses, such as covering their eyes, laughing nervously, and screaming. The scenes were inter-spaced with review snippets such as ‘Paranormal Activity is one of the scariest movies of all times’ and ‘genuinely horrifying’ [Clasen, 2017].

1) Evolutionary Fear Mechanisms

Horror relies on the ancient, inherited defence mechanisms of the Evolved Fear System (EFS) [Öhman and Mineka, 2001], which elicit negative emotions to protect us from harm and motivate us to steer clear of danger. While today, we may see negative emotions like fear, anxiety, dread, and disgust as unpleasant feelings that prevent us from engaging in certain life activities, we would not have been alive today without them. In ancient times, these emotions protected us from predators, invisible toxins, within-species hostilities, social exclusion, and environmental hazards such as steep cliffs and deep water [Clasen, 2017], [Gurven, 2013].

For example, system selectivity makes us react fearfully towards stimuli based on primal dangers like spiders, snakes, and heights, while hypersensitivity to cues indicating danger makes us anxious when encountering things like shadows or unusual noises, which are perceived as malicious agents [Clasen, 2017], [Öhman and Mineka, 2001].
The logic underlying this reaction is the aphorism ’Better safe than sorry’, since it is preferable to react fearfully towards cues indicating danger than ignoring it. When these mechanisms are triggered as a result of fear-induced stimuli, the Sympathetic Nervous System (SPNS) activates in anticipation of the perceived threat, resulting in increased sweat production to reinforce grasping behaviour [Clasen, 2017], [Potter and Bolls, 2012].

2) Modern Fear Modulation

To prevent us from jumping at every cue that might indicate a threat, we have developed a Fear Modulation Module (FMM), which enables assessment of cues to determine the appropriate fear response. Hence we can often rationally override aversive impulses, which allow us to interact with predators, step onto a skybridge, jump off a cliffside into deep water, and more. The FMM is, however, limited in its ability to accurately modulate and control the EFS, resulting in a constant struggle between primal emotional prompts and rationalized decision-making [Clasen, 2017].

3) Lure of Horror Fiction

Horror media is designed to provide enjoyment by evoking sensitized negative emotions. It achieves this by engaging us in fiction; Recognizable universes that anchor us in the form of one or more humanoid characters, like controllable avatars in video games, from whose perspective we experience the unfolding narrative.
This usually involves dangerous situations that exploit the EFS and bypass the FMM, such as monsters that exploit prepared fears with supernormal additions, like giant mutated spiders, walking decomposed corpses or clowns with claws for hands [Clasen, 2017].
This engagement enables the ability to project ourselves into the virtual world to establish stronger emotional bonds with the fate of its inhabitants.

Horror examples include mirroring Danny's fear in The Shining [Kubrick,], feeling sympathy for the demonic possessed Regan in The Exorcist [Friedkin,], and anxiously watching Starling investigate a dark building in Silence of the Lambs [Demme,]. These scenes trigger fear responses by targeting the EFS and short-circuiting the FMM. *"Horror fiction, (..) works by throwing a live wire into ancient structures in the audience's central nervous system. It captures and holds our attention by engaging the fear system, which, when we are immersed, does not really care that it's fiction, make-believe, and illusory sleights-of-hand."* [Clasen, 2017, p. 29]. Rationally, we know it is fiction, which typically makes us react to a lesser extent, yet sometimes real effort is required to control the EFS. Failing to do so, results in numerous examples of audience members becoming overwhelmed by the fear response and fainting, assaulting the screen or fleeing. This is why psychologists use horror media when studying emotion since it produces the strongest, genuine, emotional responses [Clasen, 2017], [Mellmann,].

4) Horror Games: Face Your Fears

In traditional movies and literature, we are merely present as passive observers, with no influence on the unfolding narrative. However, in video games we become an active part of the fiction with an agency to, within the rules of the specific game, act directly and indirectly upon the virtual reality and face the consequences of our actions. This allows us to experience high-intensity emotional and cognitive stimulation, which is further reinforced by the personification of acting in the form of one or more player-controlled virtual avatars that enable stronger emotional attachment [Clasen, 2017]. In survival horror games, we typically embody the role of a humanoid character who has to escape an enclosed virtual setting such as a castle, forest, or island, by solving puzzles, destroying or evading monsters [Kirkland, 2009].

In this regard, we unconsciously engage with the game as mental play behaviour, in that we use the low-risk and low-cost virtual environment to simulate how we would act in a given scenario and whether or not our course of action would lead to surviving, or even overcoming the presented threat [Clasen, 2017].

Applying this to a popular survival horror game, Amnesia: Dark Descent [Frictional Games,], where players take on the role of an amnesiac named Daniel. The player is not provided with any means of defence and has to avoid the humanoid monsters wandering the dimly lit corridors of a medieval castle by hiding in select locations. Daniel further suffers from psychosis, in that the game's visuals distort whenever he experiences something horrifying or disturbing like looking at a monster or finding a corpse, as seen below in fig. 1. This condition is projected to the player by gradually worsening visual and auditory physiological feedback, such as Daniel's heartbeat and breathing accelerating, which reflects fear-induced perceptual and physiological changes. Supplementing this with the monsters' singular motivation of hunting the player down, using their supernormal predatory qualities like large claws and gaping fanged maws, which prompt the player to navigate carefully, since lacking awareness of potential hiding spots can quickly result in death.

Fig. 1: *Screenshot from Amnesia [Frictional Games,], showing distorting visuals as Daniel engages with an enemy.*

This all blends into a scenario that perfectly resonates with our fear system: We are being hunted by supernormal predators while navigating dangerous, unfamiliar, dark environments, relying on caution and cunning to survive [Clasen and Christiansen, 2016], [Clasen, 2017], [Frictional Games,].

B. *Fear, Enjoyment and Presence*

Keeping this relationship between exploitative evolutionary fear mechanisms and horror as a simulation that promotes enjoyable mental play behaviour in mind. This subsection explores how recent studies have looked at player experience factors in recreational fear activities.

While fear has been extensively researched due to its significant relevance to our psychological health [Öhman and Mineka, 2001], research into fear as an enjoyable activity; Pleasure derived from playful engagement with fear-inducing situations, is a relatively unexplored field [Andersen et al., 2020]. A recent study [Andersen et al., 2020], discovered an inverted U-shaped relationship between self-reported fear and enjoyment, indicating that under-and-over-sensitization of fear resulted in gradual declines of enjoyment during haunted house (haunts) experiences. Linear relations were also found for large-scale heart-rate fluctuations and fear, as well as small-scale fluctuations and enjoyment.

Another recent study [Terkildsen and Makransky, 2019], found that presence could be reliably measured by counting the number of arousing events per minute, determined by a Galvanic Skin Response (GSR) sensor as amplitude peaks. Presence in this context consists of three sub-dimensions; Spatial, Social and Self-Presence. Together, they provide the subjective sensation of 'being there' in mediated content, to the degree where it feels like the Virtual Environment (VE) is the dominant reality [Barfield and Zeltzer, 1995], [IJsselsteijn et al., 2000], [Lee, 2004]. Social presence represents the psychological state of interacting with virtual agents, as if they were real people rather than blocks of code [Lee, 2004]. Self-Presence refers to the player's self-embodiment with their virtual avatar as if it was part of them, reacting as though game events happened to them, and not an expendable avatar [Tamborini and Skalski, 2006], [Kilteni et al., 2012]. Spatial presence describes the feeling of being physically located in the VE, including being attentive toward it and interacting with objects as if they were real, whilst ignoring external stimuli [Slater, 2002], [Fontaine, 1992]. The degree of overall presence is influenced by increasing sensory vividness; Breadth and depth of stimulated sensory channels and interactivity; The user's ability to influence the VE [Tamborini and Bowman, 2009]. Hence presence can be defined as a combination of technological and psychological factors that results in a perceptual state where the player feels as if the VE is their currently dominant reality on a spatial, social, and self-presence level [Terkildsen and Makransky, 2019].

