A Design Exploration of Affective Gaming

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By

Raquel Robinson

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OR

Dean
College of Graduate and Postdoctoral Studies
University of Saskatchewan
116 Thorvaldson Building, 110 Science Place
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Abstract

Physiological sensing has been a prominent fixture in games user research (GUR) since the late 1990s, when researchers began to explore its potential to enhance and understand experience within digital game play. Since these early days, it has been widely argued that "affective gaming"—in which gameplay is influenced by a player's emotional state—can enhance player experience by integrating physiological sensors into play. In this thesis, I conduct a design exploration of the field of affective gaming by first, systematically exploring the field and creating a framework (the affective game loop) to classify existing literature; and second by presenting two design probes, to probe and explore the design space of affective games contextualized within the affective game loop: *In the Same Boat* and *Commons Sense*.

The systematic review explored this unique design space of affective gaming, opening up future avenues for exploration. The affective game loop was created as a way to classify the physiological signals and sensors most commonly used in prior literature within the context of how they are mapped into the gameplay itself. Findings suggest that the physiological input mappings can be more action-based (e.g., affecting mechanics in the game such as the movement of the character) or more context-based (e.g., affecting things like environmental or difficulty variables in the game). Findings also suggested that while the field has been around for decades, there is still yet to be any commercial successes, so does physiological interaction really heighten player experience? This question instigated the design of the two probes, exploring ways to implement these mappings and effectively heighten player experience. *In the Same Boat (Design Probe One)* is an embodied mirroring game designed to promote an intimate interaction, using players' breathing rate and facial expressions to control movement of a canoe down a river. Findings suggest that playing *In the Same Boat* fostered the development of affiliation between the players, and that while embodied controls were less intuitive, people enjoyed them more, indicating the potential of embodied controls to foster social closeness in synchronized play over a distance. *Commons Sense (Design Probe Two)* is a communication modality intended to heighten audience engagement and effectively capture and communicate the audience experience, using a webcam-based heart rate detection software that takes an average of each spectator's heart rate as input to affect in-game variables such as lighting and sound design, and game difficulty. Findings suggest that *Commons Sense* successfully facilitated the communication of audience response in an online entertainment context—where these social cues and signals are inherently diminished. In addition, *Commons Sense* is a communication modality that can both enhance a play experience while offering a novel way to communicate. Overall, findings from this design exploration shows that affective games offer a novel way to deliver a rich gameplay experience for the player.

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For more information, please see `www.thankyouforbeingamazing.com`

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Acronyms

BVP Blood Volume Pulse. 4

ECG Electrocardiography. 3

EDA electrodermal activity. 2, 3, 20, 24

EMG Electromyography. 4

FER Facial Expression Recognition. 4

GSR Galvanic Skin Response. 3

GUR Games User Research. ii, 5, 99

HR Heart rate. 20

PPG Photoplethysmography. 4

SDK Software Development Kit. 3, 4, 28, 99

1 Introduction

1.1 Problem Motivation

Digital games have been a popular leisure activity since the 1970s, and have gained in popularity through the decades as researchers and developers continue to invent new technologies, push the boundaries of game design, and innovate new approaches to digital play. The rising popularity of gaming is paralleled by the rise of self-tracking technologies, in which physiological data is captured and displayed back to the wearer from off-the-shelf devices like the Fitbit [229] or Apple Watch [15]. Not surprisingly, these two trends have merged in growing research and development of systems that integrate physiological self-tracking technologies into digital games.

In the context of digital gaming, physiological interaction has contributed to innovations such as how players provide input to games (e.g., [19, 83]), how games adapt and respond to player affective state (e.g., [127, 134]), how developers understand player experiences (e.g., [55, 22]), and how players communicate their state as part of livestreaming their experiences (e.g., [251]). The role of physiological interaction in digital gaming has been generally categorized into two primary motivations [207]: for innovating game interaction (with the intention of improving player experiences) and for evaluation (with the intention of improving understanding of players and their experiences).

As early as 1984, game designers were exploring how integrating physiological interaction into digital games could enhance player experience [175]. The game CalmPrix measured psychological arousal through Electrodermal Activity (EDA), sensed by a modified Apple II mouse, and adapted a racing game. Subsequently, a heart-rate sensor was shipped with the Japanese version of Tetris 64 for the Nintendo 64 to adapt play based on heart activity. Shortly thereafter, academic researchers also started exploring physiological game inputs. For example, in 1997, Picard presented AffQuake [238], a system that monitored physiological arousal through EDA and adapted the player's Quake avatar graphically in response. Custom games, such as Relax-to-Win [274], in which arousal was sensed via EDA and used to control the speed of a racing dragon, appeared as early as 2001.

These are early examples of "affective gaming" [97], in which gameplay is influenced by a player's emotional state, generally described by psychological arousal (i.e., degree of activation) and valence (i.e., ranging between negative and positive). Affective gaming researchers noted early on that: "The role affective technologies will play in the gaming industry is certain to create some new and exciting user experiences…" [98], that it could allow "for more dynamic, unpredictable, but also more personalized and situated game experiences" [14], and that it would "strongly affect the game playing experience while simultaneously being meaningful from the game-play perspective" [153]. Since these early systems, a variety of hardware and software advances that ease challenges in physiological sensing (e.g., Empatica E4 wristband [93], Affdex Software Development Kit (SDK) by Affectiva [187]) and that make it easier to integrate signals into well-developed games (e.g., Unity 3D [308], Source SDK [311], Unreal Engine [75]) have been introduced, supporting the proliferation of affective gaming research.

However, there are still no widespread commercial successes of affective gaming on a major platform. In reflecting on these decades of research that occurred without accompanying commercial success or widespread adoption, in this dissertation, I ask the research question: **How can affective gaming enhance engagement?**

1.2 Grounding for the work presented in this Dissertation

Over the last decade, biometric sensors have been explored in the context of game design and research. These sensors have primarily been used as novel (interaction) inputs to games (e.g., [207]), and as tools to evaluate games and their effect in players [177, 176]. In this thesis, I focus primarily on former, looking at ways that physiological signals might enhance the player experience.

1.2.1 Physiological Signals

Physiological measures are often restricted to, and assessed along the lines of, valence and arousal. While some measures—such as EEG—are arguably capable of representing an affective state in both dimensions, most signals are unidimensional (i.e., associated with either arousal or valence).

Here, I define all physiological signals that will be discussed in this thesis.

Physiological Measures of Arousal

Electrodermal Activity (EDA) also known as galvanic skin response (GSR), skin conductance level or response (SCL or SCR) measures sweat gland activity in the dermis—the skin layer below the surface (epidermis).

EDA data is primarily collected by electrodes placed on the palm and fingers, due to this location's dense collection of eccrine sweat glands. Careful attention must be paid to environmental conditions (which could greatly affect the accuracy of the EDA recordings), electrode type and placement.

Electrocardiography (EKG/ECG) is the measurement of electrical changes that occur before, during, and after the heart's contractions, and is responsive to stressor stimuli (such as frustrating, frightening, or exciting events) [13]. Several common methods of analysing ECG data include the analysis of heart rate (often measured in beats per minute), interbeat intervals (time that has passed between the 'peak' of each beat), and heart rate variability (variations in periods between heart beats over time).

This data is usually collected from electrodes, straps, or belts placed on or near the chest region. This signal generally requires little amplification due to its clarity and explicit presentation, thus making it easier to collect.

Photoplethysmography (PPG) is a specific technique which utilizes an infrared light to measure the variations of blood circulation. *Plethysmography* is a broad term which refers to the various techniques used to measure blood volume changes, but the use of a photoelectric transducer is what differentiates PPG from other techniques. Heart rate and other such metrics can be extrapolated from measurements of blood volume (i.e. changes in blood volume are synchronous to the heart beat).

This data is collected from sensors (often a pulse oximeter) placed on the finger tips [285].

Blood volume pulse (BVP) represents the contractions of the heart in local blood vessels, and thus can be extrapolated as a measure of heart rate (HR), interbeat intervals, and (to some extent) respiratory patterns.

Respiration (RESP) is a measure of respiratory rate or—alternatively—breathing amplitude (the depth of the breath). Respiration is typically assessed either by changes in the circumference of the chest (indicative of inhalatory and exhalatory contractions in the diaphragm), or by the rate of inhalation and exhalation as recorded by an inhaler or microphone.

Temperature (TEMP)—breath temperature, body temperature, or skin temperature—measures the internal or external temperature of a person. Increases in skin temperature are associated with decreases in arousal, as skin temperature elevates when body muscularity relaxes (causing vascular expansion).

This data is usually collected from a sensor—thermistor or thermometer—placed on the skin, extracted through the webcam in the case of skin/body, or from an inhaler for breath temperature.

Physiological Measures of Valence

Electromyography (EMG) measures the electrical potential of muscle activation and tension [285] that may be used to collect muscle movement data from any bodily site. While EMG can be deployed to investigate a variety of topics (for example, physical performance or muscle health), facial expression—as recorded by the activation of facial muscles associated with emotional expression—is most useful as a measure of valence.

This data can be collected by placing an electrode into the muscle itself, or by placing the electrode on top of the skin above the relevant muscle.

Facial Expression Recognition (FER) is a technology that is used to measure facial movement, usually through a standard webcam or Kinect device [187]. Facial landmarks are detected on the face through a camera, extracted, and classified as facial expressions using a classification software trained on a data set of thousands of facial images (e.g., GENKI-4K and KDEF). The software is trained to use these data sets to classify and model facial expressions based on the Facial Action Coding System (FACS)—or some similar coding strategy for determining each visually discernible facial movement. Many different FER software exists (e.g. Affectiva SDK, InSight SDK) on the market for widespread use.

1.2.2 Terminology

While the terms 'affect' and 'emotion' are often used interchangeably in game user research (GUR) and game development, they are distinct in psychological and physiological literature. In these contexts, affect—or affective states—are the psychophysiological constructs that represent the domain relationship between mental states and physiological response, and surmise the experience of valence and arousal; for example, 'pleasure' and 'displeasure', or 'tension' and 'relaxation'. In contrast, emotion (e.g., anger, pride, envy) is cumulative of both affect and other co-occurring components such as outward expression or behaviour, attention, and cognitive appraisal [258]. In simplest terms, affect captures both physiological and emotional elements that are experienced in terms of valence and arousal, whereas emotion is complex—as it is higher level—includes learned cultural and contextual influences, and is labeled with language [23].

The terms 'biometrics', 'physiology', 'biosignals', and 'biofeedback' are used often and at times interchangeably in GUR, I make a distinction between them for the purposes of this thesis. While the term 'Physiology' refers to the body-based signals themselves, the terms 'Biometrics', 'Biosignals', and 'Biofeedback' refer to the measurement of these body-based signals.

Physiology refers to both brain or body-based systems or signals.

Biosignal refers to any system or signal which can be measured or monitored. This term is commonly used in GUR to denote the monitoring and tracking of physiology.

Biometric refers to the identification and measurement of individual biological characteristics of a human. This term is usually used in reference to biometric verification techniques implemented by governmental agencies (DNA, fingerprinting, etc).

Biofeedback refers to a technique used to learn to control body-based functions (or physiology). This term usually refers to the monitoring and display of data back to the individual.

1.2.3 Physiological Game Interaction

The loss of face to face (f2f) social cues and signals important for communication in the digital domain warrants sensing users' physiology as the communication channel that affords the most natural and promising mapping [188]. Physiology has been shown to be an effective tool that has "opened up a new channel of communication between players and spectators" [251]. In the context of digital gaming, physiological interaction (i.e., "affective gaming") has contributed to innovations such as how players provide input to games (e.g., using facial expressions to control movements of an avatar [198]), how games adapt and respond to player emotional state (e.g., adding "horror-like" elements to the game based on players' GSR and EKG data [14]), and how these games might contribute to advances in the mental and physical health domains (e.g., an electromyography-based dancing game to help people with rehabilitation for Amyotrophic lateral sclerosis (ALS)[1] patients [317], or a breathing biofeedback game to help children with cystic fibrosis [28]).

[1]a progressive neurodegenerative disease that attacks motor neurons in the brain and spinal cord

Affective games—games that are influenced by a player's emotional state—have, for example, incorporated the players' GSR and adapted the player's avatar graphically in response [334], used the player's heart rate to control the speed of a bird in a Flappy Bird-like game [47], have altered the difficulty of the non-player character (NPC) enemies depending on the GSR of the player [212], or have varied the environment effects in the game, based on heart rate [208].

Physiological interactions have also been used to connect people in settings adjacent to games—for example in my master's work, I created a tool called All the Feels that provides an overlay of biometric and webcam-derived data onto the interface of the popular video game streaming service, Twitch [251]. In the non-academic domain, physiology also has been used to enrich the spectator experience during live events and games. In 2011, Dreamhack, a biannual esports event taking place in Sweden, equipped players with heart rate monitors while they streamed, which was celebrated by the audience [246]. In subsequent years, it has become common for streamers to add their own physiological signals to their stream while playing horror games, speedrunning (playing through the game as fast as possible), or adding an eye tracker to their game stream. Physiology has also seen commercial adoption: Flying Mollusk's 2015 title, Nevermind, uses the player's physiological input to influence the environmental effects of the game (i.e., making the game scarier with a higher heart rate) [169].

Reviewing prior work in this domain articulates the pronounced opportunity in affective gaming to use the spectators' physiology for the sake of a rich overall experience, enhancing viewer/streamer enjoyment, connectedness, and engagement.

1.3 Methodological Approach

In this section, I discuss the approaches to generating knowledge and research contributions in this thesis, including the systematic review and the various design and evaluation methodologies used in the two design probes, In the Same Boat (Design Probe One) and Commons Sense (Design Probe Two).

This thesis is situated within the larger multidisciplinary context of Human Computer Interaction (HCI), at the intersection of Interaction Design (IxD) and Games User Research (GUR). While HCI has been in existence since the inception of computing systems, it became formalized as a field in 1982 at the seminal Human Factors in Computing Systems (CHI) conference. In the years since this initial conference, HCI has expanded to include many different sub-domains and disciplines (e.g., ubiquitous computing, visualisation, user centered design) with some domains developing in unique directions and launching their own conferences (e.g., computer supported cooperative work (CSCW), computer human interaction in PLAY (CHI PLAY)). One of these fields includes Interaction Design, which can be considered a sub-domain of HCI, or a design discipline entirely of its own [170, 77]. Interaction Design primarily concerns "creating user experiences that enhance and augment the way people work, communicate, and interact" [257]. Theory and research from the field of Interaction Design played a role in informing the design of the probes.

The other domain that helped shape this thesis, both in the design and evaluation phases of the research, is Games User Research. GUR ultimately began out of the gaming industry in the 1970s—unifying as a research space in the past 20 years. The textbook "Games User Research" was released in 2014 by numerous academics and industry professionals—offering a thorough examination of the field, including methods and best practices. The authors state that GUR is a "field of practice and research concerned with ensuring the optimal quality of usability and user experience (UX) in video games" [70]. GUR is a broad field, intersecting with many different research areas and appropriating many of the methods and practices from these fields as well (e.g., validated scales in psychology used in GUR, or architectural visualization techniques used to inform 3d modelling in games).

IxD and GUR share many similarities. Each have strong roots in both industry and academic settings, meaning there are a broad range of techniques, practices and methodologies within these spaces that can be utilized and applied to designs. Researchers and designers in these domains often use a mixture of methods to evaluate designs, depending on the stakeholders and larger contextual landscape of the work. In addition, the research process in both these domains usually functions similarly. The research process consists of many different stages, including: the preliminary ideation and creation of the artefact and generation of research questions based on prior literature, the design process, which includes designing and making the artefact, and the evaluation of the artefact. Rogers et. al [257] describe the "double-diamond of design" in IxD, which consists of a multi-stage process for designing and evaluating an artefact: Discover, Define, Develop, and Deliver. These steps might occur in a linear order, or (especially in design work) in a non-linear way, moving between different steps fluidly. Often, the process functions as more of a loop, where it is possible to move backward and forward between each stage of the research process.

In the next sections, I will discuss a few methods often used to conduct literature reviews as a first step in the research process (Discover/Define), followed by the overarching design process used in this thesis, to design and implement the two design probes (Develop). Lastly, I discuss the methodological approaches used to evaluate the design probes, and the forms of data collected in the process (Develop/Deliver).

1.3.1 Literature Reviews

A literature review is often conducted to provide insight into the prior work of a field, identify gaps/areas for exploration, and create a narrowed scope of the research space. Literature reviews range from a surface-level examination of a subset of papers specifically relating to the topic, to conducting large scale formalized reviews of the space. Most literature reviews conducted as part of a research process fall somewhere between these two extremes, usually without much of a deep dive into one particular topic, but involving a look at enough papers in the space to understand how the new research expands on prior work. Two of the most common approaches to critical and systematic examinations of a research space, are called *systematic reviews* and *meta-analyses*. A systematic review "attempts to collate all relevant evidence that fits pre-specified eligibility criteria to answer a specific research question." [161] Systematic reviews should report their process in a standardized and systematized way, which helps ensure the review be comprehensive. Systematic reviews should ultimately work to ensure transparency [272] to help minimize biases. A meta-analysis, on the other hand, is the "valid, objective, and scientific method of analyzing and combining different results." [4] Meta analyses are often useful for more distinguished research domains (e.g., medicine; psychology) with many decades of research, in order to understand more precise effects of key observations and results from the field.

Protocols for conducting systematic reviews and meta-analyses are standard. The protocol I used in this thesis (PRISMA guidelines [272]) were developed in 2009, and became widely accepted in HCI as a standard practice to follow when conducting systematic reviews or meta-analyses [165].

1.3.2 Design Research

Design research in HCI has a rich history, beginning in the late 20th century. There existed the challenge to reconcile the differences between "scientific" research (the "existing") and design (the "non-existing") [287].

Research through Design (RtD) is a term coined by Richard Frayling in his 1993 paper "Research in art and design" [91] to describe the different types of design research. He posited a design framework, including three different approaches to conducting design research: *research into design*, *research for design*, and *research through design*. *Research into design* includes research on the design process itself (e.g., historical research into the field). *Research for design* is research intended to advance the field of design research as a whole (e.g., usually including new methods, tools, or practices that affects the overall field). Lastly, *research through design* focuses on designs to generate new knowledge (e.g., "customizing a piece of technology to do something no one had considered before" [91]). In the 2014 text entitled "Ways of Knowing in HCI", Zimmerman and Forlizzi discuss the forms of knowledge that are generated through Research through Design work:

"This knowledge can take many different forms including: novel perspectives that advances understanding of a problematic situation; insights and implications with respect to how specific theory can best be operationalized in a thing; new design methods that advance the ability of designers to handle new types of challenges; and artifacts that both sensitize the community and broaden the space for design action." [223, 335].