C. *Psychophysiology of Emotions*

Psychophysiological techniques like GSR and Respiration are used to understand, measure and analyse the relationship between psychological processes; such as fear impulses and accompanying physiological reactions; increased sweat generation. Insight into these relationships allows us to accurately index conscious and unconscious mental processes as they occur in real-time, for example in response to media exposure [Potter and Bolls, 2012], [Stern et al., 2000]. To understand which, and how mental processes are engaged, researchers record electrical signals; biopotentials, at the skin's surface, using electrical equipment that is either directly attached to the subject's body, or records bodily reactions from a distance, like a camera for discrete emotions [Potter and Bolls, 2012]. These biopotentials correspond to activity in one or more nervous system clusters. For example, Electroencephalography can be used to record the activity of different brain areas [Potter and Bolls, 2012].

For this particular study, the clusters of interest are the Somatic Nervous System (SNS) and Autonomic Nervous System (ANS). SNS is responsible for voluntary bodily functions like movement control, and ANS is responsible for involuntary bodily functions, like organs and glands. The ANS is further divided into two subsystems; The sympathetic Nervous System (SPNS) and Parasympathetic Nervous System (PNS). SPNS is associated with arousal and prompts our body to act in the 4 Fs; 'Fight, flight, fright and sex', which can result in increased heart and lung activity at the cost of decreased digestion, since it is not deemed vital in those scenarios. Meanwhile, PNS is associated with relaxation; 'Rest, repair, and enjoyment', by slowing down our heart and lungs to increase digestion [Potter and Bolls, 2012], [Stern et al., 2000].

1) Dimensions of Emotion

These systems are closely intertwined with our emotional states, which represent temporally fleeting impulses with either a positive (Attractive) or negative (Aversive) reaction toward a specific point of interest. To study emotion, researchers used to rely on discrete facial expressions, representing each emotional state, but this was proven unreliable since facial expressions have variations from person to person [Larsen et al., 2002], [Potter and Bolls, 2012]. Instead, researchers turned to a dimensional approach, where variations in the bi-directional relationship between valence; Ranges from pleasant to unpleasant emotional responses, and arousal; Intensity of emotional response, during media exposure to better index and determine moment-to-moment emotional changes [Potter and Bolls, 2012], [Stern et al., 2000], [Cacioppo and Gardner, 1999].

While we may be consciously aware of our emotions to some degree, this only covers the surface layer, as much of our brain activity, including emotional processes, occur with little to no consciousness in the CNS and PNS. This explains why we mostly obtain insight into conscious emotional processes when using self-report questionnaires, rather than the subconscious processes hidden below the explicit responses elicited in those methodologies [Potter and Bolls, 2012], [LeDoux, 1995]. therefore it is advised to include emotional data from at least two out of three categories: Physiological, Verbal and Behavioural [Potter and Bolls, 2012], [Larsen et al., 2002].

2) Galvanic Skin Response

Our skin reveals a lot about the emotional processes underlying our emotional arousal when exposed to stimuli such as pictures, music, films, and video games [Potter and Bolls, 2012]. Galvanic Skin Response (GSR) is used to measure physiological arousal in the form of tonic (TR) and phasic (PR) SPNS responses by recording electrical activity that varies according to skin properties. TR represents the overall arousal effect of the consumed media, typically seen as a deviation from the baseline control recorded before the experiment. PR represents the moment-to-moment arousal differences, seen as response to individual stimulus [Potter and Bolls, 2012], [iMotions, a].

3) Respiration

Our respiratory system is an autonomic and voluntary bodily function responsible for supplying the body with oxygen. The autonomic component consists of self-regulated inhalation and exhalation feedback loops. This process is overridden whenever we voluntarily decide to hold our breath, for example when preparing to dive underwater or hide from a predator. When this happens, we cut off our oxygen supply, which prompts SPNS activation and sets our body on high alert until the flow of oxygen resumes [Cacioppo et al., 2007].

*D. **Summary and Hypotheses***

Despite the growth of AG research, it seems that no studies could be found that investigated breath as a control interface in horror games. After probing the research question, it was found that recreational fear activities function as mental play behaviour that exploits the FMM to trigger SPNS activation. This results in sensitized negatively valenced conscious and unconscious emotions, that arouse us and provide an enjoyable experience as we face off against plausible and implausible threats in a safe context. We remain in this enjoyable state until the fear stimuli oversensitizes, at which point the EFS overloads and the experience becomes unenjoyable.

Based on this proposed theoretical relationship between fear, enjoyment and presence in affective horror games, the following hypotheses were formed to answer the research question stated in section 2.

H1: The experimental condition (Real-life breathing) will have a significantly more arousing experience as measured by both GSR peaks/min (H1a) and the self-reported player experience factors of enjoyment, fear, and presence (H1b) than the control condition (Keyboard & mouse).

This is proposed on the assumption that an interface which intuitively reflects the real-world action of holding your breath, reinforces the virtual environment as the dominant reality, which prompts more emotional investment.

H2: The relationship between GSR peaks/min and presence established in the paper *Measuring Presence in Video Games* [Terkildsen and Makransky, 2019], can be reproduced in this study by correlating the GSR peaks/min and MPS scores.

4. Methodology

Due to both recreational fear and affective gaming being relatively new fields of research, a pragmatic deductive approach inspired by [Andersen et al., 2020], [Terkildsen and Makransky, 2019] was used to probe the research question stated in section 2. This was achieved by investigating the proposed hypotheses to see if the established relationships between player experience factors of enjoyment, fear, and presence work in survival horror gameplay with biofeedback control [Phair and Warren,].

A. *Experimental Design*

To address these hypotheses, 20 healthy adults (11 men, 8 women, 1 other, age (Mean:30.8, Standard Deviation:10.8) were recruited from a European university through convenience sampling via its social media channels using the recruitment poster seen in fig. 2.

Fig. 2: *Poster shared via SoME to recruit.*

The participants consisted of students and staff, all of whom were proficient in English and had provided written informed consent via the form seen in appendix C.1, prior to participation.

A between-subjects experimental design with two groups, control and experimental, was used in which all participants were tasked with making their way through a specific segment of the game stimulus, elaborated upon in section 5. The control interface used to manage the game's breath-based hiding mechanic served as the independent variable. This was used to investigate how manipulation of the independent variable would affect the dependent player experience variables of enjoyment, fear, and presence pooled from the investigated studies [Andersen et al., 2020], [Terkildsen and Makransky, 2019].

In the control group, participants held their breath in-game by holding the Z key, whereas participants in the experimental group had to physically hold their breath, measured by a Go Direct Respiration Belt [Vernier,]. Participants played through the same linear game segment and were randomly assigned a condition, except when the gender imbalance exceeded 2 participants, in which case the subject was assigned to the underrepresented condition.

After gameplay, all participants filled out a post-study questionnaire containing questions inspired by [Andersen et al., 2020], [Terkildsen and Makransky, 2019], which were divided into 4 categories:

- **Enjoyment & Fear**: Self-reported general enjoyment and fear (10-point Likert scale) [Andersen et al., 2020].
- **Usability**: Ease-of-use questions regarding the breathing controls (10-point Likert scale ranging from 'strongly disagree' to 'strongly agree').
- **SAM**: Self-Assessment Manikin (SAM), used to evaluate emotional arousal and emotional control using the non-verbal pictorial assessment instrument (9-point Likert scale ranging from 'calm' to 'intense' and 'no control' to 'full control') [Bradley and Lang, 1994], [Terkildsen and Makransky, 2019].
- **MPS**: Multimodal Presence Scale (MPS), used to measure the spatial, social and self-presence sub-dimensions using five specific items for each dimension (5-point Likert scale ranging from 'strongly disagree' to 'strongly agree') [Makransky et al., 2017].

The rationale behind using a combination of these 4 rating scales boils down to the complexity of conscious and unconscious emotions previously observed when dealing with horror media and to investigate whether the established theory can be used for this type of horror game.

*B. **Summary***

This section outlined the methodological decisions required to conduct an experiment capable of answering the research question stated in section 2. In essence, a between-subjects experiment with 2 conditions (keyboard versus real-life breathing) was decided for using a pragmatic deductive approach to investigate the player experience factors of enjoyment, fear, and presence using a modified scale inspired by [Andersen et al., 2020], [Terkildsen and Makransky, 2019].

5. Design

The prototype design followed the affective game loop classification framework proposed in [Robinson, 2022], which simplified how the breath-based biofeedback would influence both players and the game stimulus by representing each aspect of the experience individually as part of an iterative process:

- **Physiological Input** collected from the player through physiological sensing devices.
- **Physiological Projection** of collected physiological data displayed to the player as real-time visual, auditory or haptic data which affects their experience but has no direct gameplay impact.
- **Input Mapping** of physiological input to an in-game element as either action-focused; affecting game mechanics or context-focused; influencing the gameworld by adjusting difficulty or environmental factors.
- **Game Feedback** received by the player from the game as a response to their physiological input.

*A. **Game Stimulus***

The 7 commercially available horror games from the introduction were judged based on
A) How long players would be expected to hold their breath to efficiently replace or supplement a gameplay mechanic.
B) How punishing it would be if players resumed breathing early.
C) How well the replaced mechanic would mirror the real-world action of holding your breath.
Maid of Sker [Wales Interactive,] fulfilled the three criteria most sufficiently and was thus chosen as game stimulus. Fulfilment of these criteria can be seen in appendix A.

1) Maid of Sker Gameplay

Maid of Sker (MoS) is a 2020 horror game by Wales Interactive who describes it as:
"a first-person survival horror, set in a remote hotel with a gory and macabre history from British folklore. Brave the nightmares of the Quiet Ones. Do not panic...don't even breathe!"
[Wales Interactive,]. MoS is rather unique in that all of the game's enemies were blinded due to their masks, so they relied entirely on sound generated by footsteps and breathing. Players could hold their breath by holding down the Z key on their keyboard to put the in-game avatar's hands over their mouth, which greatly decreased the sound they made, allowing them to sneak past enemies as seen in fig. 3. However, the player could only hold their breath for a total of 18 seconds, during which they were provided with visual and auditory cues such as darkening vision and louder heartbeats.

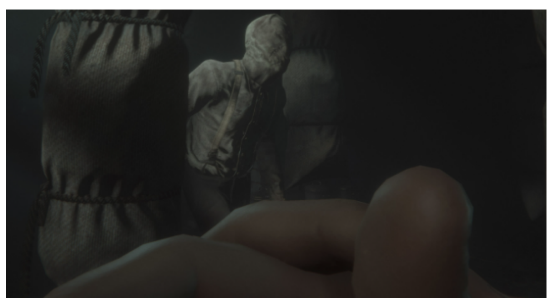

Fig. 3: *Screenshot from MoS [Wales Interactive,], showing both the blind enemy and breath-holding mechanic.*

If players held their breath for the full duration, their avatar exhaled loudly and was unable to hold their breath for 10 seconds. The sound-based AI moved toward sound sources and if the player was discovered, then they would lash out at them with their claws.

At this point, the player could run away to hide and hold their breath which threw enemies off their trail. This sympathy mechanic ensured that players were not punished too harshly when discovered, provided that they reacted quickly and paid attention to potential hiding spots. MoS was decided as the optimal candidate for game stimulus due to its short breath-holding limit of 18 seconds, its forgiving gameplay loop that enabled participants to potentially make several mistakes without dying and its authenticity of mirroring the real-world act of holding your breath.

2) Breath-based Control Interface

As seen in fig. 4, the breathing interface was designed to enhance the intimate experience of playing a horror game, by restricting the player from their most base function: Breathing.

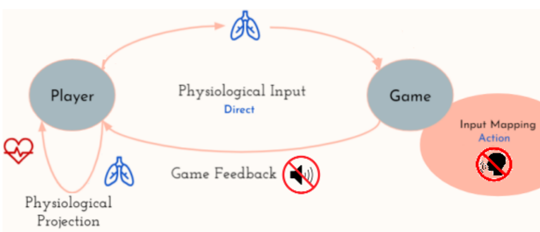

Fig. 4: *Affective Game Loop Framework [Robinson, 2022], adapted to fit the physiological sensing and game stimulus used in this study.*

In the case of MoS, this directly controlled input closely mirrored the bodily activity involved with hiding from predators and aligned with the mechanical feeling of the avatar in the provided situation. Players provided physiological input by holding their breath. This triggered the input-mapped action of holding down Z, which made the in-game avatar hold their breath by moving their hands over their mouth as seen in fig. 3.
This resulted in the player's breathing being muffled, which was indicated by a brief inhalation audio cue, followed by gradually more intense visual and auditory physiological projections until they resumed breathing or 18 seconds had passed, at which point the avatar automatically exhaled.

3) Gameplay Segment

The garden area seen below in fig. 5 is one of the earlier stages in MoS. This particular area was chosen due to its forgiving difficulty and linearity, ensuring that all players would get a similar experience.

Fig. 5: *Level overview of the garden segment. Green: Optimal path. Red: Restricted areas. Orange: Device used to proceed. Yellow: Levers(X) used to open gate(O). Gramophones: Savepoints.*

The level consisted of a hedge-maze with 3 patrolling enemies that players had to navigate, followed by a walking segment until players reached the orange star. At that point, they picked up a device that they used once in that particular room to stun enemies. Players then reached a checkpoint, followed by an exposed garden area where they had to activate two switches marked by a yellow X, one at a time. Initially, there is only one enemy in this area, but each lever activated triggered 2 additional patrolling enemies. After activating a switch, players interacted with the panel at the garden exit marked by a yellow O, which removed one of the two locks on the door. Players then activated the second lever which triggered the door opening and a scripted event where all enemies chased the player until they reached the hotel entrance, located approximately 10 seconds of running from the garden door.

B. Summary

Decisions related to the prototype design were described in this section, including why Maid of Sker was chosen as the game stimulus, how the breath-based biofeedback would be integrated as seen in fig. 4, and a description of the game segment that will be used in the experiment as seen in fig. 5.

6. Implementation

This section elaborates upon the technical details of the experimental design described in section 4, and the development of a predictor algorithm used to simulate breath-holding in the game stimulus described in section 5.

A. Experimental Setup

The iMotions control hub was used as a staging ground for the different test phases: GSR calibration, Intro-survey, Breath calibration, Gameplay, and Post-survey. iMotions was chosen due to its compatibility with both the PLUX GSR sensor [BioSignalsPlux,] and Go Direct Respiration Belt [Vernier,]. While the belt worked natively with iMotions, the GSR sensor could only be read by the accompanying PLUX OpenSignals software [Pluxbiosignals,], from which the GSR readings were streamed in real-time to iMotions. The iMotions hub also provided live filtered visuals, to ensure that the sensors were working properly without interference, and made it possible to view sensor data segmented into each test phase. This meant that the researcher did not have to worry about when to start and stop the sensor recordings, since only the sensor readings from the gameplay segment itself were extracted and used for data analysis. The entire test took place on one computer using split-screen, with the iMotions hub being present on the researcher's monitor, hidden behind the curtains seen in fig. 9, while the survey and game stimulus was shown on the participant's monitor when the accompanying stages were initiated in the iMotions hub.