In 2003, Fallman makes a broad commentary on design research in HCI, making a distinction between *research-oriented design* and *design-oriented research*. He says that in *design-oriented research*, the main goal is generating new knowledge or artefacts through research, and design is used as a method of inquiry. In *research-oriented design*, the design process itself is the primary contribution, with research used as a way to highlight and learn about elements of the design process [76]. In 2008, Fallman expands on this framework to include the more specific kinds of design research in HCI [77], inventing the concept of the Interaction Research Triangle—discerning differences between *design practice*, *design exploration*, and *design studies* (see Figure 1.1). These three areas of activity within Interaction design help to delineate different kinds of design research within the space. *Design practice* provides an "interface towards industry", which in the context of games user research might be geared more toward applications in the game industry. In a *design exploration*, the main goal is to design something to understand the possibilities and limitations within a design space. *Design studies* refer to more traditional forms of design research and research through design, where the goal of the research is to generate new knowledge (often favored in academic settings).

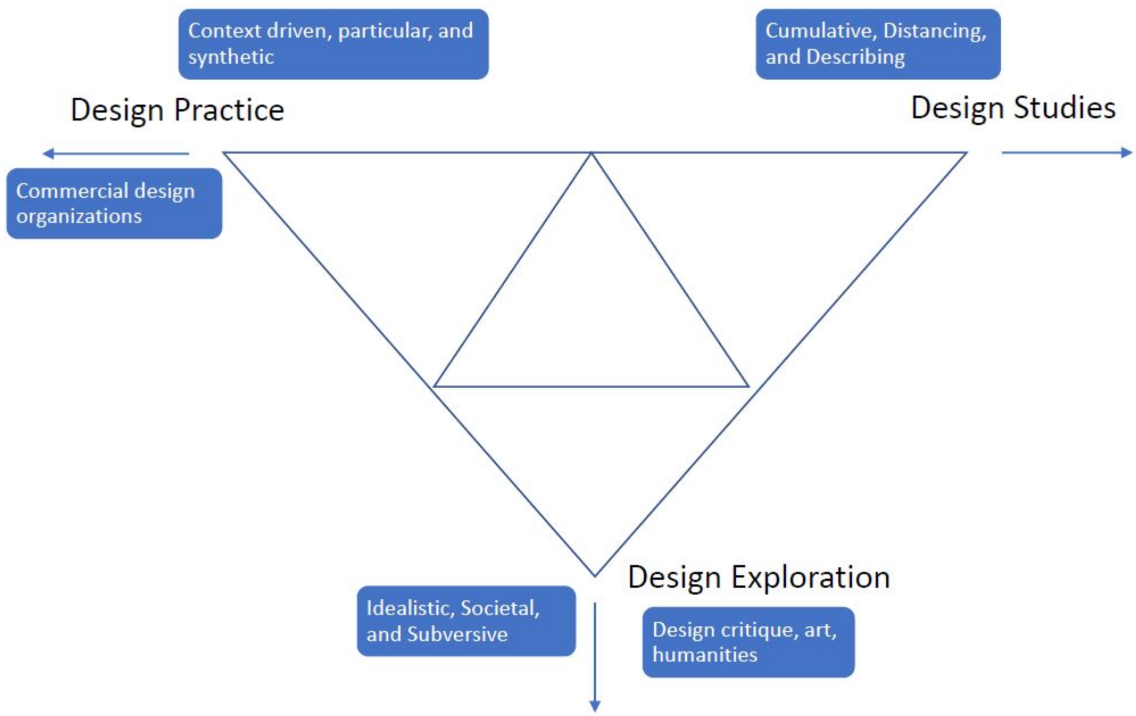

Figure 1.1: Reproduction of Fallman's Interaction Research Triangle [77]

This thesis is situated in the context of *research through design* work, for the purpose of generating new knowledge, particularly as a *design exploration* within the scope of *design-oriented research*. Research through design is the primary form of inquiry utilized in both projects. In particular, the methodologies I use are complementary, concerning both traditional (design studies) and novel (design exploration) forms of design inquiry and evaluation methods in HCI. Design Probe One leverages research through design, creating a game called *In the Same Boat* as a use case to test out the combination of various theoretical underpinnings (i.e., synchronized, embodied control schema). This probe lies primarily in the context of the more traditional form of design research: *design studies*. Knowledge is generated in this project through a series of research questions, in order to understand how the combination of these concepts might generate new knowledge. Design Probe Two, on the other hand, leverages research through design [335] to create an interactive heart rate communication modality called *Commons Sense* as a way to open up a new design space. Commons Sense is primarily a design exploration, helping understand the possibilities and limitations of the field of affective *audience* interactions.

1.3.3 Evaluating Design Research

Evaluation is a critical part of design research. Evaluations help designers understand the needs of users in order to highlight opportunities for improvements to the design. Rogers et al. [257] state: "Evaluation is integral to the design process. It involves collecting and analyzing data about users' or potential users' experiences when interacting with a design artifact...". Especially in the domain of GUR, evaluations are key components at each phase of the design process, from quick informal playtesting with early prototypes to a more formalized lab-based study with many participants. The multidisciplinary nature of HCI leads to a broad range of technologies, some more focused on the technical aspects of the contribution, and others that concern details of the design process. Thus, there exists a broad range of methodological approaches to evaluate these technologies. The methodological approach used to evaluate the particular piece of technology is largely dependent on the research question itself [70]. In the particular sub-domain of games user research where this thesis is focused, it is important to use a mixed-methods approach to evaluation [70]. While there are many methods that are often used within GUR (e.g., focus groups, card sort, ethnographic field studies), I will focus on discussing the two main methods of evaluation I used within this thesis: Experimental Research for Design Probe One and In-the-Wild for Design Probe Two. In terms of data collection, I used a mixture of quantitative (numbers-oriented, broad conclusions can be made) and qualitative (detail-oriented, focuses on user responses) [70] techniques. Using a mixture of both qualitative and quantitative data in HCI work is beneficial to understand both the broad generalizations (helpful as an argument for the efficacy of the current and future work in this area) as well as the more finely specific details of the design (usually helpful to inform future iterations of the design).

Experimental Research

Experimental research in HCI includes any kind of controlled experiment where two or more designs are given to users in order to answer some overarching research question(s) [223]. This "scientific" approach to evaluation has long been the gold standard study design in fields such as medicine and psychology for decades. The specific method often used in GUR is called *A/B Testing*. While the process used to design the artefact might differ quite broadly between research labs, A/B tests often follow a prescribed set of steps:

1. Research questions are generated based on prior work (e.g., Do people enjoy using playing video game x in VR?)

2. Two designs are created to answer the research questions (A and B), with one or more independent variables. One of the designs is the state of the art, or the *control* condition, meaning it acts as the gold standard baseline for comparison (e.g., play video game x on a regular PC). The independent variables are the portions of the design that will be manipulated to understand if this change has any effect on the dependent variables (e.g., play video game x in VR). The dependent variables are the specific variables looked at to measure success (e.g., self-reported enjoyment).

3. Evaluation is conducted with a large enough number (N) of participants to have desired statistical power.

4. Statistical analysis methods are used (e.g., ANOVA, t-tests) to determine statistical significance.

5. Conclusions are made about work (within the scope of the research).

Experimental studies are generally conducted in a lab-based setting; this allows researchers to minimize unwanted changes to the test conditions and environment that may skew or introduce bias into the results [223]. By minimizing bias, the strength of the conclusions that may be drawn is improved, because there exists less possibility that outside factors are influencing the observed effects. These studies can be either *within* or *between-participants*. A *within-participants* study means that all participants interact with both conditions A and B, whereas a *between-participants* study means that separate groups of participants interact with separate conditions (Group 1 with condition A and Group 2 with condition B). *Within-participants* studies require fewer participants to have high statistical power, because all participants will be included in the analyses for each condition (e.g., 10 users participate, thus N=10 evaluate artefact A and N=10 evaluate artefact B). Counterbalancing order of the conditions is necessary to ensure there are no order biases, and to minimize learning effects (e.g., participants will learn the system the more they play, making them much better at using the system once they reach the second condition). A *between-participants* study eliminates possible learning effects, but means that double the participants are needed to participate in order to have the same statistical power as a *within-participants* design (e.g., 10 users participate, thus N=5 evaluate artefact A and N=5 evaluate artefact B).

Experimental research is often beneficial later in the design process in HCI, in order to make broad generalizations and understand deeper questions about the technology. Often this type of study takes a lot of resources to run (due to the high number of participants required to extract any meaningful data), thus it is most effective to conduct this type of experiment only after having a solidified design. For Design Probe One, I used iterative playtesting with users throughout the design process, conducting a large scale A/B test with the game once the design was solidified and the artefact was near-completed. I used this particular method to evaluate In the Same Boat due to the nature of the research questions. I was particularly interested in how this embodied control scheme had an additive effect on enhancing player experience, using a synchronized, cooperative, and interdependent game design. This broad research question, which came out of the literature, helped me unpack a few key aspects in making a well-designed affective game that enhances player experience. The A/B study design strongly supports this kind of broader (literature-driven) research question or testing of specific theories. These early questions regarding enjoyment of the control scheme need to be answered before a more applied and ecologically valid follow-up can be conducted.

In-the-Wild

'In-the-Wild' refers to "research that seeks to understand new technology interventions in everyday living." [256, 45]. The method was popularized in the anthropology domain in 1987, and is used often today by researchers in HCI to test out technology within the studied communities in their respective environments. In-the-wild studies can often be beneficial to understand how a piece of technology might fit into broader social contexts, or routines and rituals of everyday life. In-the-wild studies are often used in conjunction with longitudinal studies (i.e., studies that are conducted over a longer period of time, to understand long term effects and user reactions to the artefact). Often these kinds of studies have high ecological validity, meaning there is a strong translation to real-life settings. While the real world applicability is a large benefit to conducting studies in this manner, there are some drawbacks as well. Chiefly, that in-the-wild studies have many uncontrollable variables making it difficult to draw broader conclusions about the data, or apply findings to any other population outside the one studied.

Design Probe Two was evaluated in-the-wild for numerous reasons. An in-the-wild study allowed for streamers to participate from home using their own live streaming setup—which is of the utmost importance to this user group, as live streamers have their own unique and customized hardware setups, which are vital to their performances. In addition, evaluating live streaming is similar to evaluating a piece of art or performance, meaning it is not possible for any two studies/performances to be alike, which makes it difficult to control or minimize bias (thus making it infeasible to run as an A/B study). For example, it would be impossible to ensure that live audiences responded to each streamer in the exact same way or that each streamer gave exactly the same performance. In the future, I envision Commons Sense becoming a communication modality used by general audiences on Twitch, as a way to capture and communicate the audience response; thus making it quite important to test in an applied setting in-the-wild, to understand the real world applicability of the tool.

As I use a variety of research approaches, and methodological approaches in this dissertation, I provide additional details on the methods employed within the description of each research contribution.

1.3.4 Personal Contribution

In this thesis, I refer to all the research using the personal pronoun "I". However, it must be noted that this work was conducted as a collaboration between numerous researchers including undergraduate research assistants, professors, and international collaborators.

In terms of my personal contributions, I was responsible for the conceptual and iterative design work, data collection and analysis, and write-up of the manuscripts for publication.

For the systematic review, I conducted the initial search, included/excluded papers along with two colleagues, created the affective game loop, analyzed the data, and wrote up the publication. I was supported by two colleagues and two supervisors.

For In the Same Boat and Commons Sense, I lead the design and evaluation processes. I designed the game, made code modifications to the games, setup the experiment, collected and analyzed data, and wrote up the publications. I managed two undergraduate researchers who contributed to the implementation of the games, and gave advice and feedback about the designs. I was supported by colleagues and supervisors.

For each research contribution in this dissertation, I acknowledge the contributions of all my co-authors on each publication. The following publications contain work presented in this thesis: [253, 252, 254]

1.3.5 Dissertation Outline

In this thesis, I present a design exploration of the field of affective gaming, to better understand how affective games might enhance player experiences. As this thesis is set in the context of using physiological signals for the purpose of innovating game interactions, I do not focus on evaluation or using physiology as a tracking technology, but rather as a nuanced and unique approach to enhance communication between people for the purpose of strengthening game engagement, and enhancing social closeness between players.

To answer the overarching research question '*How can affective gaming enhance engagement?*, I conduct a design exploration for which the contributions are multi-fold. First, to understand if the previous work in affective gaming demonstrates that the potential of using affective gaming for enhancing engagement has been realized, I conducted a systematic review to frame the design space of the field, categorizing contribution types within the 'affective game loop' that I created. Physiological sensing has been a prominent fixture in the games user research (GUR) community since the late 1990s. Reflecting in 2020 on these last 20 years of progress, my systematic review presents findings on the current state of the field and discusses how these findings, contextualized within the affective game loop, can guide the future of affective gaming—a future that I feel still holds promise to mesmerize and captivate players. In conducting this review, I learned that there exists an explicated need to explore the limitations of the field; what is holding it back? How can the promise of affective gaming start being realized?

Next, to understand how game designers can more effectively design engaging affective experiences, I designed and deployed two probes—'In the Same Boat' (Design Probe One) and 'Commons Sense' (Design Probe Two)—each affective games addressing a particular gap in the field that explore a certain aspect of the affective game loop. Both games were designed based on the Self-Determination Theory (SDT) [260], which is a theory often applied in games user research and HCI in general [307]. SDT posits that people are more likely to engage and enjoy with a task when they are intrinsically motivated to do so. Put simply, in order to foster the highest sense of intrinsic motivation in individuals, three needs must be met: competence (i.e., the need to feel good at the task), autonomy (i.e., the need to feel in control), and relatedness (i.e., the need to feel close to others). Thus, it follows, to heighten player experience, it is necessary to focus on heightening these three pillars of SDT as well, particularly with special attention paid to the *relatedness* dimension. Each probe is set within significantly different game contexts, thus design probe two does not expand on the first design probe, but rather exists within its own entirely unique setting. Lessons learned from creating each design probe help explore the overarching design space of affective gaming, by providing the reader design insights into fostering social closeness over a distance through distributed play.

In the Same Boat (ITSB) was designed as an expansion on prior work showing that cooperative, interdependent game designs are most effective at fostering social closeness amongst individuals [62]. As social closeness is vital for health and well-being and an antecedent for enjoyment as stated by SDT, I focused on heightening social closeness through synchronized play [310]. The design decisions made in the project were all in service of the goal to foster social closeness; which in turn enhanced player experience. ITSB leverages the synchronization of both players' input to steer a canoe down a river and avoid obstacles. I created two versions of the game: embodied controls, which use players' physiological signals (breath rate, facial expressions), and standard keyboard controls (mouse/keyboard). Results from the controlled experimental study with 35 dyads indicate that ITSB fostered affiliation, and while embodied controls were less intuitive, people enjoyed them more. Further, photos taken before/after of the dyads were rated as happier and closer in the embodied condition, indicating the potential of embodied controls to foster social closeness and enhance player experience in synchronized play over a distance.

Commons Sense was designed as an expansion on my master's work in the live-streaming domain [250], indicating that spectators feel closer to the streamer when their physiological signals are explicated on-screen. The design decisions in this project were all in service of the goal of helping foster social closeness between the audience and the streamer. Now more than ever, people are turning to online platforms to communicate for both and work and leisure. Twitch, the foremost platform for live game streaming, offers many communication modalities similar to other platforms (e.g., live chat), and some unique to the live streaming context (e.g., audience participation, voting). Despite these available interactions, there is no formal incorporation of these elements onto the Twitch platform, and game streaming still lacks a representation of physiological social cues and signals of the audience experience, which are both so present in performances in front of a physical audience and in other live events. Thus, I designed a technology probe that explores how to capture the audience energy and response in the digital game streaming context. I designed a game (Alien Shooter) and integrated a custom-communication modality—*Commons Sense*—in which the spectators' heart rates are sensed via webcam, averaged, and fed into the video game to affect in-game variables including sound, lighting, and difficulty. I then conducted an 'in-the-wild' technology probe with four Twitch streamers and their spectators (N=55) to understand how these groups interacted with Commons Sense, how they enjoyed the enhanced streaming experience, and how it influenced their mutual feelings of connection to one another. Spectators and streamers indicated high levels of enjoyment and engagement with Commons Sense, suggesting that physiological interaction might be a useful communication tool to enhance player and spectator experiences.

2 Let's get Physiological, Physiological: A Systematic Review

2.1 Motivation

Physiological sensing has been a prominent fixture in games user research (GUR) since the late 1990s, when researchers started to explore its potential to enhance and understand experience within digital game play. Since these early days, is has been widely argued that "affective gaming"—in which gameplay is influenced by a player's emotional state—can enhance player experience by integrating physiological sensors into play. Although there has been extensive work in the field of affective gaming over the last 40 years, there are still no widespread commercial successes of affective gaming on a major platform. In reflecting on these decades of research, I need to ask, has the promise of affective gaming to enhance player experience been realized?

To answer this, I provide a systematic review of literature on affective gaming with the goals of summarizing existing contributions, identifying gaps and suggesting areas for future investigation, and providing frameworks and the background needed to appropriately position new research activities. To appropriately scope my findings to affective gaming, I focused on physiological interaction for enhancing player experiences—as opposed to evaluating them [175]—and on affective input, including affect, arousal, and valence—as opposed to attention-based game interaction as measured through brain sensing (e.g., [182]) or eye gaze (e.g., [279]). With an initial search set of 52,834 publications, my exclusion criteria narrowed this to 162 peer-reviewed publications that explore affective gaming to enhance player experiences. I created a framework, *the affective game loop*, to classify the publications, through which I ask: *does affective gaming enhance player experience?* I then present findings on the current state of the field, and discuss how these findings, contextualized within the affective game loop, can guide the future of affective gaming. The goal of the systematic review I conducted was to summarize existing contributions within the field of affective gaming, identify gaps and suggest areas for future investigation, and provide frameworks and the background needed to appropriately position new research activities.

I scoped this review in terms of Russel's two-dimensional valence and arousal model of affect [258], and classified the physiological sensors accordingly. Valence—or tone—describes the positive or negative orientation of the emotion (e.g., joy is a positively-valenced emotion and sorrow is a negatively-valenced emotion). Arousal describes the level of activation, or intensity, of the affect (e.g., boredom is a low-arousal emotion, and excitement is a high-arousal emotion). These dimensions together describe both the tone and the intensity of the emotion: for example, anger could be classified as a high-arousal, low-valence emotion.