1) GSR

GSR measurements were obtained using a PLUX sensor recording electrodermal activity at a sampling rate of 100 Hz through bipolar Ag/AgCI electrodes. The sensors were placed with an inter-electrode distance of approximately 4 centimetres on each subject's left palm to avoid interference from movement or keyboard presses during gameplay, as seen in fig. 6(a) [Dooren et al., 2012].

(a) GSR placement (b) RESP placement

Fig. 6: *Physiological sensors used in the study.*

GSR peaks were calculated using the peak detection algorithm described in [Terkildsen and Makransky, 2019], which applied a sliding window median filter [-4s; +4s] to the raw signal so that the phasic data could be extracted from the underlying tonic signal. A low-pass filter of 5 Hz was then applied to remove line noise and peaks were defined by identifying onsets (>0.01 microsiemens(uS)) and offsets (<0 uS). The maximum amplitude in a given region was defined as a peak when above the amplitude threshold of 0.005 uS above the GSR onset value. A signal jump threshold of 0.01 uS was used to reject false positive peaks as a result of sudden data spikes, such as movement artefacts.

After running the peak detection algorithm, the number of peaks for all 20 participants was divided by the time they spent playing to produce the GSR peaks/min-measure [Terkildsen and Makransky, 2019].

2) Respiration

Breathing was measured with a Bluetooth-connected Go Direct Respiration Belt [Vernier,], which used a force sensor and adjustable nylon strap around the chest to determine how much force was exerted during respiration at a sampling rate of 30 Hz. Participants put the belt on themselves by wrapping it around their chest for male subjects and slightly above for females while being guided by the researcher as seen in fig. 6(b).

B. Breathing Algorithm

The breathing scripts seen in appendix B, had one deceptively simple goal: Trigger the in-game avatar's breath-holding mechanic by simulating a maintained keypress, while the respiration belt was detecting a sufficient force applied on the chest, implying the subject was holding their breath.

This task was split into the following steps:

1) Read and Store Sensor Output

A Bluetooth connection was used to stream the respiration data to python, where the readings were stored in a python list. To minimize interference from electrical noise and movement artefacts, the readings were downsampled into a deque *breathingBuffer* with a window of 250 milliseconds, holding the last 8 reading samples.

2) Keypress and Keyrelease Events

The calibration process was controlled manually by the researcher using designated keyboard hotkeys imported from the .pyautogui library and a *State* variable used for data conditions in each step. Keypress events changed the state variable; 0= default, 1= calibration, 2= threshold, and printed a message to the terminal indicating that calibration or thresholding had begun. Whereas keyrelease events triggered calibration and thresholding functions as seen in fig. 7.

```
31  # Terminal Instructions
32  print("KEYBOARD CONTROLS:")
33  print("F1: Hold F1 to record Calibration Data")
34  print("F2 or DIAL BUTTON: Hold F2/DIAL BUTTON to record Threshold Data")
35  print("F3: Press F3 to set Threshold based on Threshold Data")
36  print("F4: Use F4 to TOGGLE Key Simulation ON or OFF (Default: OFF)")
37  print("F8: Press F8 to turn off program and save data to CSV")
38  print('\n')
61  # CALIBRATION stage.
62      if(key == keyboard.Key.f1): # Press
63          State = 1
64          if(statementPrinted == False):
65              print("CALIBRATION STARTED. RELEASE KEY TO STOP.")
66              statementPrinted = True
68  # THRESHOLD stage.
69      if(key == keyboard.Key.f2): # Press
70          State = 2
71          if(statementPrinted == False):
72              sampleIndex += 1 #Threshold sample
73              print("THRESHOLD SAMPLE {} STARTED.".format(sampleIndex))
74              statementPrinted = True
82      if(key == keyboard.Key.f1): # Release
84          resp.calibration(respData,inputData,OnlyCalibrationData = True)
93      if(key == keyboard.Key.f3): # Release
94          # SET THRESHOLD.
95          resp.calculateThresholdArray(respData, inputData)
97      if(key == keyboard.Key.f4): # Release
98          # Toggle Button Simulation
99          if(simulateButton):
100             simulateButton = False
101             print("SIMULATING KEYPRESS: OFF")
103         else:
104             simulateButton = True
105             print("SIMULATING KEYPRESS: ON")
107     #STOP PROGRAM
108     if key == keyboard.Key.f8:
109         programActive = False
110         print("PROGRAM STOPPED.")
111         return False
```

Fig. 7: *L31-38: Terminal instructions, L61-111:Condensed keypress & keyrelease events.*

3) Calibrate Min-and-maximum Breathing Effort

Since the script was designed to be flexible, it was possible to perform continuous calibration, so that if the subject took a deeper breath during gameplay, then that became the new maximum calibration value. However, due to the risk presented by sudden movements such as stretching influencing this value, it was decided to only use samples recorded during the calibration phase.

While the calibration key (F1) was held down, the subject was instructed to perform 5 deep breaths, after which the F1 key was released to compute the minimum and maximum force values for use in thresholding.

4) Threshold Subject Breathing

The purpose of thresholding was to determine how big a change in respiration rate from one buffer to the next was tolerated when predicting whether we held our breath or not.

For this, subjects were instructed to inhale deeply, then press and hold the F2 key to begin a thresholding sample, and then release the key approximately half a second before they exhaled to stop sampling. This process was repeated 5 times.

After obtaining 5 samples, the researcher would press and release the F3 key to normalize the obtained respiration data to fit it within a 0 to 1 range. 0 and 1 respectively being the minimum and maximum calibration values obtained in the previous step. After normalizing, the buffers in each thresholding sample were averaged and compared with the previous buffer to obtain the difference in respiration rate. The thresholding sample with the biggest difference in respiration rate would then be used as the maximum tolerated threshold when determining breath holding.

5) *Trigger Simulated Keypress*

With calibration and threshold done, each main loop iteration computed the current *RespState*, as seen in fig. 8. First, the current force value was normalized and appended as the newest of the *breathingBuffer*'s 8 samples. The average of that was then subtracted from the average in the previous buffer to determine the change in respiration rate. If the normalized force value of the current sample was above a self-determined threshold variable of 0.6, then a sufficient amount of force was applied on the belt to indicate breath holding. To prevent micro-breathing and movement artefacts triggering this, a second condition was put in place, which required the change in respiration rate from the previous buffer to be smaller than the threshold defined in the previous stage. If both conditions were satisfied, the function would output a 0, indicating breath holding during that sample, whereas 1 would be output if either condition failed, indicating breathing.
These values were added to a prediction buffer containing the past 24 samples, for which a majority vote determined the current breathing state. For subjects in the experimental condition, the researcher would then press the F4 before gameplay, which activated the simulated hotkey. From that point onward, whenever the predictionbuffer determined a majority vote of 0s, the simulated keypress event would initiate and continue until the vote returned a majority of 1s.

```python
69 def calculateRespState(self, currentResp):#Thresholded,Normalized,Windowed
70     if(self.calibrationDone and self.thresholdSet):
71         self.currentNorm = self.normalize(currentResp,self.minResp,self.maxResp)
72         self.breathingBuffer.append(self.currentNorm) # Normalize Value
73         if(len(self.breathingBuffer) == self.bufferLength):
74             currentAVG = sum(self.breathingBuffer) / self.bufferLength
75             self.respChange = currentAVG - self.prevAVG # Calculate change
76             # Determine BreathingState
77             if(self.currentNorm > self.normThreshold):
78                 if(abs(self.respChange) > self.threshold):
79                     self.respState = 1
80                     self.predictionBuffer.append(self.respState)
81                 else:
82                     self.respState = 0
83                     self.predictionBuffer.append(self.respState)
84             else:
85                 self.respState = 1
86                 self.predictionBuffer.append(self.respState)
87             self.prevAVG = currentAVG
88         return collections.Counter(self.predictionBuffer).most_common(1)[0]
```

Fig. 8: *L69-75:Function used to normalize force values between calibration min& max. L71-75: Same snippet used to normalize & average during thresholding. L76-88: Hold-breath predictor.*

C. *Summary*

This section provided details on the technical decisions required to conduct an experiment that could answer the research question stated in section 2. The iMotions biometric research platform was chosen to handle data collection and monitor participants throughout the experiment. Furthermore, the main functionality of the custom breathing script used to calibrate the respiration belt to each participant's unique breathing pattern and simulate keypresses was described.

7. Experiment

With the game stimulus, sensors, questionnaire, and breathing script ready, the author travelled to the Recreational Fear laboratory in Aarhus. Here the iMotions hub was set-up and several pilot tests were carried out to ensure everything worked and provide an approximate time length for the experiment. The longest duration for the pilot test was roughly 45 minutes, with the shortest being just below 30 minutes. Hence it was decided to include a 15 minutes buffer so that each test would maximum take 1 hour, of which 25 minutes were allocated to gameplay. Participants were provided with a time to arrive at the lab, each spaced out with at least 1 hour. The tests took place between November 21st - 25th between 8.00 - 17.00.

A. *Procedure*

The steps outlined in this procedure are explained in greater detail in the moderator guide (MG) found in appendix C.2.

Upon arrival at the laboratory, participants were told to sit down in the red chair seen in fig. 9, where they were provided with a consent form to read and sign. They were then fitted with the GSR sensor as seen in fig. 6(a) and instructed to take a deep breath to test the recording quality, after which they filled out the pre-session questionnaire. They were subsequently instructed to put the respiration belt on as seen in fig. 6(b), placed at the chest area for males and slightly above for females. After which the belt was calibrated as outlined in section 6. This calibration also took place in the control condition to ensure an identical procedure for both groups.

Following calibration, participants were introduced to the game in accordance with steps 2.1 to 2.9 in the MG and then left to play until they either finished the level or 25 minutes had passed. During gameplay, the test moderator separated the testing and moderation area with a curtain so that the participant could play without distractions. Upon finishing the game segment or surpassing the 25-minute mark, participants were asked to fill out the post-session questionnaire.

Fig. 9: *Test Setup. Players sit in the red chair throughout the entire experiment. Curtains are closed during gameplay.*

B. ***Equipment***

The questionnaires, sensors, breathing script, and game stimulus was run on a high-end gaming PC (CPU: Intel Core i7-12700KF 3.60 GHz; Ram: 64 GB; GPU: Nvidia Geforce RTX 3800 TI) and displayed on an 85-inch 4k TV.

C. ***Data collection and analysis***

The iMotions biometric research platform [iMotions, b] was used to set up the experimental design and collect data from the physiological measurement equipment. The OpenSignals software [Pluxbiosignals,] was used to manage the GSR data, which was live-streamed onto iMotions from there. Google Forms [Google, a] was used to collect pre-and post-session questionnaire responses and statistical analysis was performed using IBM SPSS Statistics version 25 [IBM,].

Levene's Test for equality of variances and boxplots was used to compare the spread of data values to ensure the two groups were sampled from the same population [KentState University, a].

The independent T-test for equality of means was used to investigate whether there were any statistically significant differences between the two groups [KentState University, a], [Welch, 1947]. The magnitude of those differences was estimated using Hedge's g with the following thresholds: 0.2; Small effect, 0.5; Medium effect, and 0.8; Great effect [Datatab,], [Cohen, 1992].

Pearson Correlation was then used to provide indications of the strength and direction of variable pairs with the following thresholds: <0.3; Weak correlation, <0.5; Medium correlation, and $0.5<$; Strong correlation [Cohen, 1992], [KentState University, b].

1) Pre- and post-session questionnaires

The pre-and post-session questionnaires can be found in respectively appendix C.3 and C.4. The pre-session questionnaire consisted of demographic questions (gender, age) and questions about their consumption of video games and horror media (8-point scale ranging from 'never' to 'almost daily') [Andersen et al., 2020].

The post-session questionnaire contained self-reported player experience metrics, presented in order:

1) Enjoyment and Fear (10-point Likert scale ranging from 'not at all' to 'very much') [Andersen et al., 2020].
2) Ease-of-use questions related to the breath-holding mechanic (10-point Likert scale ranging from 'strongly disagree' to 'strongly agree').
3) Arousal and Dominance dimensions from the Self-Assessment Manikin (SAM), used to evaluate emotional arousal and emotional control using the non-verbal pictorial assessment instrument (9-point Likert scale ranging from 'calm' to 'intense' and 'no control' to 'full control') [Bradley and Lang, 1994].
4) Multimodal Presence Scale (MPS) for measuring the Spatial, Social, and Self-presence sub-dimensions using five specific items for each dimension (5-point Likert scale ranging from 'strongly disagree' to 'strongly agree') [Makransky et al., 2017].

8. Results

Boxplots used in this section can be found in appendix D, and all statistical calculations in appendix E.

The following abbreviations are used in this section and section 9:

- **C** = Control Condition; Participants controlling the in-game breathing using the Z keyboard hotkey.
- **E** = Experimental Condition; Participants controlling the In-game breathing using their real-life breathing.
- $\mu(\sigma)$ = Mean scores(Standard deviation).
- **t** = Independent-samples T-test statistic.
- α = Probability value.
- **d** = Difference in mean scores between groups. Positive equals a higher mean in the control condition and negative equals a higher mean in the experimental condition.
- **DF** = Degrees of Freedom.
- **r** = Pearson correlation coefficient between independent variables

TABLE I: Group Differences - N = 20, DF = 18.

Item	**C** $\mu(\sigma)$	**E** $\mu(\sigma)$	**t**	α	**d.**
Age	31.6(13)	29.9(8)	.343	.736	1.7
GameFreq	3.5(2.4)	4.3(3.1)	.649	.524	-.8
HorrorFreq	4.2(1.9)	3.7(2.1)	.568	.577	.5

Table I show no significant difference in age, with participants in control (C) being an average of 1.7 years older than experimental (E). Boxplot[1] shows that 7 participants in each group were aged between 20 and 30, with the remaining 3 in C aged 35, 51, and 60, while the outliers in experimental were aged 35, 44, and 44.

No significant difference was found in video game familiarity (GameFreq), as both groups used the full 7-scale rating. Boxplot[2] does show that the median was significantly lower for C (2.5) compared to E (5.5), but E suffered from more extreme scores (2x 0, 5x 7) than C (1x 0, 2x 7).

No significant difference was found for horror familiarity (HorrorFreq), despite Boxplot[3] showing the InterQuartileRange(IQR) of C being 4-5, whereas the IQR of E was 2-6. This is explained by the two outliers in C (0, 7).

Furthermore, when asked which of the aforementioned horror games participants had played. Boxplot[4] showed very different results with C ($\mu0.2(\sigma0.4)$ only having 2 participants who had played any of them, whereas E ($\mu1.1(\sigma1.1)$ had 6 members who had played at least 1 of them. This difference in horror game expertise might have had an unspecified influence on the results.

TABLE II: Emotion Dif - N = 20, DF = 18.

Item	**C** $\mu(\sigma)$	**E** $\mu(\sigma)$	**t**	α	**d.**
Enjoyment	6.5(2.4)	6.5(2.5)	.000	1.00	0
Fear	4.2(2.0)	4.1(2.0)	.111	.913	.1
Arousal	6.2(1.6)	5.3(1.5)	1.29	.213	.9
Control	4.9(1.8)	6.7(1.7)	-2.3	.033	-1.8

Table II shows that no significant difference was found in self-reported enjoyment, with μ being identical. Boxplot[5] show that both groups frequented the upper half of the scale, with the IQR of C being 6-8, and E being 5-9. The whiskers of both groups reached the lower end of the scale, indicating that some participants in both groups did not enjoy it.