While there are a broad range of signals that may be considered physiological, for the purposes of narrowing the scope of this thesis, I define physiological measures as those which are primarily body-based. Therefore, tracking or location based signals (e.g., GPS), brain-based signals (e.g. Electroencephalogram (EEG)), and movement-based signals (e.g. body-based electromyography (EMG), accelerometer) are not included in the systematic review.

In a book chapter on biometrics in gaming technologies, Mandryk and Nacke [175] categorize physiological sensing into two groups: brain-based sensing and body-based sensing. While brain-based sensing is a relevant topic in Human-Computer Interaction (HCI), I excluded it from this review on the grounds that a) brain computer interfaces (BCI) and neurofeedback games represent a substantial focus of research in the GUR community, and would require a separate review to fully capture the scope of this topic, b) BCI in games has already been the recent subject of a systematic review [148], and c) brain-based sensing tends to focus on sensing attention, cognition, and concentration, rather than affect (arousal and valence), and thus is out of scope for the review of affective gaming. In addition to excluding brain-based sensing, I made the decision to exclude gesture/movement for similar reasons. I also argue that gesture/movement represent the physical domain (e.g., actions) rather than the physiological domain (e.g., bodily function). As such, this systematic review is scoped to encompass physiological body-based sensing measures in affective gaming.

Recently, a systematic review was conducted focusing on how specifically *biofeedback* interaction methods—a branch of affective gaming—are used in entertainment technologies. This work includes all the signals discussed in my systematic review, in addition to eye tracking. The authors found that while there were some technical limitations with physiological sensors, biofeedback interaction still enhances enjoyment, immersion, and player experience [210].

2.2 Method

To scope the findings, I focused on physiological interaction for enhancing player experiences—as opposed to evaluating them [175]—and on affective input, including affect, arousal, and valence—as opposed to attention-based game interaction as measured through brain sensing (e.g., [182]) or eye gaze (e.g., [279]). To report this systematic review, I followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [166]. Figure 2.1 illustrates a flow chart of this systematic review process. I narrowed down an initial set of 52,834 papers to 162 through a systematic process including multiple reviewers.

I decided on a list of keywords encompassing general terms relating to physiology and affect such as “biometrics” and “emotion detection”, a specific list of body-based physiological signals, and games. These keywords were used to extract all relevant papers from a set of databases which are commonly used for publishing papers in the field of games user research: ACM Digital Library, DiGRA, ProQuest, ScienceDirect, Scopus, Sagepub, Pubmed, and IEEE Xplore. As an example, the search string used for ACM Digital Library

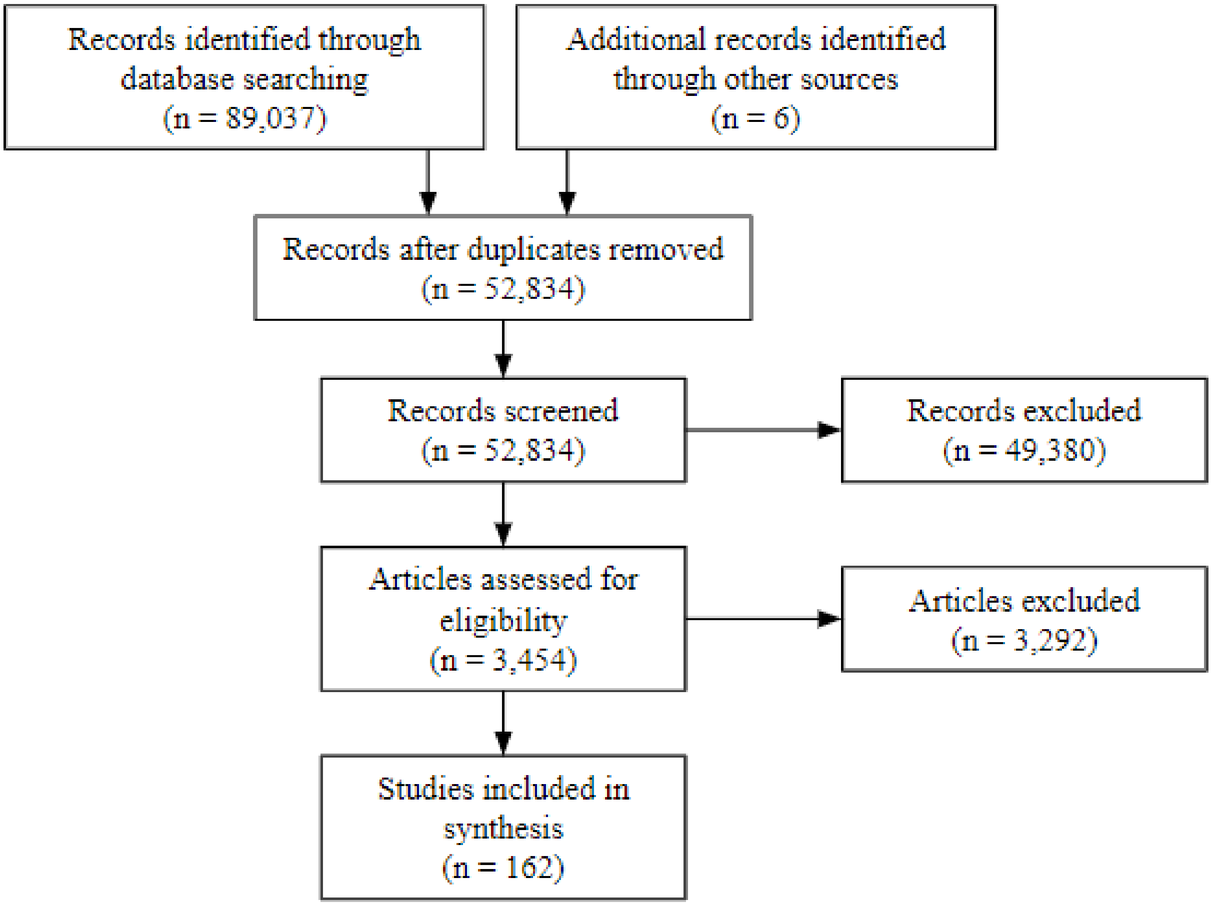

Figure 2.1: Systematic Review Process Flow Chart

database was: ("brain* OR BCI OR neuro* OR FMRI OR FNIRS OR physiolog* OR psychophysiolog* OR biofeedback OR biometric* OR biosignal OR heart* OR HR OR HRV OR IBI OR BPM OR PPG OR galvanic* OR "skin conduct" OR EDA OR EDR OR GSR OR SCL OR SCR OR breath* OR respiration OR respiratory OR electro* OR EEG OR EMG OR EKG OR ECG OR facial* OR face* OR valence OR arousal OR eye* OR gaze*) AND (game* OR gaming)".

These databases returned a set of 89,037 papers. I imported these citations to the Mendeley Reference Management software [86] and a total of 33,984 duplicates were automatically deleted by the software. An additional set of 2,225 duplicates were then removed manually, leaving 52,834 papers for review. To ensure all papers were captured, I also checked Google Scholar and the references of key papers [152, 141] for any studies missed by the databases, resulting in an additional 6 papers for review.

For the next steps, I used Rayyan QCRI [226], an online software system developed for conducting systematic reviews. I imported the papers into this software and conducted the inclusion/exclusion based on a set of pre-decided eligibility criteria. Within the software, reviewers were able to mark the paper as, 'include', 'exclude', or 'maybe'.

The eligibility criteria required each paper to be a peer-reviewed journal article or conference proceeding published in English. Each paper needed to include a digital game and use a physiological body-based signal for enhancing experience. The search was performed in January 2020, and thus I included papers published up to December 31, 2019.

I conducted the initial title and abstract screening of these papers; I reviewed a portion, and a colleague reviewed a separate portion. 3,454 papers were marked as "maybe" by us, indicating a more in-depth screening was necessary. Next, myself and two colleagues read through the set of 3,454 papers (some just the title/abstract and others the full paper, depending on how much detail was needed) and made a decision.

Papers were excluded from the review for reasons including using physiological data only for tracking player experience, not being about a digital game, or using a form of physiological data outside the scope of the review (e.g., body movement). Conflicts between myself and other reviewers were resolved through discussion, and a total of 170 papers were selected for analysis. The full-texts of 8 papers were not available online in any digital library. I made all efforts to contact the authors; despite this, I was not able to successfully establish reciprocal contact with the authors nor find the full texts in the English language. This left a final set of 162 papers.

2.2.1 Coding

Because the final set of papers was so large, myself and two colleagues all reviewed a set of 15 randomly-selected papers and worked out any disagreements with the coding process. Following this, the remaining papers were split randomly between the three of us. A spreadsheet containing a set of questions was completed for each paper, listing: the name of the game used and if it was off-shelf, customized, or modified from an existing game; each physiological input device and on-body placement, what signal it sensed from the wearer, and its corresponding in-game action and purpose; a summary of the system; outcome measures and a summary of results; and the sample population and size.

A number of papers contained descriptions of multiple games, using as many as 4 different physiological sensors. 78.4% of papers used 1 sensor, and the rest used 2 or more sensors in their game(s). Therefore, instead of counting the number of papers, I counted each unique game or system within the paper, as well as each sensor that was used. For the framework described in the next section, I counted each implementation of the physiological sensor as a separate instance. For example, if the paper contained 2 studies using the same game/sensors, but implemented the sensors each in a different way in the game, I counted each implementation separately. Further, if a set of authors used the same game/implementation in several publications, I counted each publication individually as an instance.

2.3 Findings

In this section, I describe the findings from the systematic review. The full paper is published at the *Computer-Human Interaction in Play* Conference (CHI PLAY) 2020 [252].

2.3.1 Affective Game Loop

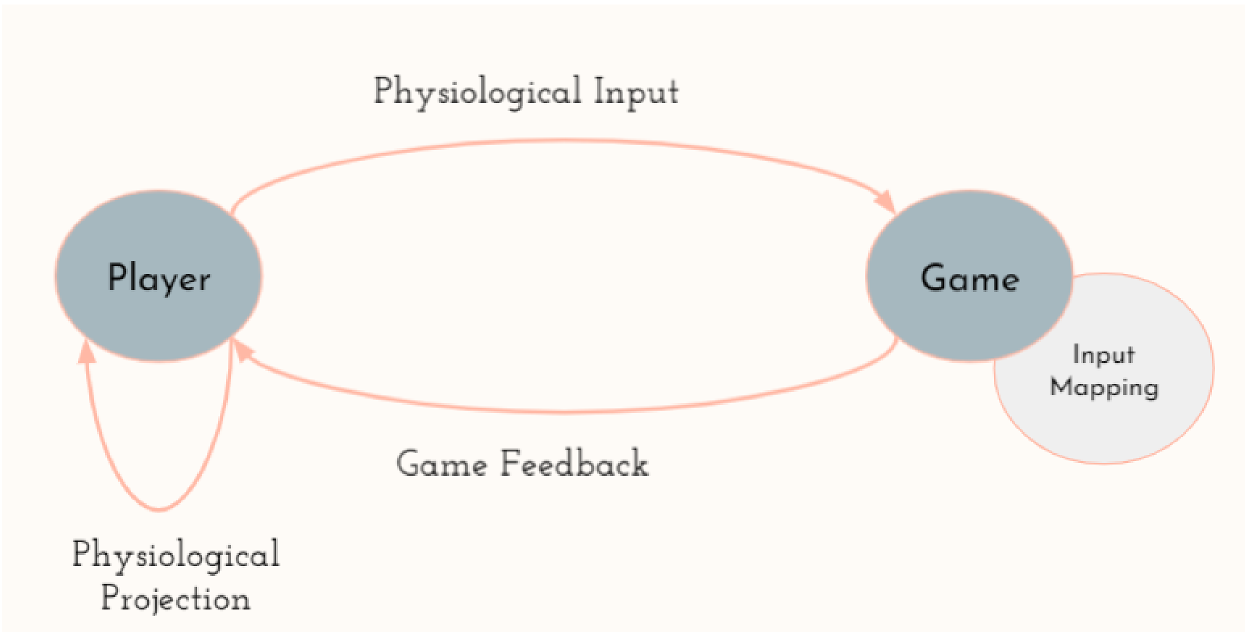

Figure 2.2: Affective Game Loop

As part of developing the questions to ask within the systematic review, I also considered how to represent all aspects of the affective gaming experience. Taking inspiration from Fullerton's model of feedback loops [92], I considered how to classify ways in which physiological signals influence the player(s), the game, and the gameplay experience. My goal was to come up with a classification system that both supported all types of physiological input for a broad range of purposes, and supported a variety of approaches for integration with the game. It was also critical to express a distinction between papers that simply show a visualization of data to the player, and ones that influence gameplay directly. Figure 2.2 shows the general framework of the affective game loop. A sensing system measures physiological state and provides it as input to the game, which then integrates that input in some form, providing feedback to the player through the game or an external method. Further, sometimes, the physiological state is not incorporated into the game loop, but is simply projected to the player (generally through visual, auditory, or haptic methods) to inform the player of their physiological state outside of the game context.

In the coding process, I categorized the way in which the physiological sensor influenced the gaming experience in each part of the Affective Game Loop:

1. *Physiological Input*: Physiological data collected from the player (e.g. HR or EDA) through a sensing device and fed into the game as input. In a non-physiological gameplay loop, this form of input would be mouse and keyboard or a standard game controller.

2. *Physiological Projection*: Physiological data collected from the player through a sensing device and displayed back in the form of real-time data (visually, audibly, and/or haptically) which affects their perception/experience, but has no direct impact on gameplay. This information is often overlayed over the gameplay itself.

3. *Input Mapping*: Describes the mapping of the physiological input to an in-game element, i.e., how the physiological state is integrated into gameplay. This could take the form of a more action-focused control—affecting the mechanics of the game; or context-focused—by influencing a part of the game the player does not usually control directly and continuously (e.g., difficulty, environmental).

4. *Game Feedback*: Feedback the player receives (visually, audibly, and/or haptically) from the game.

I used this initial framework to guide the classifications, with the intent of expanding and refining it when publications could not be classified within its bounds; however, the findings demonstrate that its overall structure did not change significantly from the coding process.

In the next sections, I summarize findings from the full-text screening of the 162 papers included in the review. Overall, I am interested in creating and applying a framework to understand the existing contributions in the field of affective gaming, and to identify the gaps and potential for future work in this area. I start with a high level summary of the contributions of the literature, followed by an in-depth look at the affective game loop and its usefulness in categorizing the literature.

2.3.2 Affective Gaming Over the Years

First, there was quite a bit of differentiation between papers included in the review. Of the 162 papers included, 16 papers conducted only preliminary—2 participants or fewer—user studies to evaluate system performance. Additionally, 19 papers conducted no evaluation study at all. The number of papers on affective gaming by year increased substantially beginning in 2004, with only 8 papers published prior (see figure 2.3 for a breakdown). Each year, the number of papers steadily rose, with an all-time high of 21 papers published on the topic in 2018.

While most researchers used real-time physiological data collected from participants, 4 systems [42, 213, 219, 241] reported using fake data for the implementation (e.g., pre-recorded physiological data from people outside the study). The majority of games and systems are custom-made by the authors or modifications made to an existing game (e.g., physiological adaptations to existing games such as Pong, Dance Dance Revolution (DDR), and Flappy Bird). Only a small set of papers used off the shelf games; the "Journey to the Wild Divine" biofeedback game system was the most commonly implemented off-the-shelf product.

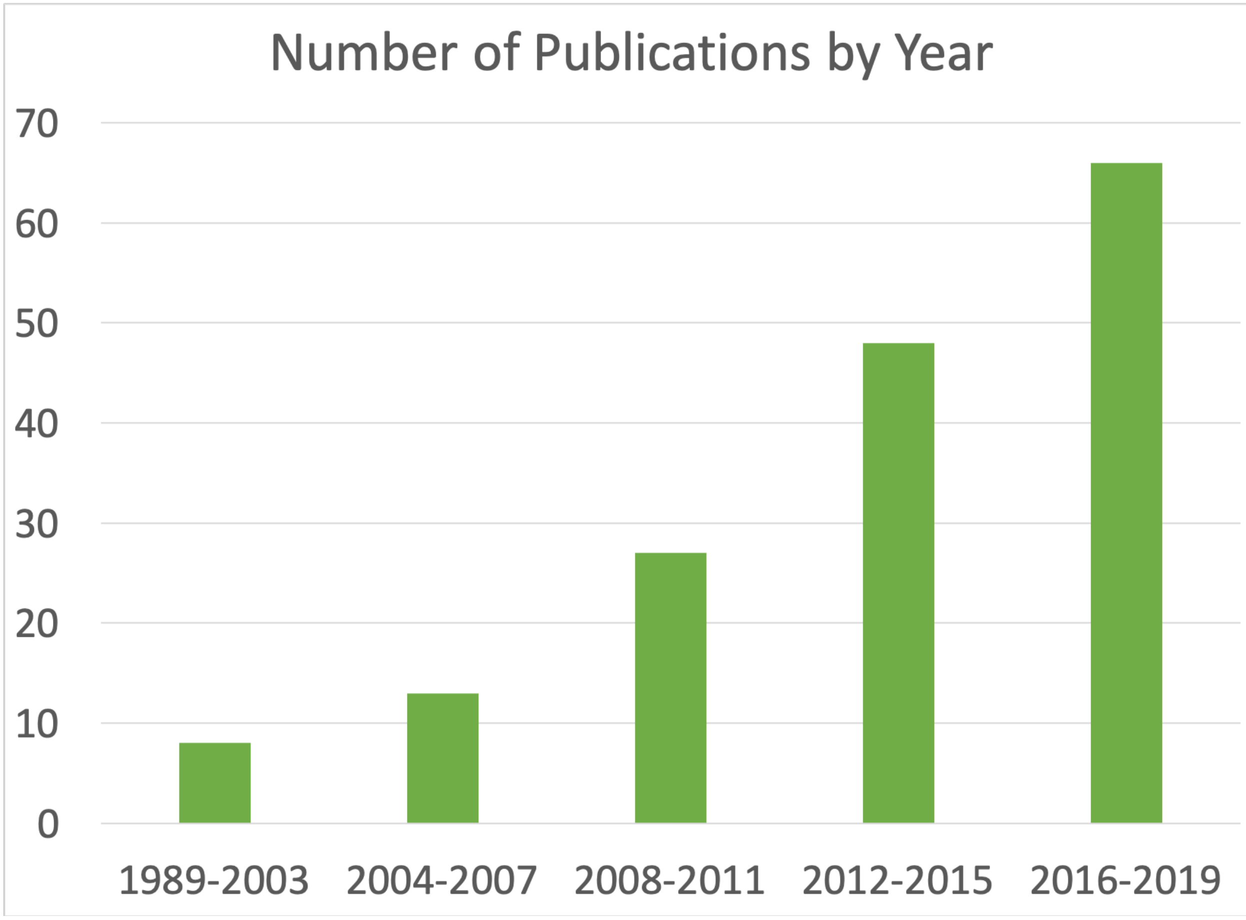

Figure 2.3: Number of publications by year

2.3.3 Literature Contributions

I summarized the contribution of the papers by separating each paper into categories based on the overall purpose of the game or system, as shown in figure 2.4:

General Engagement: The majority of studies (76 papers) created affective games to enhance player experience for a general audience. This enhancement was measured by constructs such as enjoyment, fun, novelty, and usability of the system through the post-game analysis of the physiological records of users or questionnaires [203, 201, 155]. Games designed to enhance immersion, for example, by inducing anxiety, suspense or fear, fall under this category.