No significant difference was found in self-reported fear. Boxplot[6] shows that C frequented the upper half of the scale with an IQR of 4-6 with an outlier scoring 0, whereas the larger 2-6 IQR of E shows a more diverse experience regarding self-reported fear.

No significant difference was found in emotional arousal using SAM, a medium effect size (Hedges g: .553) was however observed which is likely the result of several outliers in C (3, 4) and E (2). Boxplot[7] does show that a significant difference could be reached by removing the outliers, as evident by the 6-7 IQR of C and the 5-6 IQR of E.

A significant difference was found in emotional control using SAM, with indications of a large effect size (Hedges g: -.986), indicating that participants in E overall felt more in control of their emotions. This is supported by Boxplot[8], with a 3-6 IQR of C, and a 6-8 IQR of E.

TABLE III: Breath Ctrl Dif - N = 20, DF = 18.

Item	C $\mu(\sigma)$	E $\mu(\sigma)$	t	α	d.
Intuitive	5.4(2.8)	7.5(2.1)	-1.9	.075	-2.1
Easy	6.3(2.8)	6.9(2.3)	-.5	.608	-.6
Responsive	7.6(1.9)	5.5(2.9)	1.9	.072	2.1

Table III shows that a close to significant difference was found in the intuitiveness of breath controls (α075>.05), indicating that participants in E mostly found the breathing controls significantly more intuitive than C. Boxplot[9] shows that C used the entire scale with an IQR of 3-8, whereas E mainly used the upper half with an IQR of 6-9. E further has a lower whisker ranging between 3-6, indicating the presence of several outliers.

No significant difference was found in how easy it was to use the breath controls, as supported by Boxplot[10] being close to identical.

A close to significant difference was found in the responsiveness of breath controls (α072>.05), indicating that participants in C found the breathing controls more responsive than E. Boxplot[11] shows that C had a very small IQR of 7-9 at the upper end of the scale with an extreme outlier scoring 3, whereas E used the whole scale with an IQR of 3-8. By removing the outlier a significant difference might be reached.

TABLE IV: MPS Dif - N = 20, DF = 18.

Item	C $\mu(\sigma)$	E $\mu(\sigma)$	t	α	d.
MPS Score	2.9(0.9)	2.9(0.6)	-.313	.758	-.11
Spatial	3.3(1.0)	3.5(0.8)	.390	.701	.16
Social	2.8(1.1)	3.1(0.7)	-.767	.453	-.32
Self	2.4(1.0)	2.3(0.9)	-.390	.701	-.16

Table IV shows that no significant difference was found in the averaged MPS scores or averaged sub-dimension scores in regard to Spatial, Social, and Self-presence. Boxplots [13], [14], and [15] show that participants in C used a broader range of the scale whereas E had slightly smaller IQRs, as evident by the smaller standard deviation as well.

TABLE V: GSR & Game Dif - N = 20, DF = 18.

Item	C $\mu(\sigma)$	E $\mu(\sigma)$	t	α	d.
PPM	6.4(3.7)	5.7(2.6)	.493	.628	.69
PeakAmp	.35(.2)	.4(.3)	-.161	.874	-.02
Duration	21.3(6.3)	20.5(4.6)	.319	.754	.79

Table V shows that no significant difference was found in GSR Peaks-Per-Minute (PPM) or Peak-Amplitude (PeakAmp). Participants in C had slightly more peaks and bigger variations in the number of peaks but participants in E had slightly higher amplitude peaks.

No significant difference was found in the duration of gameplay sessions, however, those in C spent an average minute longer than those in E. 7 participants from each group completed the level in the allocated time, the rest were stopped once they had played for approximately 25 minutes.

TABLE VI: Correlation Dif - N = 20, DF = 18.

Item	r	α
Significant		
Arousal & Fear	.743	α<.001
Easiness & Intuitiveness	.683	α<.001
Easiness & Responsiveness	.592	.006
Fear & GSR PPM	.520	.019
Easiness & Fear	-.682	α<.001
Enjoyment & GSR PPM	-.520	.019
Easiness & Arousal	-.500	.025
Responsiveness & Fear	-.479	.033
GameFreq & GSR PPM	-.462	.041
Near Significance: 0.05 <α <0.100		
MPS Score & Intuitiveness	.419	.066
GSR PPM & Easiness	.401	.080
MPS Spatial & GameFreq	.399	.081
Noteworthy Associations		
MPS Score & Responsiveness	.327	.160
Enjoyment & Fear	.233	.324
Enjoyment & Arousal	.231	.327
MPS Self & GSR PPM	-.334	.150
MPS Score & GSR PPM	-.288	.219
MPS Social & GSR PPM	-.224	.343
MPS Spatial & GSR PPM	-.161	.497

Table VI shows correlational relationships and noteworthy associations between data measures, sorted by descending correlational strength. Pink correlation coefficients (r) indicate Negative; decreasing relationships, when one measure increases, the other decreases. Whereas r without colour indicates Positive; relationships where both measures increase together.

9. Findings

This section condenses the study data presented in section 8 into key findings, which are further discussed in section 10.

A. *Hypothesis 1: Real-life breathing results in a significantly more arousing experience*

For H1a, no significant difference was observed in GSR PPM (α628, d .69), which aligned with the lack of significant difference found in self-reported SAM Arousal (α213, d .9). This indicates that players did not experience a significant conscious or physiological arousal difference.

For H1b, no significant difference was found for self-reported Enjoyment (α1.00, d 0), Fear (α913, d .1) or MPS scores (α758, d -.11). Likewise, no significant difference was found for the Presence sub-dimensions: Spatial (α701, d .16), Social (α453, d -.32), or Self (α701, d -.16). Indicating that players did not have a significantly different player experience in regard to either enjoyment, fear or presence.

B. *Hypothesis 2: The relationship between GSR PPM and MPS Scores can be reproduced.*

No significant correlational relationship could be found for GSR PPM & MPS Scores (r-.288, α219). Nor between GSR PPM and the Presence sub-dimensions: Spatial (r-.161, α497), Social (r-.224, α343), or Self (r-.334, α150). While statistically insignificant, the weak negative correlational relationship between MPS Score & GSR PPM (r-.288, α219) and its sub-dimensions: Spatial (r-.161, α497), Social (r-.224, α343), and Self with medium correlation strength (r-.334, α150), does show mild indications that presence actually decreases as GSR PPM increases.

C. *Controls*

A significant difference was expected for the intuitiveness of breath controls, which was almost achieved (α075 >.05, d -2.1), and shows that participants found it more intuitive to use their real-life breathing rather than holding down a button, which may be in part due to novelty bias.

A close to significant difference was achieved for the responsiveness of breath-holding controls (α072, d 2.1), showing that participants found the Z keypress more responsive than the respiration belt. This may have affected their presence, as indicated by the statistically insignificant positive medium correlation between MPS Score & Responsiveness (r.327, α160).

1) *Controls and Fear*

Significant strong positive correlations were found between Easiness & Intuitiveness (r.683, α <.001) and Easiness & Responsiveness (r.592, α006) of controls, showing that when participants found the controls easy, they likely also found them intuitive or responsive.

Significant strong negative correlations were however found for Easiness & Fear (r-.682, α <.001) and Easiness & Arousal (r-.500, α019), showing that participants got more scared if they found the controls difficult.

A similar tendency was seen with the significant medium-to-strong negative correlation between Responsiveness & Fear (r-.479, α033) and GameFreq & GSR PPM (r-.462, α041), in that unresponsive or unreliable controls made participants more scared and that familiarity with video game controls resulted in lower GSR readings. Likely a result of the participant reacting to game-induced fearful stimuli to a lesser extent.