Physical Assistance: 32 studies used the affective game for physical rehabilitation, improvement of exergaming, or simply enabling people with severe motor impairments to interact with computers [58, 113, 160]. Evaluation of systems in this section included task performance analysis to determine system functionality, as well as the assessment of physiological signals (e.g. heart rate, breathing) with respect to a target value corresponding to the desired level of physical exertion.

Mental Health: With 47 papers, this category constituted the second most investigated field for affective

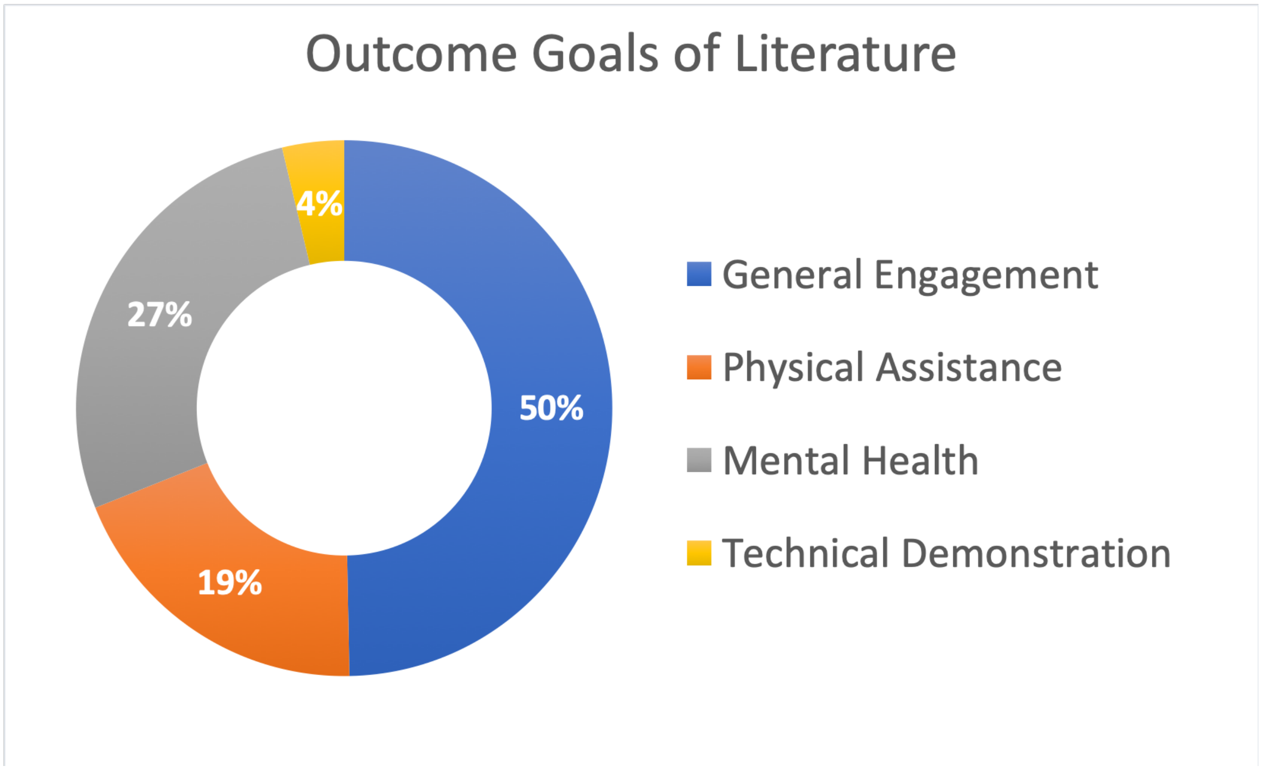

Figure 2.4: Thematic groupings of literature contributions

gaming. These studies used affective games to promote emotion regulation or improve communication skills. The target populations included people suffering from Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), hypertension, or anxiety disorders [11, 48, 12, 150]. Some studies also targeted populations that were not necessarily suffering from an illness, but were prone to high levels of stress due to the nature of their jobs, such as financial decision makers and military service members [21, 106, 35]. Evaluation methods included pre- and post-game psychological tests to assess the symptoms of specific disorders and post-game analysis of physiological data gathered during gameplay.

Technical Demo: 7 papers focused primarily on the technological aspects of the system rather than the affective gaming elements.

The vast majority of studies reported that affective games resulted in improvements in targeted areas, including general sense of engagement/fun/flow, mental health symptoms or rehabilitation goals. In cases where research goals were not entirely achieved, the following themes were identified:

a) Four papers reported that the sensors were either hard to use [224], distracting [14] or uncomfortable [174, 298].

b) Six papers reported that improvements were needed in the system design. Of those, three games did not induce sufficient levels of physiological/affective stimulation or enjoyment in players [11, 46, 89], one was deemed too easy [211], and two needed better strategies to achieve target heart or breathing rates [113, 151].

c) At least three papers reported sensor functionality needed improvements [29, 155, 39].

d) Finally, three papers reported that the systems did not enhance the gaming experience. One was hard to use, tiring and uninteresting [334], one caused frustration, dizziness and anxiety [332], and one had no measurable impact on player experience [66].

2.3.4 Sensing Modalities

In this section, I classify physiological data captured from the player irrespective of physiological input and projection categorizations. I identified five groups of signals used (Heart activity, EDA, Breathing Activity, Facial Expressions through EMG/webcam, and Temperature); Figure 2.5 shows the frequency of use of the signals within the papers. Heart activity was the most commonly used physiological signal in affective games, with 78 instances of use. The frequency of use of EDA, breathing activity, and facial expressions was in the same range, i.e., 45, 48 and 50 times, respectively. Temperature was by far the least frequently used physiological signal with only 9 instances of use. Table 2.1 indicates the physiological signal and the corresponding papers that used that signal, designated by citation number.

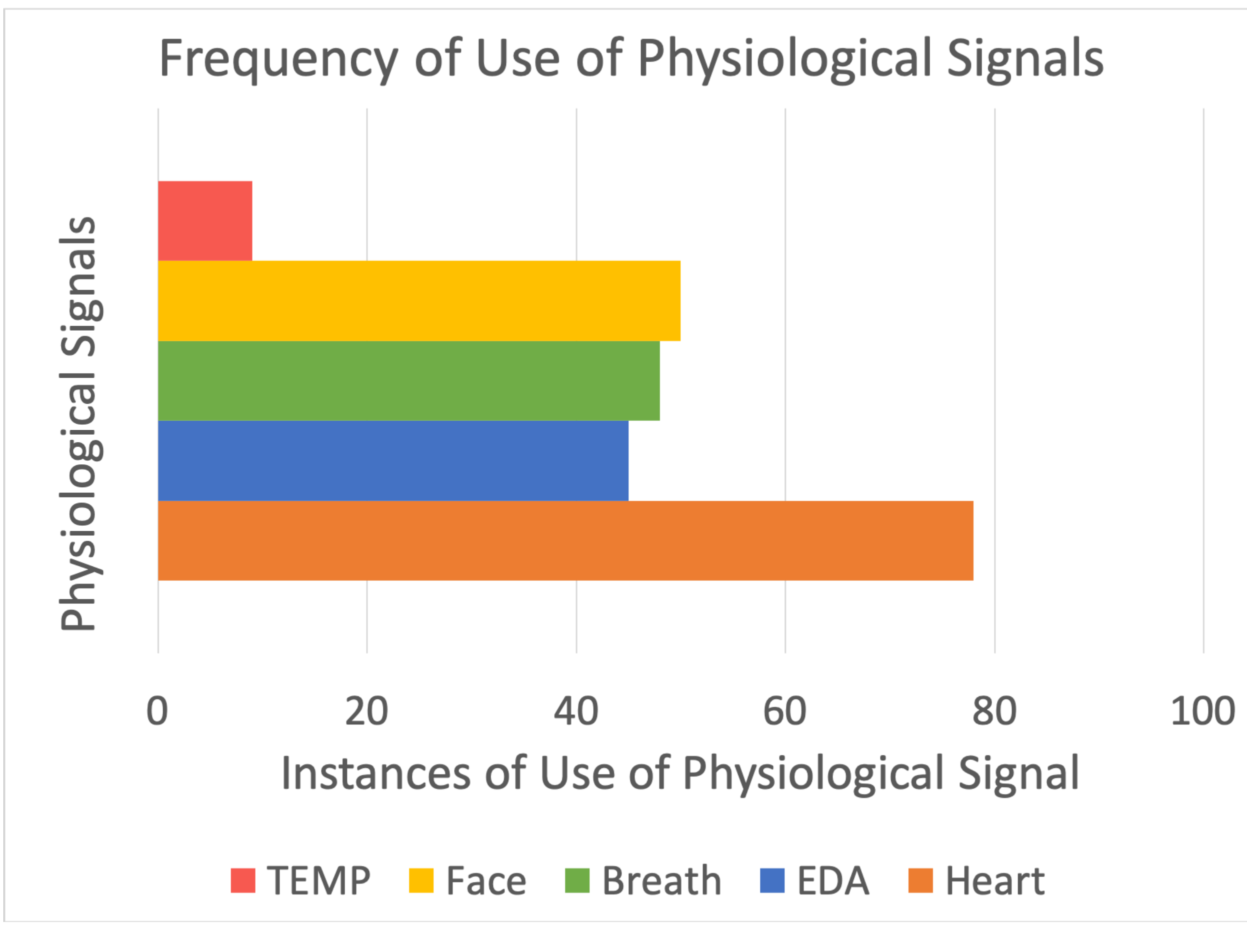

Figure 2.5: Frequency of Use of Physiological Signals

In terms of the sensing hardware used, many papers either used custom-built devices or did not specifically report which device they used to capture the physiology from the player. The more popular known brands used in the studies included the Zephyr Bioharness ($$)—which tracks breathing and heart rate—and the POLAR heart rate monitor ($), used by 12 and 8 game systems respectively. Affectiva SDK (free) was the most popular software used to classify facial expressions, used by 7 game systems. At a higher price point, the FlexComp and Procomp Infiniti devices ($$$$) by Thought Technology Ltd. were used in combination with EDA/ECG/EMG electrodes by 5 game systems each. These devices are encoders which can collect data from up to 10 simultaneous physiological signals, and then send the data to a computer via USB in real-time.

2.3.5 Input Mapping

Games can integrate physiological signals in a variety of ways, which I term input mapping. In reading the papers, I recognized three main categories of approaches for integrating physiological signals into gameplay. When categorizing these papers, I chose mappings that best fit the paper in terms of action-based or context-based mappings. See Figure 2.7 for these mappings situated within the base affective game loop.

Mechanical (Action): Papers in this category used physiological input to control game actions or mechanics, usually performed by the player-character (e.g., the "shaking off or killing a spider" mechanic in the game controlled by the players' arousal, as measured by EDA [334]; the "running" mechanic in the game controlled by the player making a facial expression [316]). These actions are usually those which are usually mapped to a standard keyboard/mouse or game controller.

Environmental (Context): Papers in this category used physiological input to affect the mood or context of the game including but not limited to audio/visual effects, lighting, or weather effects. These were background elements of the game in which the player would usually not have direct control. Examples included adjusting the volume of the game with the player's EDA [14], or increasing the levels of ambient light level when player exhibits positive emotions through facial expressions [34].

Difficulty (Context): Papers in this category used physiological input to influence the difficulty of the game through a range of approaches, including by affecting non-player character (NPC) abilities, player abilities, or background contexts specifically relating to difficulty of the game. This was a context-based mapping that the player would not normally directly control, and was sometimes referred to in gameplay as dynamic difficulty adjustment (DDA) [312]. Examples included raising the number of enemies with the player's affective state [32, 138], or increasing the speed of the air hockey puck based on arousal as indicated by heart rate and breathing rate [58].

I classified each physiological sensor used in each game as one "instance". While Physiological Projection (physiological display to the player) is not itself a form of physiological input or input mapping, I included it here as a classification because it is a way in which physiological data can be collected from the player in the affective game loop. See Table 2.2 for details.

Difficulty was the most commonly-occurring input mapping, with mechanical and environmental having a similar frequency of usage. Physiological Projection had approximately half the use of the other categories within the literature, at 48 instances.

Not all uses of physiological input belonged to a single category, which results in the total number of instances in each category appearing larger than the total number of investigated papers. For example, the game "PerPing" [298], a breathing-controlled variation on the popular classic arcade game Pong, contained physiological signals I classified as mechanical, environmental, difficulty, and projection. Multiple input mappings of a single game can occur in two ways: a) a single physiological signal (e.g., heart rate) is mapped to one element (e.g., fog density) which has multiple effects on the game (e.g., mood—environmental, and reduced vision—difficulty), or b) a single physiological signal (e.g., heart rate) is mapped to multiple separate elements of the game (e.g., fog density—environmental, and enemy damage—difficulty). In the case of "PerPing", a player's breath affected multiple separate elements in the game: Breath rate—how fast the player breathes—affected the paddle size, which is a difficulty mapping; breath flow rate (i.e., breathing hard) affected the speed of the paddle, which is a mechanical mapping. While many mappings were positioned in only one category explicitly, 41 systems fit into 2 or more categories.

2.3.6 Interaction Between Signals and Mappings

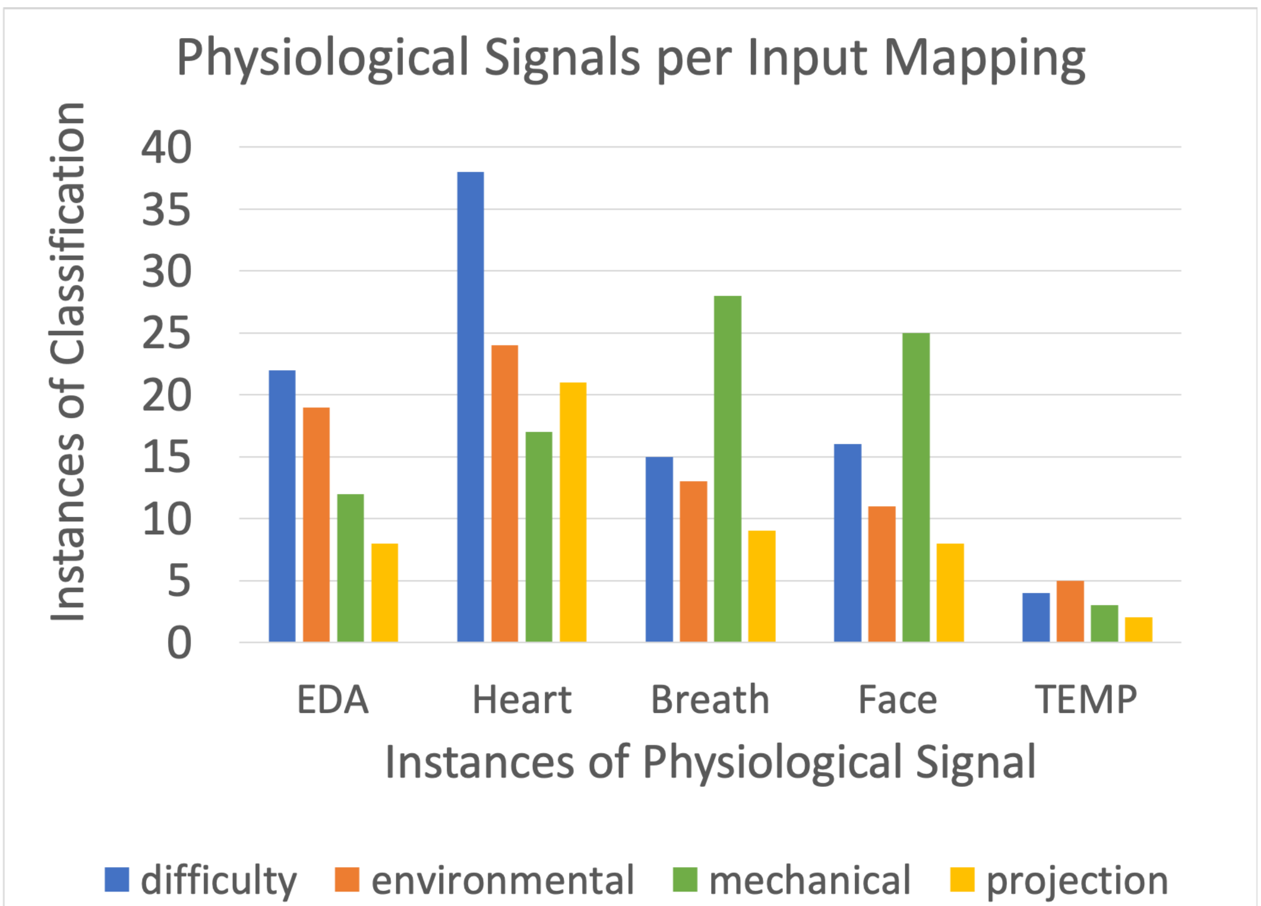

Figure 2.6: Input Mapping per Physiological Signal

I extracted each physiological signal discussed in the literature, and the input mapping of the signal as categorized by the affective game loop framework to determine how these aspects of the loop interacted. Figure 2.6 shows the frequency each physiological input is used, in association with the four input mappings: difficulty, mechanical, environmental, and projection. The figure shows that heart rate and EDA were mapped to difficulty most frequently, whereas facial expressions and breathing were primarily mapped to mechanical. Additionally, temperature was used mostly as an environmental mapping. While projection was implemented the least, it was used most often with heart rate.