A close to significant positive medium correlation was found between MPS Spatial & GameFreq (r.399, α081), hinting at participants with game familiarity being more spatially present in the virtual world.

D. *Fear, Arousal and Enjoyment*

As expected, there was a significant positive strong correlation between Fear & GSR PPM (r.520, α019) as well as between SAM Arousal & Fear (r.745, α<.001), which supports the relationship between fear stimuli and heightened arousal as a result of SPNS activation.

However, a significant negative medium-to-strong correlation was found between Enjoyment & GSR PPM (r-.520, α019), which indicates that heightened arousal combined with fear response reduces enjoyment.

While statistically insignificant, indications of a weak positive correlation between Enjoyment & Fear (r.233, α324) and Enjoyment & Arousal (r.231, α327) can be seen, which point in the opposite direction.

An interesting finding related to this was the significant difference in SAM-reported emotional control (α033, d -1.8), which show that participants using the breath-based controls felt more in control of their emotions, yet no significant difference was observed in enjoyment, fear, or presence. This indicates that conscious control of your breathing provides a degree of emotional control, however seemingly without any effect on other metrics.

10. Discussion

The following subsections investigate the different facets of the research question stated in section 2, through an individual examination of the associated hypotheses and data patterns.

A. *Experiment Discussion*

Overall the experiment was a success.
The breath-based biofeedback was tested as an alternative control interface in a commercial survival horror game and found to be a feasible alternative to a keyboard hotkey. Furthermore, the hold-breath prediction worked flawlessly for most participants, indicating that the script was accurate enough when participant bodytype was not an issue.

Disregarding the small sample size and population diversity, the experiment went as planned with the only technical difficulties being the aforementioned responsiveness issues of the respiration belt for some participants.

An interesting general observation was that participants in the control condition (Keyboard) relied more on crouching than in-game breath-holding and mostly stayed further away from enemies than those in the experimental condition (Real-life breath). This may be partly due to the easy difficulty setting that afforded players to mostly ignore the breathing mechanic and still succeed. It may also be partly due to participants in the experimental condition fixating on the system novelty, hence why they used it more than those who had to hold down a button.

Some participants also went the wrong way either at the beginning or at the forking road after the hedge maze. When that happened, the researcher would verbally inform them to turn around, which may have affected their experience.

Some participants also asked for permission to interact with the device required to continue, marked by an orange star in fig. 5, which may also have detached from the experience. These issues could have been accounted for if the researcher had access to a developer kit of the game.

Lastly, the format used to provide information during the gameplay introduction may have felt unnatural to participants, since they are likely used to being eased into gameplay by in-game tutorials, rather than an external actor.

B. *Population Diversity*

As seen in Table. I and Boxplots [1-4], both groups contained very diverse demographic profiles, with the majority being aged between 20 and 30. While no significant difference could be seen, the 3 age outliers in each group nonetheless represent a bias. Furthermore, participants seemingly belonged to 4 subgroups, which affected results:

1) Engaging with both games and horror.
2) Engaging only with games.
3) Engaging only with horror.
4) Engaging with neither games or horror.

C. *Hypothesis 1: Real-life breathing results in a significantly more arousing experience.*

As described in section 9-A, no significant difference was observed in GSR PPM or SAM arousal, nor in regard to player experience factors of enjoyment, fear, or presence.

1) Breath-holding and GSR Habituation

However, since holding breath-holding is used to create a spike in the GSR signal to test if the equipment works during pre-calibration or baseline recording, it was expected that participants using the breath-based controls would have a higher GSR PPM than those using the keyboard.

One explanation aligns with a clinical trial [BreathingLabs,], which suggests that repeated voluntary inhalation and breath-holding may result in habituated GSR readings. Furthermore, voluntary breath control may have a calming effect on the fear response. This aligns with an ongoing study [NinjaTheory,], that teaches people breathing exercises for stress relief in a calm VR setting and then exposes them to a horrifying monster that must be avoided using breathing exercises.

Another explanation could be that the observed significant difference in emotional control and the emotional effects on the GSR signal was more dominant, making the effect of breath-holding insignificant by comparison.

2) Over-sensitized Fear, Decreased Enjoyment

In regard to H1b, the lack of significant difference in enjoyment and fear may lead back to the inverted U-shaped relationship proposed in [Andersen et al., 2020], since participants may have become under-or-over-sensitized to fear which resulted in lessened enjoyment. This assumption is supported by the significant correlations in section 9-D, which further indicate that for video games, the inverted U-shaped curve might be smaller, making it easier for participants to become under-and-over-sensitized.

Several additional factors that may have affected this are that some players got caught and died several times, resulting in them having to start the level again from the beginning. Whereas others got lost in the earlier maze-like area or backtracked from the midpoint room where they had to interact with a device to continue. These deviations in gameplay experience may have resulted in a sense of confusion or frustration that may have had an effect on the player experience. However, a bigger sample will be required to determine the true impact.

D. ***Hypothesis 2: The relationship between GSR PPM and MPS Scores can be reproduced.***

As described in section 9-B, no significant correlational relationship could be established between GSR PPM and MPS scores.

Interestingly, the statistically insignificant negative relationships between GSR PPM & MPS scores indicate an inverse relationship than what was reported in the Measuring Presence in Video Games paper [Terkildsen and Makransky, 2019]. However, a bigger sample will be required to determine whether this decreasing relationship is purely due to chance as indicated by the large probability value, interference from the breath-holding, or whether the relationship may be different in action-oriented survival horror games.

E. ***Hold-breath Controls***

As described in section 9-C, The significant difference in the intuitiveness of controls in favour of real-life breathing aligns with findings in the AG literature review [Robinson, 2022]. However, as noted in the review, since this study was cross-sectional rather than longitudinal, it is currently impossible to determine whether this was because of novelty bias.

Furthermore, several participants using breath-based controls stated after testing that the difference in their physiological input; holding their breath and game feedback; avatar holding their hands over the mouth, resulted in detachment from the virtual avatar. This may have had an impact on the player experience and intuitiveness of controls.

No significant difference was found in the difficulty of the breath-holding controls, indicating that participants quickly adapted to the real-life breathing interface.

As expected, a close to significant difference was found for the responsiveness of breath-holding controls in favour of the keyboard button-holding. This aligns with what was observed during testing, since a couple of participants, despite having no issues during calibration of the respiration belt, experienced periods where the prediction script would inaccurately state that they were holding their breath, causing the avatar to lift their hands and then lower them. The opposite was also observed, where participants held their breath but the predictor script would state they had resumed breathing, resulting in an early release of the hold-breath mechanic. As supported by the statistically insignificant positive medium correlation between MPS Score & Responsiveness, this likely had an effect on the experience. Hence different placements for the respiration belt should be tested to improve the accuracy across different body types.

1) Controls and Fear

The decreasing relationship between control difficulty and fear observed in section 9-C, shows that participants who had ease-of-use problems with the controls became more afraid and had higher GSR readings, highlighting the importance of agency to avoid feeling vulnerable.

In addition to this, game familiarity correlated with lower GSR readings, whereas horror familiarity did not. This indicates that participants had an easier time adapting to the virtual world and its rules if they were familiar with games than if they were familiar with horror. Participants with game familiarity also showed a close to significant difference in spatial presence, indicating that game familiarity eases the process of feeling present in virtual worlds.

*F. **Real-world Applications***

Due to the currently many unknowns of the very young recreational fear research field, these findings can be applied to a wide range of applications. The easily customizable script enables researchers to conduct experiments on commercial products using simulated hotkeys which can significantly increase productivity in that future experiments do not have to be built from scratch. This also increases the ecological validity of these studies, since they can be performed on state-of-the-art productions.