To visualize the connections shown in figure 2.6 further, I used figure 2.7 to show the relationship between the player, physiological signals and their input mappings. As the figure demonstrates, I categorized each physiological signal as either direct or indirect input. This categorization, first introduced by [207], is based on the player's extent of control over the manipulation of the signals. The player has direct muscle control over their facial expressions and breathing, as opposed to heart rate and EDA, in which the control is either autonomously responsive to physiological state or mediated by some other factor—like controlling one's thoughts or engaging in rapid movement. I categorized temperature as both indirect and direct inputs since it can refer to either breath or skin temperature; two out of nine studies used breath temperature. The figure also demonstrates that each physiological input can be used in association with any or all of the input mappings. The input mappings shown in this figure are classified as action-based or context-based.

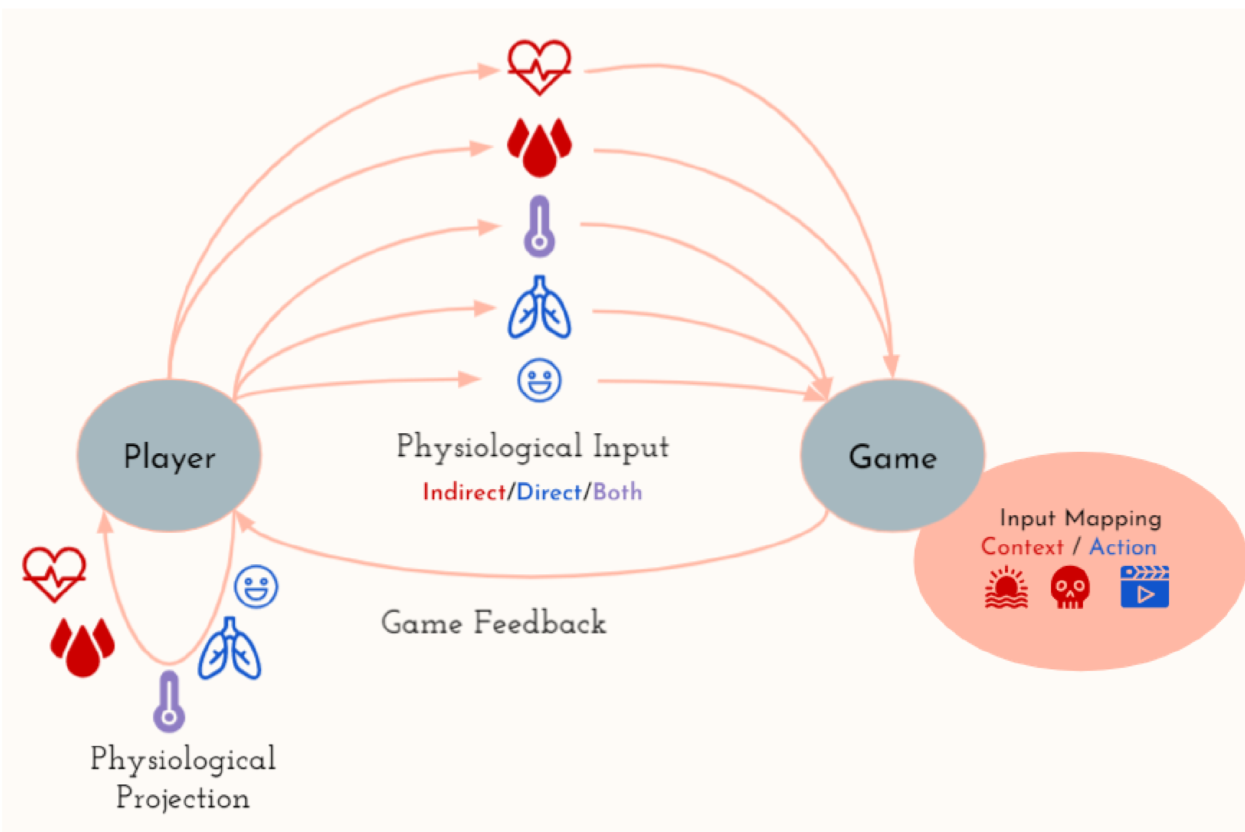

Figure 2.7: Enhanced Affective Game Loop.

The direct physiological inputs and action-based mappings are shown as the same color, as are the indirect inputs and context-based mappings, to indicate the intuitive relationship between the inputs and mappings. This relationship was verified and revealed in figure 2.8.

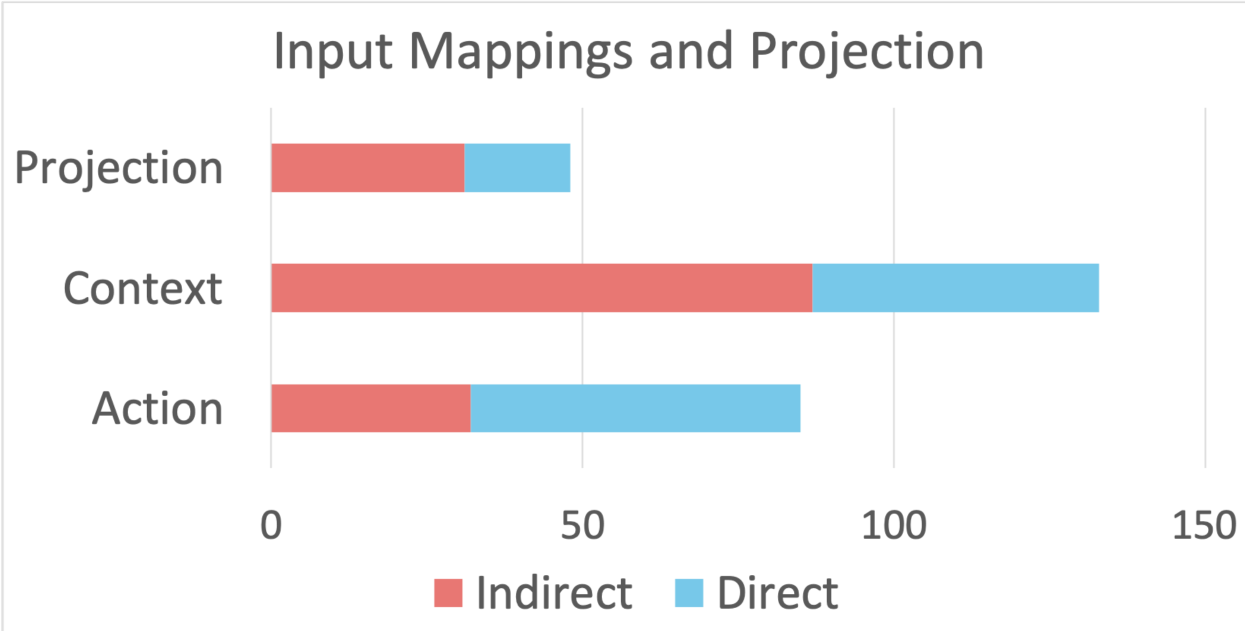

Figure 2.8: Bar chart of Direct and Indirect Physiological Mappings

Looking at the signals grouped into their respective categories (indirect/direct) and (action/context) in figure 2.8, one can see the connection between the type of signal and how it is mapped in the game. The most popular use of directly-controlled input was with action-based mappings and indirectly-controlled input with context-based mappings. Nacke et al. [207] suggested that directly-controlled input might best be used for game mechanics (i.e., action), whereas indirectly-controlled input might best be used for ambient, environmental factors (i.e., context), and the findings demonstrated that the literature generally followed this pattern.

2.4 Discussion

In this section, I discuss implications of the findings and gaps that I observed in the literature. The findings, and therefore the discussion, is a direct result of the categorizations of the included papers within the "Affective Game Loop".

Earlier I asked the question "Has the promise of affective gaming to enhance player experience been realized?" My goal is to explore this question by discussing if, how, and why affective gaming enhances the player experience. I offer newcomers to the field an overview of the published work by providing examples from select papers, discussing objectives of the current research, and possible future areas of exploration in this still-emerging field.

2.4.1 Literature Contributions

Literature Content

The rise in the field of affective gaming over the last 30 years is shown by the increasing number of papers published on the topic. Beginning in 2004, the number of papers published on the topic began to accelerate, which coincided with the release of the Unity 3D Real-Time Development Platform [308], published in 2005. Early papers on affective gaming [158, 159] discussed technological limitations of their work in detail. A paper published in 1992 [159] discussed the specifics of port connectivity between a heart monitor and the computer, as well as indicating the programming that was involved to send a 5-volt DC current from the monitor to the computer when heart rate exceeded a threshold. Even today, as a range of off-the-shelf physiological devices exist (and are more accessible than ever), they either take a lot of work and customization to integrate into digital games, or are produced by major technology companies that only gave researchers access to their Software Development Kits in the past few years—the Apple watch SDK became available in 2015 and Fitbit SDK in 2017.

Figure 2.4 shows that half the literature is focused on engagement for a general audience and the other half is applied—for example, addressing emotion regulation or physical rehabilitation for specific populations. While both areas could benefit from expansion in future work, the large number of applied papers signifies a notable potential for accelerating research in this space. Literature supports that affective gaming is capable of significantly enhancing conventional (both technological and non-technological) rehabilitation and mental health interventions. A notable example is RAGE-Control [136], a game that incorporated heart rate into gameplay to encourage players to maintain emotional control. The game was tested on a group of in-patient children who exhibited high levels of anger and aggression at the psychiatric unit of Boston's Children Hospital, by integrating the game with the children's existing anger control therapy. Historically, children in the unit who had combined State and Trait Anger (SA & TA) scores of 30 or above (out of 60) did not show measurable improvements in anger during their hospitalization and were considered "stuck". However, after just five sessions of playing RAGE-Control, one child was able to reduce her combined SA & TA scores to 30, down from 59.

In terms of rehabilitation, many games leveraged the use of breath as an alternative game controller. One example of this is a serious game that requires players to manipulate a plane up and down, dodging obstacles in a 2D side-scrolling game using only their breath—the goal of which is to encourage patients to perform post-operative breathing exercises [154]. Another paper discusses a 2D side scrolling game called "ChillFish", in which the objective is to collect starfish by moving a fish up and down using a breath-based biofeedback controller. This game is aimed at calming children during blood sampling procedures [280]. Not only did the use of this game have a positive impact on the pain and fear of the children during the blood test, the medical technicians noted that the use of ChillFish was more effective to distract the kids than another alternative passive distraction. Affective games—with the benefit of heightened user engagement—have shown potential for improved outcomes over other types of therapeutic methods.

Literature Outcomes

Generally, the outcomes of the reviewed papers showed that most studies achieved their goals. Constructs such as flow, enjoyment, fun, immersion, and usability were examined, and physiologically-adaptive games improved the player experience compared to non-adaptive games. For some games in which the general purpose was physical assistance, threshold physiological responses (e.g., a target heart rate or breathing rate) were defined based on the desired level of physical exertion. The use of a physiologically-adaptive game helped players achieve and/or maintain the target threshold physiological response and, thus, improved the quality of the physical activity in question. For studies in which the general purpose was for Mental Health Intervention, comparison of pre- and post-game psychological tests, as well as analyzing the physiological data collected during gameplay, showed that affective games had a positive effect on emotional regulation.

While most studies generally yielded the desired outcomes, about 10% of studies (16 out of 162) explicitly stated that aspects of their goals were not realized. Among those, only three studies failed to enhance the player experience after the implementation of the affective component, indicating an ineffective design of the system [66, 332, 334]. Physiological sensors in at least three games (a military gas mask with a breathing monitor as filter [298], Wild Divine lightstone finger sensor [14], and the Mobi system earplugs [174]) were observed to interfere with gameplay in some cases, thus resulting in decreased enjoyment, flow, and immersion in the game. For example, sensors that were placed on the fingers or face of players were thought by players to be distracting or uncomfortable [14, 174]. Sensor functionality was also an issue in at least three studies, leading to non-real time tracking of players' physiological signals, which translated to lowered game control responsiveness. It was therefore observed that non-invasive and well-calibrated implementations of sensors was essential in order to maximize the intended player experience. In addition, several papers reported that players found the games too easy, or their level of stimulation plateaued after some play time. Players in two exergames failed to reach or maintain the target physiological responses. These cases indicate a need for game designers to use the real-time physiological information gathered from the players to iteratively fine-tune game events—in terms of challenge, flow, and unique and engaging experiences—to correspond with players' physiological responses.

2.4.2 Sensing Modalities

Findings showed that the physiological signal used most frequently by researchers overall was heart activity (heart rate variability or heart rate). This preference may be ascribed to the wider availability of sensors (both research and consumer oriented—including Fitbit, Apple watch, Empatica E4 wristband, and Polar heart rate monitors) that measure cardiovascular activity, as well as a higher prevalence of colloquial knowledge regarding the interpretation of such signals as it relates to arousal. The price point of available off-the-shelf hardware may have also been a factor determining which devices were used most often. However, facial expression tracking software such as Affectiva SDK and Insight SDK are available at no cost and used in combination with webcams—making them the cheapest and most widely available of any other physiological sensing device. Nevertheless, facial expressions were used at a similar frequency as EDA and breathing, likely reflecting the relatively poor quality of facial expression technologies [71]. Physiological devices were often custom made by researchers, which suggests customizability of the software was important, as well as cost. TEMP had the lowest usage rate; potential reasons this might have been the case is explained in the "Limitations" section.

2.4.3 Input Mapping & Interaction

In terms of physiological projection, indirect signals were the most prevalent. This was possibly due to the implicit nature of the signal (e.g., players have access to their breathing/facial expressions but might not be aware of their temperature or heart rate), and therefore more interesting to make known than explicit signals like facial expressions. Additionally, this might have been because of the interpretability of heart rate—a visual/auditory/haptic representation of heart rate intuitively makes sense to players over another signal like EDA. Some games [49, 219] used a heart beating sound as an audio projection in the game. Another system called All the Feels [251] displayed heart rate information to Twitch spectators and participants commented that they found the heart rate information the most interesting.

It was shown that indirect physiological inputs (heart activity, EDA) were most commonly used to adapt context-based in-game activities, while direct physiological inputs (breath, facial expressions) were used mostly to control action-based mechanics. Action-based input mappings, such as jumping or shooting, require immediate and on-command responses, which is the most feasible when using a directly-controlled input. On the other hand, context-based input mappings such as difficulty and environmental changes are often subtle, gradual, and implicit game occurrences, making indirect physiological inputs a suitable match.

While this indirect-context/direct-action mapping was the most common and intuitive, there seems to be promise in the opposite: context-based mapping of direct signals and action-based mapping of indirect ones. Studies showed that this pairing of physiological input with game mapping is not only feasible [228], but can enhance player engagement and arousal [32, 173, 212].

Indirect Control with Action-Based Mappings

In a paper by Nacke et. al [207] which used EDA (indirect) for a mechanical (action) mapping, participants comment on using EDA to change the length of the flame on a flamethrower weapon:

> "I liked that it was always a challenge to control just with my thoughts [...] and forced me to use a part of my brain I wouldn't normally use in a video game."

> "I disliked the fact that one of the only ways that I found I was able to use the GSR was by biting my lip which isn't actually all that fun after it starts hurting."

In the same paper, the authors used ECG (indirect) for a mechanical (action) based mapping. The authors asked participants how they felt about using ECG to control the avatar's speed and jump height:

> "I couldn't control as instantly as the others—the effect from it tended to last over longer periods of time."

In another game by Parente et al. [228], participants were instructed to maneuver a continuous line representing their physiological data (EDA, heart rate, and TEMP) through targets on screen. The physiological input (indirect) was used as a mechanic (action) based control. In this case, EDA was the most sensitive means of control, and people in pairs were more successful at controlling the device than individuals.

EDA was seen as the most sensitive signal in a few papers [85, 51] suggesting that it might be the easiest indirect physiological input to use with action-based mappings [60, 41]. EDA was more effective at signifying lower ranges and small variations of arousal, while HR was reported to be more suitable for indicating higher ranges, more prominent levels, and somatic expressions of arousal [36, 51]. Therefore, an appropriate mapping of physiological input considering the level and variation of arousal can enhance the usability of indirect forms of input for action-based game events.

While using indirect signals (heart activity, TEMP, EDA) to control actions may be initially difficult, advances in biofeedback technology can aid players in learning these controls. Indirect signals are usually implicit (e.g., a player may not be aware of how fast their heart is beating), but biofeedback technology makes these signals explicit (e.g., a display that shows heart rate). Combining this technology with games can further motivate and train players to exercise heightened control over their indirect physiological signals (e.g., game play is controlled through changes in heart rate). Pairing indirect signals with action-based mappings in-game offers both novel gameplay, and potential for training.

Direct Control with Context-Based Mappings

In a paper by Blom et al. [32], the authors used facial expressions (direct) as a difficulty (context) based input mapping. In-game difficulty was correlated to distinct player affect (revealed in facial expressions) in a game implementation which was similar to Super Mario Bros. Generally, the personalized adapted game elements were preferred over the control condition (non-personalized difficulty adaptation) in terms of challenge level of play.

In the paper by Nacke et al. [207] discussed earlier, they also tested breathing (direct) mapped to target-size, or a difficulty (context) based mapping. Participants commented on the mappings:

> "it got you more into the game." (P8, Male)

> "[It] felt very natural, particularly when it was tied to target size in the game [...]. It's one I felt I could control to a fine degree." (P2, Female)

A paper by Tennent et al. [298] described a game which used breathing (direct) mapped to fluctuations in the aiming reticle on-screen (context). Players were required to hold their breath to steady their aim, which was indicated as an enjoyable aspect of gameplay. Participants commented on the adaptation:

> "[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."

Both facial expressions and breath activity—while used less for context-based mappings—seemed effective for both action and context mappings.

2.4.4 The Current State of Affective Gaming

Research has seen success in using affective gaming not only for enhancing player engagement, but for rehabilitation and treatment of both physical and mental health problems. However, many studies were preliminary in nature and there has not been gold standard physiological devices or biofeedback games that have emerged for affective gaming within GUR. This gap between research and adoption could be due to the difficulty of customizing sensors for each individual research need. Another reason might be that the GUR community is still a relatively small field; researchers might instead be focused on other domains such as brain-computer interfaces, gesture/movement, or using physiological devices for player experience measurement.

I also found that while a few researchers noted technological limitations (e.g. signal loss, noisy data) with their studies due to the physiological sensors used, most did not. This indicates the efficacy of using widespread physiological technology for affective gaming. While context/action mappings with indirect/direct physiological controls respectively represented the most common case, there is a potential opportunity for growth in the opposite case as well.

In terms of evaluation, for the field to advance, there needs to be a critical reflection on contributions, which means evaluation is a necessary component. I initially intended to present evaluation data, but evaluations were generally lacking in consistency and standards (low N, no control condition, poor statistical treatment). This lack of rigorous evaluation in affective gaming research is a barrier that prevents its advancement as a field.

Most researchers who used physiological devices customized them to their particular need; as both development and calibration of these devices can be time-consuming, I posit that the time spent conducting a user study for research in this domain is high and may slow the research cycle down significantly, meaning it might be less feasible to publish papers at the same rate as other fields. Further, the focus on novelty in contribution may have led to a dearth of formal evaluations. Additionally, the infeasibility of research labs to front expenses for the higher end devices (which are much more accurate than their off-the-shelf counterparts, but expensive) might limit the type of research the labs are able to conduct—as they might not be able to conduct studies in which accuracy of the devices matter (eg. for Physical Assistance or Mental Health domains).

2.4.5 Limitations

Some databases I looked into using, such as SpringerLink and EBSCO host, returned far too many entries (400,000+) in the initial keyword search, so they were not included. I tried to scope the keywords such that they would be narrow enough to not return too many irrelevant papers, but broad enough to capture all the papers matching the inclusion criteria. With over 50,000 articles to screen, I erred on the side of having too many irrelevant papers; however, I feel that this caution provided a comprehensive accounting of the field of affecting gaming.

'Temperature' came up in my classifications, but was not anticipated in advance as it is not common for assessing arousal and valence. Therefore, it was not explicitly included as a keyword in the review, so if temperature was used as the sole physiological signal in the research, and researchers did not categorize temperature as 'physiological' or 'affective', the searches might not have captured these papers.

As far as the variation in the literature, I acknowledge outcome bias relating to the varying sample sizes of each study, study methods, and questionnaire validity. I also acknowledge the potential influence of publication bias, in that research in which the physiological input was not successful may have a lower chance of publication (either through not surviving the peer review process, or not being reported). I did not specifically look at bias as part of the PRISMA checklist, because the research question was exploratory in nature. With this systematic review, I am not making any conclusive claims about the state of the art, or discovering the best way to enhance player experience. Instead, I care about understanding this field from an exploratory perspective, to give recommendations for future advancements.

2.5 Contribution

I explored the field of affective gaming—game play that is influenced by the affective state of the player [97]—by conducting a systematic review to understand if, why, and how player experience is enhanced by integrating physiological sensors into play. I narrowed down an initial set of 52,834 papers to 162 through a systematic process including multiple reviewers, and classified this set of papers using a framework I created called the *Affective Game Loop*. This framework helped me classify the publications into one or more categories based on the system, gameplay experience, and intended purpose. I learned that signals used for Physiological Projection—physiological signals displayed back to the player—are used the most frequently when using indirect signals (i.e., heart activity or EDA), possibly due to the novelty of viewing what is otherwise an obfuscated response. Physiological input was classified into 3 categories: Mechanical, Environmental, and Difficulty. These categories helped me uncover that indirect signals were mostly used for environmental and difficulty mappings, while direct signals (i.e., breathing and facial expressions) were mostly used for mechanical ones. However, I understand that while this was the most common phenomenon, the opposite mapping shows potential and novelty, suggesting an opportunity for innovation. In other words, game designers should consider using breathing and facial expressions for more context-based mappings in their games; EDA and heart activity could be used for more action-based mappings—with an intentional design that takes into consideration that this mapping scheme might be less intuitive for some.

Overall, while the field of affective gaming is still preliminary in nature, researchers who have explored the topic have overwhelmingly found success in their use of physiological input to enhance the player experience. However, formal evaluations are rare and attempts to replicate previous findings almost entirely absent, suggesting that the field is still in its infancy, relative to other domains with established evaluation protocols and standards.

Future work might capitalise on the strengths of affective gaming through the development and adoption of gold standard physiological devices with integration into existing game development platforms like Unity3D. Additionally, the development of an affective gaming software library for researchers and developers would both allow for more easily reproducible research—and reduce the temporal and financial burdens associated with developing and evaluating home-brew systems and artefacts. The unification of research in affective gaming can only benefit the field, and will help to realise its complete potential.

This systematic review asked: *Does affective gaming enhance player experience?* My findings emphatically support the efficacy of physiological input for both improving the experience of play (as measured through constructs such as flow, enjoyment, and immersion), and as an intervention tool in health contexts. While the promise of affective gaming is still not yet fully realised, it is well on its way.

Table 2.1: Papers that used each physiological signal, by citation number

Physiological Signal	**Citation Number**
Temperature (TEMP)	[108, 111, 144, 145, 167, 228, 240]
Facial Expressions (FACE)	[7, 10, 32, 31, 34, 44, 48]
"	[65, 94, 100, 102, 105, 107, 120]
"	[134, 135, 155, 156, 162, 190, 191]
"	[198, 200, 215, 216, 217, 218, 225]
"	[227, 244, 250, 263, 271, 291, 293]
"	[294, 299, 302, 303, 304, 316, 317]
"	[321, 325, 328, 330, 334]
Breathing (Breath)	[12, 19, 20, 28, 31, 56, 58]
"	[59, 83, 101, 128, 132, 151, 153]
"	[154, 199, 203, 208, 209, 221, 224]
"	[232, 233, 234, 236, 237, 280, 282]
"	[292, 298, 305, 313, 318]
"	[331, 332, 333, 334]
Electrodermal Activity (EDA)	[3, 174, 11, 14, 16, 17, 20, 31]
"	[34, 35, 50, 52, 67, 85, 108]
"	[127, 144, 145, 150, 153, 160, 167]
"	[8, 200, 201, 202, 208, 212, 215]
"	[220, 224, 228, 231, 232, 235, 236]
"	[243, 250, 281, 288, 312, 334, 336]
Heart Activity (Heart)	[9, 11, 14, 20, 21, 24, 29]
"	[30, 35, 38, 40, 39, 42, 46]
"	[47, 49, 50, 59, 66, 82, 85]
"	[88, 90, 108, 111, 112, 113, 116]
"	[117, 127, 136, 137, 138, 140, 144]
"	[145, 147, 150, 157, 158, 159, 167]
"	[171, 173, 174, 178, 183, 204, 205]
"	[206, 208, 211, 213, 215, 219, 220]
"	[224, 228, 232, 236, 240, 241, 243]
"	[250, 276, 278, 281, 283, 286, 292]
"	[301, 309, 312]

Table 2.2: Instances of Use of Input Mappings

Category	**Number of Instances**
Difficulty	95
Environmental	72
Mechanical	85
Projection	48

3 In the Same Boat: Design Probe One

3.1 Motivation

People who care about each other, work together, or know one another do not always live in the same location. As social closeness—i.e., feeling connected to others—is vital for well-being [260], building and evaluating tools that connect people over a distance has been a priority for designers and researchers in human-computer interaction (HCI). For example, technology-enabled communication, such as always-on video chat [133], mobile streaming of experiences on-the-go [121], and connected tangibles [146] have helped people feel closer and more connected over a distance. Games and playful activities have long been used to support *co-located* social interactions; pick-up sports leagues or board game nights can help satisfy people's need to feel related to others [261] and create shared experiences that draw people together. With recent technological advances, these shared game experiences can now connect people remotely as well. Gamers spend an average of 6 hours/week playing with others online and 5 hours/week playing with others in person [2]. More than half of frequent gamers report that video games help them connect with their friends and family [2].

Game researchers have been deconstructing online social games to identify their value for relationship formation and maintenance. For example, World of Warcraft (WoW) players maintain preexisting relationships, form new ones, and even find romantic partners [323] in game. Playing games like Second Life [119] or Counter-Strike [126] can generate social capital, and these positive online game communities are associated with offline social support [300] and reduced loneliness [61]. In addition to examining off-the-shelf games, researchers in HCI have been designing novel social games that can be played over a distance; for example, to help people enhance friendships through social network games [327], to enable seniors to connect by playing online poker together [275], and to support children with mobility disabilities to bond through online multiplayer games [109]. Games have even been designed to support players being physically active together over a distance [193, 192].

In this project, I focus on creating meaningful social connections through collaborative play over a distance. To actualize this problem, I restricted the design space to a game that supports people in creating or maintaining intimacy, trust, fondness, and affection over a distance through networked play. With this aim in mind, I created an embodied physiological mirroring game, 'In the Same Boat', designed to foster social closeness. The novelty of this game lies in the need for players to synchronize their physiological data—using respiratory (or breathing) rate, and facial expressions—as a core mechanic of gameplay. I present the design and motivation of the game, plus results from a study with 35 dyads comparing embodied to keyboard controls. I found that playing In the Same Boat fostered the development of affiliation between the players, and that while embodied controls were less intuitive, people enjoyed them more. Further, photos that were taken of participants together both before and after play (under the auspices of record keeping) were rated by independent participants online; dyads using embodied controls were rated as happier and closer, indicating the potential of embodied controls to foster social closeness in synchronized play over a distance.

3.1.1 Affective Game Loop

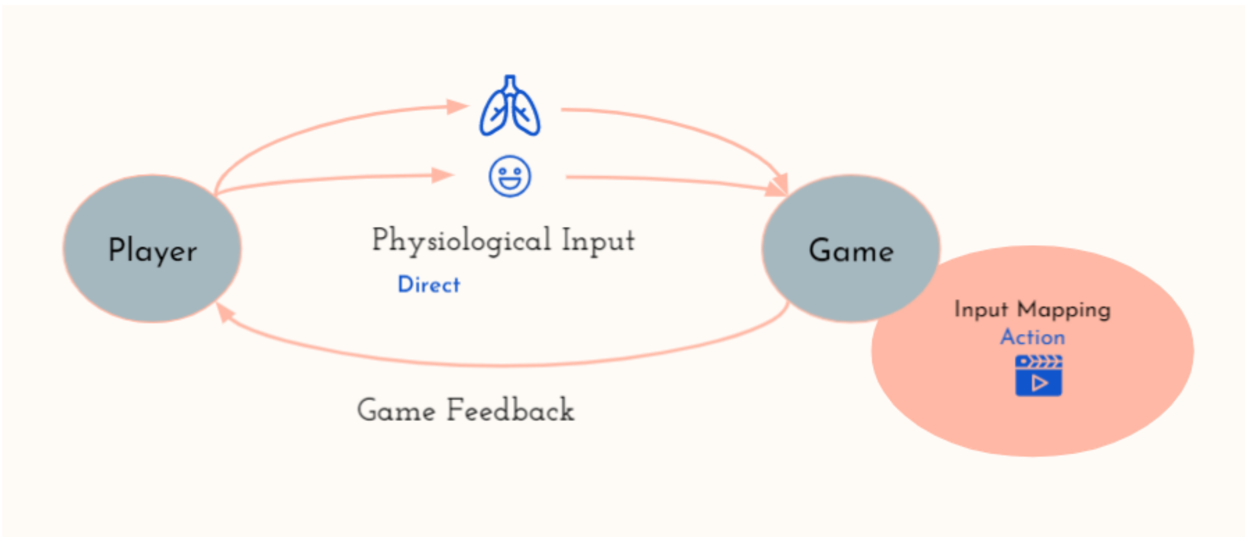

Figure 3.1: In the Same Boat within the Affective Game Loop.

I designed and created an embodied mirroring game—In the Same Boat—to explore social closeness between players over a distance. In the context of the affective game loop (see Figure 3.1), this game explores using directly-controlled physiological signals (breath rate, facial expressions) as a 'mechanical' based mapping (i.e. movement, jumping of the boat).

The aim of this project was to understand how affective games enhance engagement in a distributed play experience. In the Same Boat leverages players' physiological data as input and focuses on the synchrony of this input as the mechanic that realized cooperation and interdependence in the game. In the Same Boat was designed to promote an intimate interaction, by focusing on embodied interaction using physiological input, mirroring emotions through syncing, and networked play. As a first game to leverage physiological syncing over a distance, ITSB has the potential to help geographically-distributed friends, family, and partners to feel closer through playful interaction.

Now that it is apparent the promise of affective gaming hasn't been fully realized (from the systematic review), there also emerged many opportunities to expand the field. I explore gaps in the field by creating two design probes. This project is the first design probe, looking at how synchronized and distributed affective gameplay can enhance player experience.

3.2 Background

Figure 3.2: Two players synchronizing facial expressions

To inform the design choices in the game, I drew inspiration from three areas of related design and research. First, I was inspired by work showing that the mechanics of cooperation and interdependence are effective at fostering social bonding [62, 124]. Second, I leverage the idea of mirroring—i.e., two players synchronizing their movements or expressions—which has been successfully employed in co-located playful interactions designed for collaboration [122, 143]. Next, I make use of embodied interaction—using bodily movements [68]—as an input mechanic, as embodied interaction has been shown to facilitate playful connected experiences [122, 123, 124]. Lastly, I explore the use of physiological input as an intimate form of interaction *over a distance* through facial expressions and breathing. In the upcoming subsections, I first describe the prior work that contributed to the design of the game, and then describe the game itself.

3.2.1 Cooperation and Interdependence

Seif el Nasr et al. created a framework for evaluating cooperative games [270] and proposed the Cooperative Performance Metrics (CPM) to evaluate cooperative patterns in games. While cooperation is an important mechanic when trying to increase closeness felt between players [125, 270, 284, 334], it is not the only contributor to successful social play. To promote social closeness in distributed play experiences, researchers have tried to identify the mechanics of digital social play that best facilitate bonding. Various mechanics have been proposed; asymmetric roles [104], shared goals [255], cooperation [270], closely-coupled interaction [26], and complementary knowledge [73]. To provide guidance to game designers on which mechanics are most effective at facilitating social bonding, Depping et al. [62] scoped and summarized the literature on game design for social closeness and proposed a framework with two dynamics: cooperation (i.e., working towards a shared goal) and interdependence (i.e. how much each player relies on the actions of the other), and showed that these dynamics can be leveraged separately to increase the social closeness felt through games played over a distance [62].

3.2.2 Mirroring

In thinking about game mechanics that leverage cooperation and interdependence, I look for design inspiration from games that use mirroring as a technique—as it has been widely shown to lead to greater feelings of connectedness, mutual liking, and rapport between people [181]. Mirroring is often used in dance/movement therapy [326] and therapeutic relationship interventions [95]. For example, Isbister's game Yamove! [122, 143] is a social dance game in which players sync their physical movements. However, the use of mirroring or syncing as an input to a game has not been extensively leveraged in the design of collaborative games.

3.2.3 Embodied Interaction and Physiological Input

In terms of bodily engagement, researchers have designed various supports for physically-synchronized movement [179, 180, 193, 197]. In 2017, Isbister et al. created interdependent wearables to build camaraderie and connection by design, and to improve co-located social atmosphere and coengagement [124]. In the context of family, Gerling et al. [96] show that playing a cooperative and interdependent motionbased game improves caregivers' bonds with an older adult. To understand the potential of heart rate displays in a social context, Mueller designed an augmented cycling helmet that displayed heart rate data [315]. Höök et al. established methods of Soma (or body) based design [115], and Márquez-Segura expanded on this work by developing methods for designing bodily interactions such as embodied sketching [179], bodystorming [269], and co-creating bodily experiences with users [180]. Simon coined the term "gestural excess" in his 2008 work 'Wii are out of Control' [277]. This term describes the phenomenon that for many players, the fun lies in moving the body and performing funny or silly gestures in front of other players, above and beyond what is required to drive the programmed gameplay. In this work, I use facial expression synchrony as a large design space for this gestural excess to occur amongst players. Bianchi-Berthouse et al. [27] propose that bodily engagement in play can both enhance engagement with the game and facilitate an affective—i.e., emotional-experience. Because embodied interactions and physiological input have been shown to increase social closeness amongst people [251], I was interested in using these as the mechanics to realize mirroring in the game. There are many ways to embody interaction, and I view physiological input as one form of embodied interaction (i.e., a subcategory). I see physiological input as a very intimate form of embodied interaction, and I use it here as a means to reinforce and heighten both bodily engagement and interdependence in the game. Physiological input has been used in other games as a novel input approach, designed to enhance engagement through intimate interaction with the system. For example, Nacke et al. [207] built a system in which a game played using a traditional controller is augmented using both direct (e.g., facial expressions) and indirect (e.g., galvanic skin response) physiological sensor input. In other work that combines both physiological signals and bodily movement as input to the game, Zangouei et al. [334] created an emotional game experience for co-located players in which they solve riddles to progress.

3.2.4 Playing over a Distance

Most of the prior work described above—especially the games that use embodied or physiological input—primarily place an emphasis on the co-located game experience. However, there have also been games designed to support interaction over a distance—e.g., Mueller's framework for exertion interactions over a distance [193] described games such as table tennis for three [194], jogging over a distance [195] and sports over a distance [196]. These games are playful exertion experiences that were designed to connect distributed players through exertion.

This work expands on this reported prior work by combining collaboration mechanics, embodied interaction (through physiology), mirroring, and networked play. Lastly, 'liking' and 'trust' have been investigated before in various contexts over a distance, and games appear to affect the way in which these interpersonal connections manifest (e.g. [57, 62, 64]). Those games, however, did not utilize embodied interaction and physiological input.

3.3 Designing 'In the Same Boat'

To explain my design intent and decisions, I will use the Mechanics-Dynamics-Aesthetics (MDA) framework [110]. According to MDA, mechanics are the specific rules, actions, and behaviors a player is afforded and how the system responds (e.g., limited time to complete an action). Dynamics are the experiences resulting from execution of the mechanics and the interactions between them; for example, limited time (mechanic) might result in the experience of urgency (dynamic). Finally, aesthetics are the emotional experiences evoked in the player as a result of the dynamics.

I aimed to achieve a player aesthetic of connection and intimate interaction, achieved through the use of physiological and embodied game mechanics that created interdependent and cooperative dynamics between players.

3.3.1 Requirements

I first describe the requirements for a game designed to foster social closeness, and then discuss how they were realized in terms of gameplay in the next section.

Gameplay

The requirements of ease-of-use and reliability shaped my decision-making about the control mechanisms for the game as well as the selection of genre.

Cooperation and Interdependence

Prior work showed that a game with both cooperative and interdependent dynamics is one of the best ways to foster trust development amongst players [62], so I considered the best way to maximize the cooperation and interdependence dynamics of the game. This informed my choice of overall goals, primary mechanic, and objectives of the game.

Embodied Interaction and Physiological Input

Embodied interaction has been shown to facilitate the aesthetic of social closeness in prior work [251, 315], and I was interested in expanding this idea by using players' physiological input as an alternative controller. A key design decision I faced was choosing which types of physiological devices would be easy for players to use and make sense of rapidly in a collaborative play situation, and would also be reliable input mechanisms.