*G. **Summary***

As stated in sections 2, 3, this study aimed to fill the research gap in affective games and recreational fear when it came to breath-based biofeedback in horror. While this study was unable to determine a significant impact on the player experience factors of enjoyment, fear, and presence, it showed that a breath-based control interface can be seamlessly integrated into commercial products using a flexible and easily configurable script for breath-based biofeedback calibration and thresholding. Key takeaways include that participants relying on real-life breathing found it more intuitive, used the breath-holding mechanic more, showed greater emotional control, and may have had their arousal dampened as a result of the controlled breathing when compared to those relying on a keyboard hotkey. Furthermore, despite population diversity, no significant differences in data variance were observed. Correlations between variables also point toward participants having lower enjoyment scores when both fear and arousal over-sensitizes and control difficulty resulting in heightened fear and arousal.

11. Future Work

This section presents potential avenues for how the knowledge obtained over the course of this study can be used by researchers and developers going forward.

*A. **Study Replication***

As mentioned in section 10, the first step is to replicate the study. This can be done in a multitude of ways to acquire valuable information related to affective horror gaming, emotional impact and more.

1) Repeated-Measures Study

A repeated-measures study can be used to perform a direct comparison between the traditional button-held controls and the breath-based control interface, without the risk of novelty and group bias. The repeated-measures experimental design was considered for this study but was rejected due to a combination of time and resource constraints since the researcher only had 1 week to conduct the tests. Furthermore, repeated-measures testing would require 2 randomization groups and 2 different gameplay segments to reduce the risk of fatigue and carryover bias, which would either require designing 2 similar segments from scratch or finding two very similar level designs from the game.

*2) **Between-Subjects Study***

Replicating this between-subjects design with more participants to account for the assumed 4 subgroups of video game and horror familiarity, or screening with inclusion and exclusion criteria to focus on one subgroup could provide valuable insight as well. This could help to determine how the experience differs for participants with different combinations of game and horror familiarity.

In both cases, it could be interesting to further segment each subgroup into the 3 types of horror fans:

- Adrenaline Junkie; Gets a mood boost and immediate gratification from the rush of recreational fear-based activities.
- White Knuckler; Dislikes horror and reports frequent negative side-effects of recreational fear activities such as nightmares but uses it to learn about themselves.

- Dark Coper; Uses recreational fear to help control and cope with negative emotions like anxiety and depression [Scrivner et al., 2022].

B. *Different Player Experience Metrics*

This study investigated the player experience by looking at specific metrics established by earlier research on recreational fear [Andersen et al., 2020], [Terkildsen and Makransky, 2019]. Investigating the player experience using more standardized frameworks, such as the Game Engagement Questionnaire [Brockmeyer et al., 2009], or Player Engagement Process [Schønau-Fog, 2011], could provide valuable insight into the gameplay experience as a whole and what motivates players to continue playing rather than focusing on the specific effect on positive and negative emotions.

However, further investigation into the emotional effects using different psychophysiological techniques like Electrocardiogram [Andersen et al., 2020], [Potter and Bolls, 2012], Electroencephalography [Terkildsen and Makransky, 2019], [Potter and Bolls, 2012], Facial Expression Analysis [Potter and Bolls, 2012], amongst others, would help to understand precisely how we are consciously and unconsciously affected during normal and affective survival horror gameplay.

C. *Different Control Interfaces*

As mentioned in section 10, some participants felt detached from their virtual avatar since the real-life action of holding their breath did not accurately mimic how the in-game avatar would move their hands over the mouth as seen in fig. 3. It would be interesting to see how participants would react if they were instead required to physically place their hands over the mouth to control the breath-holding mechanic. This would however make them unable to use a keyboard or controller while performing the mechanic, which could possibly be mitigated by using the virtual reality version of the game stimulus.

D. *Different Games*

As mentioned in section 10-F, since the created script maps specific sensor thresholds to a keyboard hotkey, it can in theory be used with any sensor utilizing thresholds to simulate any key-related action.

Hence it would be interesting to see studies conducted on different horror games or even different game genres and horror media. This would help gauge the extent to which breath-based biofeedback, and biofeedback in general, can be used to enhance games and general media products. It would also provide a user-friendly open-source software solution to anyone interested in conducting affective studies, which could lighten the current technological barrier that affective gaming research faces [Robinson, 2022].

E. *Expanding into Multiplayer*

It could also be interesting to continue investigating how breath-based biofeedback can be used in multiplayer horror, as proposed in the two case examples from [Robinson, 2022].

The author of this paper is particularly interested in seeing how it will affect narrative horror titles with multiplayer movie-night modes like the dark anthology series [Supermassive Games,].

F. *Summary*

Due to the multitude of unexplored avenues when it comes to this type of research, this section focused primarily on future perspectives directly related to affective gaming and recreational fear, despite it being applicable to fields where breath-based interfaces are frequently used such as rehabilitation, psychology and transformative games.

12. Conclusion

This study investigated an academic research gap in affective gaming and recreational fear regarding breath-based biofeedback in affective horror games. To achieve this, the following research question was asked in section 2:

"How is the player experience in the survival horror game Maid of Sker affected by replacing the button-held breathing mechanic used to avoid enemies with real-life breath holding?"

To answer this research question, the player experience was investigated as a complex relationship between enjoyment, fear, and presence using a pragmatic deductive approach based on findings from earlier studies [Andersen et al., 2020], [Terkildsen and Makransky, 2019].

From the research presented in section 3, a between-subjects experiment was carried out where participants had to navigate a linear stage in the commercially available horror game Maid of Sker. The game's breath-holding mechanic used to avoid the blind, but sound-based enemies served as the independent variable. Depending on which group participants were randomly assigned, they either controlled this mechanic by holding down the Z key on their keyboard (Control condition) or by using the breath-based control interface described in section 6, which used data from a respiration belt to determine whether the subject was holding their breath, in which case a keypress would be simulated (Experimental condition).

The findings show that the breath-based biofeedback proved a feasible alternative control interface in the commercially available horror game. However, no significant difference could be found in the player experience factors of enjoyment, fear, and presence between the control group using the button-held breathing mechanic and the experimental group using the respiration belt. Likewise, no correlational relationship could be established between GSR peaks-per-minute (PPM) and scores from the Multimodal Presence Scale (MPS), which goes against the relationship proposed in [Terkildsen and Makransky, 2019].

The lack of significant difference is assumed by the author to be due to a small sample size (N=20) with very diverse game and horror familiarity within both groups which affected the results, despite finding no significant difference in data variation between groups. Hence it is assumed that significant findings can be found for both the manipulation of the independent variable and in the response patterns of participants with varying game and horror familiarity if the study was replicated with a larger sample size.

With that in mind, findings point toward breath-holding habituating GSR signals and having a calming effect on the fear response in affective horror games. Furthermore, indications can be seen that the inverted U-shaped relationship proposed in [Andersen et al., 2020] may be smaller in horror games than in haunted attractions.

Adding to this, ease-of-use issues with gameplay controls resulted in subjects becoming more afraid as they likely felt vulnerable due to the decreased agency.

Hence to answer the research question:
Evidence points toward the player experience factors of enjoyment, fear, and presence being affected both positively and negatively by integrating a novel breath-based biofeedback as a control interface into a commercially available horror game. The effect on these measures seems to vary based on horror and game familiarity, which combined with a low sample size makes it unable to reliably conclude how each measure is ultimately affected positively and negatively.
Future research and study replications are necessary to ultimately determine how breath-based biofeedback influences the player experience in horror games. Including testing with different evaluation metrics, single and multiplayer games, incorporation into other entertainment mediums and fields like psychology and rehabilitation.

"To end this thesis. Will it motivate researchers to continue investigating the effects of breath-based biofeedback in a horror setting? Or will this particular research area fall dormant once more?"

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