3.3.2 Game Design

Gameplay

I chose the endless runner genre because of its popularity in recent years due to mobile games like Temple Run [1], making it accessible for the average smartphone user. With the genre's current widespread familiarity, it is easy for most players to pick up the control scheme quickly, supporting my design requirement of having easy-to-use game controls.

Cooperation and Interdependence

In developing mechanics that maximize interdependence, I considered real-life activities in which two people heavily rely on each other. I decided on canoeing because this activity is not only interdependent, but also highly cooperative. In canoeing, it takes two or more people synchronizing their stroke rate in order to keep their speed constant when traveling down river. I heightened interdependence by making each player directly responsible for their "side" of the canoe. I focused the game on the core mechanic of players synchronizing their inputs. Prior work suggests coordinated action leads to a heightened sense of social closeness [123], so this choice of mechanic supports my aesthetic goals as well. In line with my design goals, I implemented mirroring as a mechanic that realizes the coordinated action dynamics that are present in physical-world canoeing. My choice of the infinite runner genre further emphasizes the impact that syncing has on the gameplay; failing to sync your control with the other person in time will cause you to lose the game and force you to restart. This puts primary focus onto the interdependence of the gameplay—the players rely heavily on each other to progress in the game.

Embodied Interaction and Physiological Input

I chose to implement physiological input in the game to further enhance cooperation and interdependent dynamics. I used primarily explicit physiological signals, as these are the easiest to control for a fast-paced game environment such as an infinite runner. Implicit signals are ones that cannot be directly controlled (i.e., heart rate) and explicit signals are ones that can be directly controlled (i.e., facial expressions, breathing rate) [207]. I initially designed the game to allow players to choose a signal: heart rate (implicit) or breathing rate (explicit); however, I found during playtesting sessions that heart rate was too difficult to control. In terms of social signaling in the physical world, people can generally sense others' implicit signals through non-verbal and facial cues, and explicit signals through verbal and facial cues [43]. Certain neurons activate when watching movements that others make; these same neurons also fire when one make the same movements that others make [123], and these neurons map the correspondences between the observed and performed actions [214]. Additionally, in line with Nacke's findings [207] that direct physiological sensors should be mapped intuitively to reflect an action in the virtual world, I mapped the direction of the canoe's movement to the sync between the players' breathing rates. While there is some subjectivity with intuitive mappings due to individual differences [188], my overall goal with the controls was to create less abstraction between the task (canoeing) and the action to achieve it (body-based controls). Humans are more practiced in breathing and making facial expressions than using a mouse and keyboard, therefore use of these controls should feel more natural [188]. This is further in line with the types of bodily activities needed for real-life canoeing. I chose to have higher breath rate represent higher pull (i.e., steering) on a player's side of the canoe. Both players must maintain a similar breath rate so the canoe would not steer to one side or the other, and to navigate purposefully around obstacles. Keeping track of this and managing breath rate together would require a great deal of coordination. This could facilitate a greater sense of cooperation, concentration, and engagement amongst players.

For the initial prototype, I focused on more positive emotions to control the most frequently triggered aspects of the game, as research has shown that making a particular facial expression can induce that particular emotion [123] and I wanted to create an overall positive experience. In terms of MDA, an example of an in-game mechanic could be making a happy face. A dynamic that emerges is both players making happy faces together. The aesthetic experience that might occur out of this experience is evoking happiness and shared laughter. I supplemented these with a few select expressions (disgust and surprise) that were easy for the system to recognize for events that were triggered less rarely. When a player needs to make a facial expression to dodge the obstacle, emojis corresponding to the facial expression display alongside the river. Then, the players must make this expression (shown as an emoji on the bottom of the screen), which makes the necessary in-game control occur (i.e., making a Joy expression translates to the boat jumping).

3.3.3 'In the Same Boat' Gameplay

In this section, I describe the game design in terms of how embodied synchrony was realized in the game.

The game is a two-player infinite runner, with a randomly generated never-ending map, played over a network. Players use their physiological input to control a canoe traveling down a river, while dodging obstacles along the way (see Figure 3.2). The two players must sync their facial expressions to dodge obstacles that occur in the middle lane of the river, and they must sync their breathing rate to remain in the middle of the river. If they fail to synchronize in time the canoe will move to either the left or right portion of the river which has more obstacles; therefore, increasing difficulty.

For this version, the on-screen camera displays the player's own face back to them, and an emoji representation of their partner's current facial expression displays at the bottom right of the screen. I use the Affdex facial recognition software [187] to detect levels of Joy, Sadness, Fear, Surprise, Disgust, and Anger of each player. An emoji was chosen as the representation of the partner's face due to the universality of emojis as representations of emotion across cultures [273], as well as technical limitations of the Affdex software. I chose Joy, Disgust, and Surprise as the main emotions of the game. If 'Joy' is triggered by both players at the same time (see Figure 3.3), the canoe will jump, 'Disgust' will trigger duck, and 'Surprise' will collect a power-up. Figure 3.5 depicts screenshots of both players syncing a disgusted facial expression to duck under a log. The controller mappings are such that the front player (in the canoe) controls the right side of the boat and the back player controls the left. If the front player paddles faster (i.e., their breathing rate increases), the boat begins to turn left. The same mechanic applies to the player in the back. If either player's breathing rate decreases significantly, both players need to quickly sync their breathing rates back up to one another in order to move back to the middle path.

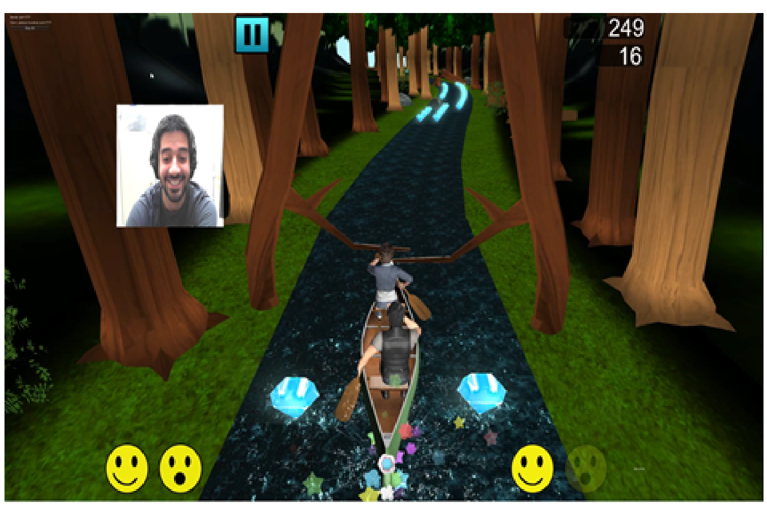

Figure 3.3: Players jumping over a tree branch.

3.3.4 Game Setup/Hardware

The game setup includes two seated players connected over the network on voice chat. In front of them is a webcam, the game on the screen, and the breath sensor (see Figure 3.4). I built the game using the Unity 3D game engine. I used the Affdex Facial Recognition software by Affectiva [187] to capture each player's facial expressions through a webcam, and the Affdex SDK package for Unity. For the breath sensor, I used the built-in microphone on the Adafruit Circuit Playground. The Circuit Playground Express by Adafruit[1] was used as the base of the biometric controller due to its price point, relative availability, and the high number of features built into the board. With the future goal of allowing easy distribution of instructions and part lists online, it was important to have a low-cost board that has a high degree of function out of the box. The current hardware allows other control methods to be explored without requiring a physical redesign. The features of the circuit playground allow for flexible design of custom hardware during development. In addition, the sensors and built-in features of the board would allow for a fully-functional version of the game that would collect heart rate and breathing rate using the board alone.

Figure 3.4: Gameplay setup.

3.4 Experiment

Following pilot tests, I conducted a between-participants experiment with 70 participants paired into groups of two, called dyads. This study was meant to inform the continued design of the prototype and find out

[1]https://www.adafruit.com/

whether my design goals—enhancing the social play experience and fostering social closeness among players—were met.

3.4.1 Game Versions

I designed two versions of the game, for the purposes of comparing the state of the art (keyboard controls) to this new control scheme (embodied controls). The first version of the game was the embodied controls version, in which participants used their facial expressions (joy, disgust, surprise) to maneuver over obstacles (see Figure 3.5). Breathing into the microphone on the Circuit Playground moves the canoe left and right in the river. The second version of the game was the keyboard controls version, in which participants used the up/down arrow keys to maneuver over and under obstacles. Left and right arrow keys on the keyboard moved the canoe left and right in the river. The players' goal in both versions was to maneuver the canoe down the river, dodging as many obstacles as possible. If they failed, they crashed into an obstacle and restarted the game.

Figure 3.5: Embodied & Keyboard controls game versions.

3.4.2 Participants

I recruited seventy participants (N=70) from the University of Saskatchewan. Game condition was randomly assigned and balanced (Embodied=36, Keyboard=34). Ethical approval was obtained through the University ethics board, and participants gave consent before participating. Participants were all between the ages of 18 and 41 (M=25.77, SD=5.40). Although the survey items were completed by individual participants, their individual ratings are subject to the experience of being in a dyad with another participant. Therefore, I asked them to describe their relationship to the other player when they arrived. Most participants were strangers, with a few pairs who knew each other beforehand. Type of relationship was balanced across versions of the game. There was reasonable, but not exact balance in terms of gender across conditions because participants were randomly matched and randomly assigned to groups. In the embodied condition there were 4F-F, 7M-F, 4M-M, 1M-No answer, and 2M-Non binary. For keyboard, there was 3F-F, 5M-F, and 9M-M. Participants were given a $10 honorarium for 1 hour of participation.

3.4.3 Apparatus and Location

Two separate stations were set up in different rooms of the testing lab (Figure 3.6) and participants were able to talk to each other over voice chat. Gameplay (audio/video) was recorded using Open Broadcasting Software. The game is meant to be played over a network between distributed players, so this setup was meant to mimic a context in which players are not co-located.

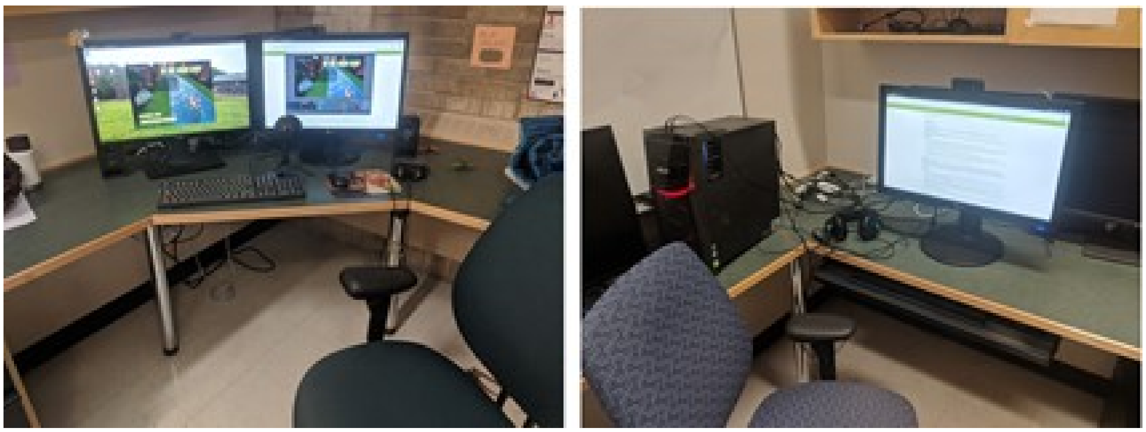

Figure 3.6: Test setup.

3.4.4 Procedure

After participants arrived, I briefed them about what was expected of them (playing the game with their partner for 10 uninterrupted minutes). A photo was taken of both players together using the experimenter's phone, and participants were told that it was needed it to keep a record of who had played together. Next, they completed the consent form, which included information regarding intended usage of their photos, propensity to trust scale, and affiliation scale. For the groups that played the embodied controls version of the game, I introduced participants to the facial recognition software used in the game. I had them practice successfully making joy, disgust, and surprise facial expressions, coaching them with suggestions if they struggled (e.g., "Try raising your eyebrows"). I was concerned about the difficulty of the embodied control scheme, so I additionally administered a tutorial to half of the groups to see if this influenced performance.

The tutorial included the same base gameplay as the multiplayer version, with the absence of the syncing mechanic (i.e., a single-player version of ITSB). I introduced a tutorial in both the keyboard and embodied control conditions for consistency, so players in each condition became familiar with their respective controls either through the tutorial or when playing together. I balanced tutorial inclusion across conditions (Embodied=7 groups, Keyboard=8 groups). The groups who received the tutorial were then instructed to play for 5 minutes at their separate stations. To play the game, both players were connected over voice chat to their partner for the 10-minute gameplay period in which they played the synchronized version of the game. Once finished, they completed the post-play questionnaires and were brought back into the same room. I told them the first photo I took was blurry and asked to take another. Finally, they participated in a retrospective interview together, and were given an opportunity to leave comments.

3.4.5 Measures

I gathered subjective responses to measure participant experience, social closeness, and demographics. Responses from each scale were measured using a 7-point Likert scale from Strongly Disagree to Strongly Agree, except Propensity to Trust, which was measured on a 5-point scale. Objective measures included gameplay data.

Affiliation

A variety of criteria are relevant for evaluating how players experience social interactions, such as willingness to cooperate, interdependence, trust, and supportiveness [62, 64]. I summarize these qualities under the umbrella term affiliation, which I measure using an 11-item scale used in previous work on social closeness in games [62]. I tested the scale on the data and found it to have excellent internal consistency ($\alpha = .952, M = 5.46, SD = .93$). I administered this scale to participants before and after playing the game.

Player Experience

To gather play experience, I measured interest/enjoyment, effort/importance, pressure/tension, and perceived competence using the Intrinsic Motivation Inventory (IMI) [181], which has been used in games research effectively [62, 64]. I additionally used two dimensions of the Player Experience of Needs Satisfaction (PENS) scale: relatedness and intuitiveness of controls [249] to measure aspects of player experience not captured by the IMI.

Propensity to Trust

I measured propensity to trust as a trait [329] as propensity to trust is an indicator of people's likelihood to feel affiliated toward another player. The 6-item scale asks participants to rate statements such as "Most people are basically honest." I administered this scale to participants before playing.

Ten-Item Personality Inventory (TIPI)

I assessed personality using the TIPI [72], which measures the personality dimensions extraversion, agreeableness, openness to new experiences, conscientiousness, and neuroticism, commonly known as the Big Five [110], using 10 items. I included this primarily to control for differences in personality between the groups that could influence their behavior (e.g., extraversion, agreeableness).

Before/After Image Ratings of Connectedness and Affect

Using third-party observers to rate before/after photos of participants has been used effectively in the psychology domain for personality traits [290] and relationships [262], so I decided to employ a similar method in my work. I took a photo of both participants together both before and after the experiment, justified in that I needed a record of who played together, and that the first one was blurry. To rate the before and after images, I conducted a separate study in which I asked online participants to rate: "How close do these people seem to be?" from 1 (total strangers) to 100 (very close); and "How happy do these people seem to be?" from 1 (unhappy) to 100 (very happy). I gathered these ratings using Amazon's Mechanical Turk (AMT), which has been shown to yield good data in HCI studies when precautions are taken [62, 64]. The AMT workers were compensated $1.50 for the 5-10-minute task. Gender was balanced for the AMT raters across sets of photos (19W, 30M rated one set and 19W, 32M, 1 Non binary the other). Photos were divided into two sets that each contained a mix of before and after photos, with the two photos from an individual dyad split between the two sets. Sets were used so that no individual participant reviewed both the before and after photo of a given dyad. I had 106 participants provide photo ratings. To ensure quality ratings, I filtered out any participants who answered too quickly (n=1), leaving ratings from 105 participants.

High Score

High score was determined by the longest amount of time each dyad played before they failed, which I deemed a good indicator of success in the game. High score is depicted in the upper right corner of the screen (see Figure 3.5) and is represented in number of milliseconds.

3.4.6 Data Analyses

For all analyses and graphs, I used the programming language R. The data are parametric and therefore satisfy the assumptions of ANOVA.

3.5 Results

I categorize the findings by the dependent variables, grouping gameplay measures, player experience measures, and measures relating to affiliation. I then present findings from the retrospective interviews conducted after the play session. Because participants are in dyads and their experiences (thus their ratings) are dependent on another participant, I conducted an inter-rater reliability analysis over the subjective ratings using Cohen's kappa to determine how much each participant in a dyad was in agreement with the other. The result was less than slight agreement (M_k=0.05); because the average kappa value did not meet the recommended value for moderate agreement (K of 0.40), each participant's self-reported ratings were treated individually in subsequent statistical tests.

3.5.1 Group Demographics

Because of the between-participants design, I wanted to ensure that there were no systematic differences in personality trait variables between groups that could affect their experience and affiliation. A two-way MANOVA with controller (embodied/keyboard) and tutorial (on/off) as between subjects-factors on extraversion, agreeableness, conscientiousness, neuroticism, openness, and propensity to trust showed no main effects of tutorial ($F_{6,61} = 0.78, p = .593$) or demographic controls ($F_{6,61} = 0.45, p = .844$) and no interaction ($F_{6,61} = 0.63, p = .709$). Further, I inspected the Univariate results and found none of the main effects or interactions to be significant (all p>.05). Thus, I do not consider these demographic traits further.

3.5.2 Gameplay

I randomly assigned 18 dyads to the embodied controls condition, and 17 dyads to the keyboard controls condition. I characterize each game restart as a "round" of the game. The groups using embodied controls played an average of 21.83 rounds (SD=3.798), and groups using keyboard controls played 17.71 (SD=3.597). I conducted a two-way ANOVA on high score (i.e., time of the longest round in milliseconds) with controller (embodied/keyboard) and tutorial (on/off) as between subjects-factors. There was a significant main effect of controller, showing that groups using keyboard control performed better than groups using embodied controls ($F_{1,66} = 12.26, p = .001, \eta^2 = 0.16; Keyboard_{mean} = 812ms, Embodied_{mean} = 502ms$). There was no effect of tutorial ($F_{1,66} = 0.25, p = .616$) and no interaction of tutorial and controls ($F_{1,66} = 0.35, p = .558$).

3.5.3 Player Experience

I present the PENS scale first, followed by the IMI.

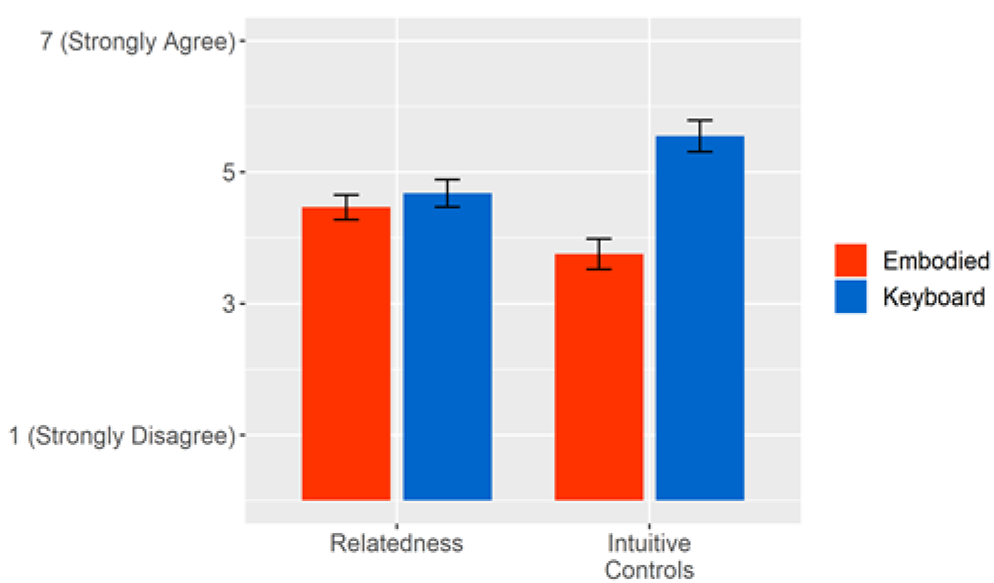

Figure 3.7: PENS Bar graph

Intuitive Control

A two-way ANOVA on intuitive control with controller (embodied/keyboard) and tutorial (on/off) as between subjects-factors showed a main effect of controller ($F_{1,66} = 30.24, p < .001, \eta^2 = 0.31$). Figure 3.7 shows the mean (±SE) ratings for Player Experience of Needs Satisfaction (PENS) subscales (separated by condition). As Figure 3.7 shows, participants playing the embodied control version rated the intuitiveness of the controls lower than participants playing the keyboard control version. Embodied versus keyboard control explained 31% of the variance. There was no main effect of tutorial ($F_{1,66} = 3.44, p = .068$) and no interaction between tutorial and controller ($F_{1,66} = 2.08, p = .154$).

Relatedness

A two-way ANOVA on experienced relatedness with controller (embodied/keyboard) and tutorial (on/off) as between subjects-factors showed no main effect of controller ($F_{1,66} = 0.74, p = .391$) or of tutorial ($F_{1,66} = 1.18, p = .281$), and no interaction between tutorial and controller ($F_{1,66} = 0.04, p = .844$); see Figure 3.7.

Intrinsic Motivation

Experienced satisfaction of needs within games is theorized to lead to greater intrinsic motivation [260, 261]. The intuitiveness of controls in the PENS scale is an antecedent of experienced competence [261], which leads to enjoyment [261]. I conducted a two-way MANCOVA on enjoyment, effort, competence, and pressure with controller (embodied/ keyboard) and tutorial (on/off) as between subjects-factors and intuitive control as a co-variate (see Figure3.8, which shows the estimated marginal means (±SE) for Intrinsic Motivation Inventory (IMI) subscales (separated by condition)). Because the embodied controls were rated as less intuitive to use in the study, I controlled for intuitiveness of controls in tests of intrinsic motivation.

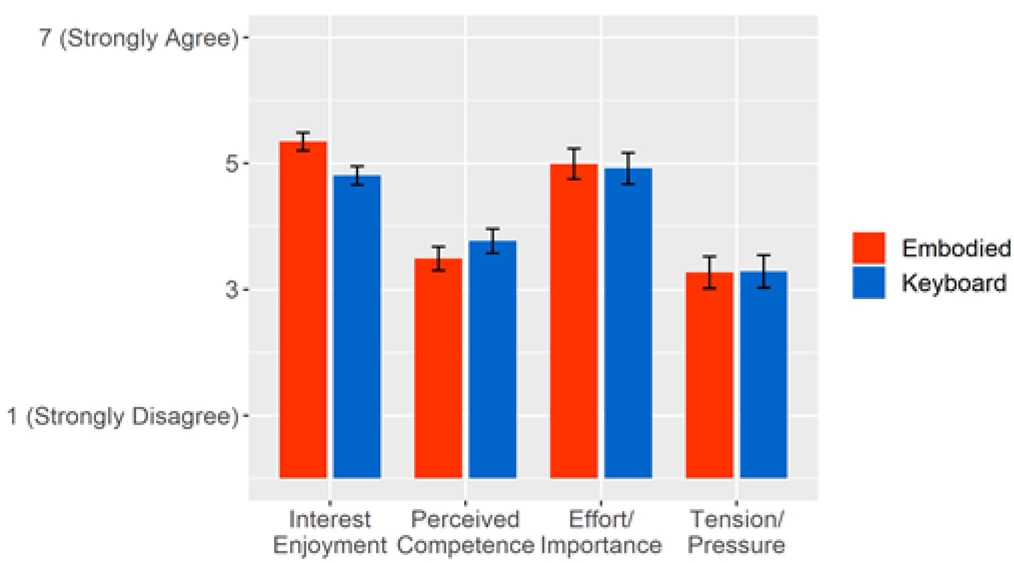

Figure 3.8: Bar graph of IMI

Pressure/Tension: There was no main effect of controller ($F_{1,65} < 0.01, p = .967$) or of tutorial ($F_{1,65} = 0.55, p = .460$), and no interaction between tutorial and controller ($F_{1,65} = 0.04, p = .847$) on pressure/tension.

Effort/Importance: There was no main effect of controller ($F_{1,65} = 0.04, p = .847$) or of tutorial ($F_{1,65} = 0.27, p = .603$), and no interaction between tutorial and controller ($F_{1,65} = 0.10, p = .749$) on effort/importance.

Perceived Competence: There was no main effect of controller ($F_{1,65} = 0.90, p = .346$) on perceived competence. There was a significant main effect of tutorial ($F_{1,65} = 4.48, p = .038, \eta^2 = 0.06$; Tutorial: mean=3.53, SD=1.37, No Tutorial: mean=3.76, SD=1.07), showing that participants felt more competent when there was no tutorial provided. This was a small effect, explaining only 6% of variance, but can be potentially explained by participants attributing their performance more negatively to themselves [63] when having played both the single-player and multi-player versions. There was no interaction between tutorial and controller ($F_{1,65} = 0.11, p = .747$) on competence.

Enjoyment/Interest: There was a main effect of controller ($F_{1,65} = 5.81, p = .019, \eta^2 = 0.08$) on enjoyment. As Figure 3.8 shows, participants enjoyed the game more in the embodied version than the keyboard version, although controller only explained 8% of the variance in enjoyment. There was also a significant main effect of tutorial ($F_{1,65} = 17.27, p < .001, \eta^2 = 0.21$; Tutorial: mean=4.76, SD=0.94, No Tutorial: mean=5.40, SD=0.72), showing that participants enjoyed the game more when there was no tutorial provided (explaining 21% of the variance). There was no significant interaction ($F_{1,65} = 3.00, p = .088$) on Enjoyment. Participants rated affiliation to their partner both before and after playing. I conducted a repeated-measures ANOVA on affiliation ratings before and after, with controller (embodied/keyboard) and tutorial (on/off) as between-subjects factors. Interaction effects were explored using Bonferroni-corrected pairwise comparisons.

Affiliation

There was a significant main effect of time ($F_{1,66} = 13.70, p < .001, \eta^2 = 0.17$), showing that ratings for affiliation increased after playing ITSB (see Figure 3.9). There was also a significant main effect of controller ($F_{1,66} = 7.16, p = .009, \eta^2 = 0.10$), showing that keyboard controls were higher in ratings of affiliation, but this needs to be interpreted in light of the significant interaction of controller and time ($F_{1,66} = 4.12, p = .046, \eta^2 = 0.06$). Figure 3.9 displays the mean (±SE) ratings for affiliation (by condition). As Figure 3.9 shows, affiliation increased in the keyboard condition ($p < .001$), but not with embodied controls ($p = .240$). There was no main effect of tutorial ($F_{1,66} = 0.79, p = .377$), no interaction between tutorial and time ($F_{1,66} = 0.19, p = .666$), and no 3-way interaction ($F_{1,66} = 0.59, p = .444$).

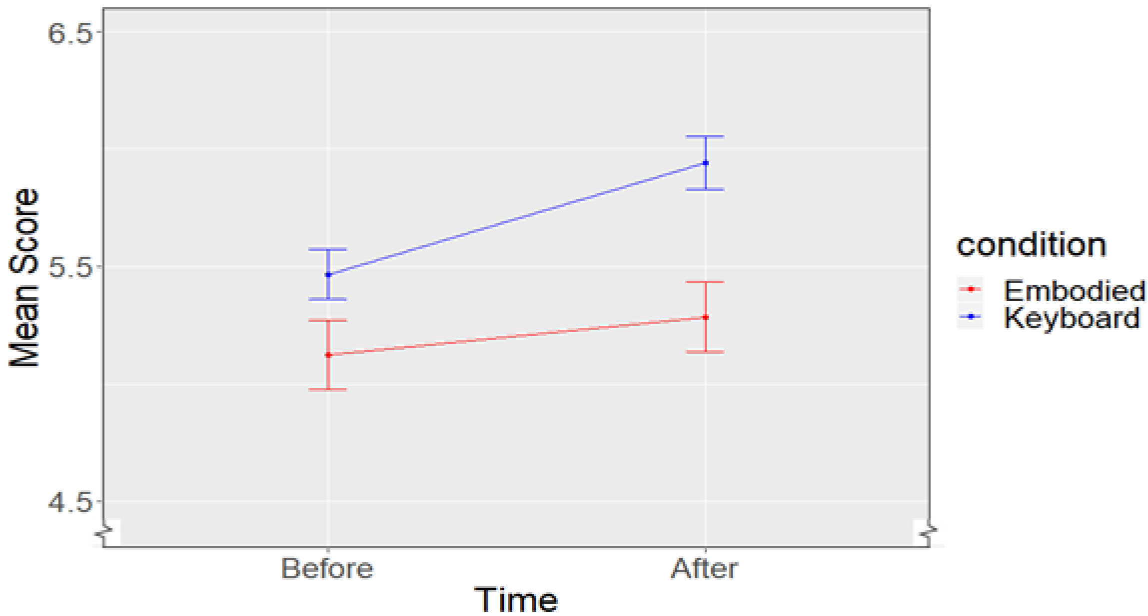

Figure 3.9: Bar graph of Player Affiliation

Before/After Image Ratings

As an objective measure of affiliation, I considered the photo ratings. I first ensured that both groups of raters did not have any significant differences in their overall ratings for closeness ($F_{1,101} = 0.62, p = .43$) or happiness ($F_{1,101} = 2.08, p = .15$). I conducted a two-way ANCOVA on the mean ratings of closeness (after) with controller (embodied/keyboard) and tutorial (on/off) as between-subjects factors and mean rating of closeness (before) as a co-variate. There was a main effect of controller ($F_{1,29} = 4.19, p = .050, \eta^2 = 0.13$) on closeness, with ratings of the embodied control version higher for the keyboard version, explaining 13% of the variance. There was also a significant effect of tutorial ($F_{1,29} = 6.3, p = .019, \eta^2 = 0.18$), showing higher closeness ratings with a tutorial (explaining 18% of the variance). There was no significant interaction ($F_{1,29} = 0.88, p = .356$). I conducted a two-way ANCOVA on the mean ratings of happiness (after) with controller (embodied/ keyboard) and tutorial (on/off) as between-subjects factors and mean rating of happiness (before) as a covariate. There was a main effect of controller ($F_{1,29} = 8.81, p = .006, \eta^2 = 0.23$) on happiness, with ratings of the embodied control version being higher the keyboard version, explaining 23% of the variance. There was no significant effect of tutorial ($F_{1,29} = 3.99, p = .055$) and no significant interaction ($F_{1,29} = 1.51, p = .229$).

The photo ratings showed that participants appeared both closer and happier when playing with embodied controls than with keyboard controls (see Figures 3.10 and 3.11). Figure 9 shows the mean (±SE) ratings for happiness ratings of dyads from before to after playing, grouped by condition. 1 is anchored by 'Unhappy' and 100 is 'Very Happy'. Figure 10 shows the mean (±SE) ratings for closeness ratings of dyads from before to after playing, grouped by condition. 1 is anchored by 'Total Strangers' and 100 is 'Very Close'.

Figure 3.10: ITSB Happiness Ratings

3.5.4 Participant Feedback

In this section, I discuss common feedback extracted from the recordings of the interviews with both players after their 10-minute play session. In these interviews, I asked them to talk about memorable moments of the game, how they felt they communicated with one another, if they felt closer to one another, and any other feedback they might have had. Most participants in both conditions mentioned the delay in the game due to network latency was challenging; there is ~ 1 second delay in which the input is sent from one player to the other, which caused players to be more careful and precise in timing their movements with the controls. Some expressed that breath rate was the most difficult mechanic, while others had the most trouble triggering Disgust. Most participants thought they generally communicated well with their partner and expressed that they performed better once they assigned someone to take the lead role (i.e. dictating commands of when to make actions in the game). Lastly, most participants expressed they enjoyed the game and wanted to play even longer than 10 minutes to get better at it.

3.6 Discussion

In this section, I summarize the results, provide possible explanations rooted in the literature for the findings, and discuss limitations and future directions. I limit the discussion to lessons learned about the design of

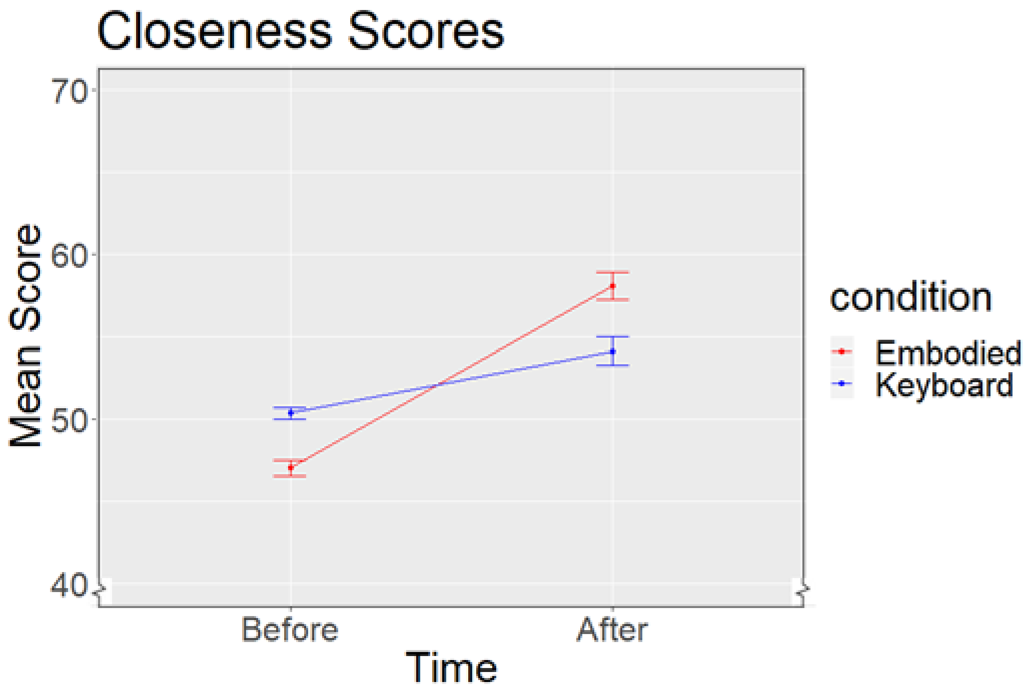

Figure 3.11: ITSB Closeness Ratings

this game.

Summary of Results

The analysis of control scheme (embodied vs. keyboard) showed that embodied controls were less intuitive; however, participants using the embodied controls enjoyed playing more than those using the keyboard. Those who played with the tutorial enjoyed the game less overall, which suggests that joint discovery of the controls was more desirable. Affiliation scores after play were higher in the keyboard condition, which might be partially explained by the significant difference in game performance: people who played embodied controls performed worse in terms of high score than those who played with keyboard. Finally, to corroborate the player-centric analyses, I had 105 independent participants rate before and after images of the dyads together. Participants rated photos of the dyads that played with the embodied controls as significantly happier and closer to one another than those who played with keyboard controls.

Gameplay

I saw that groups who played with keyboard performed significantly better than those who played with embodied controls. This might be explained through individuals' prior knowledge of each control scheme: 84% indicated that they actively play console or desktop games, showing an overall base familiarity with traditional input controls for most participants. Alternatively, embodied controls were new for all players, therefore presenting a steeper learning curve. A dynamic that I observed emerging during gameplay, which was also supported by the retrospective interviews, was that one player often took the lead in guiding the experience, making each facial expression before their partner. Generally, this resulted in those groups having a higher score than those that did not figure out this strategy. Physical coordination literature suggests that strongest team function occurs when one person takes the lead, and poor function happens when people fight over the lead [181].

Intuitive Control and Instrinsic Motivation

Players' performance can be partially explained by how they felt about the difficulty of the control scheme. People in the embodied condition rated the controls as significantly less intuitive than those who played with keyboard. However, when controlling for intuitiveness of controls ratings, I found that players in the embodied version enjoyed it more. Self-Determination Theory [260] explains how people are motivated and has been extended into game contexts to explain player experience [249]. It suggests that players' enjoyment is affected by how they experience the control scheme of the game [260]. This means that those who felt the controls were not intuitive also reflected this with lower overall scores for game enjoyment. The findings are also in line with McEwan et al.'s [189] work on game control devices, in which participants felt more challenged and less competent with the naturally mapped input devices (i.e., a race car wheel for a racing game), yet still preferred them to a standard keyboard or controller. To account for the difficulty with learning a new control scheme, I administered a tutorial to half the participants. Surprisingly, the tutorial seemed to hinder the experience of those who played with one. Enjoyment was rated significantly lower by those who played with the tutorial in both the keyboard and embodied conditions. This finding might suggest that the experience of discovering the game and control scheme with a partner was more enjoyable than on their own [123]. People who played with a tutorial also felt they were less competent when switching to the multiplayer game than those who did not play with a tutorial. It is possible to account for these lowered feelings of competence in the multiplayer version by drawing from the application of attribution theory into game contexts [63]. Attribution theory explains how people assign causes to events and how these attributions affect peoples' emotional reactions and motivations. In this context, players who were exposed to the single-player version of the game through the tutorial might have attributed their joint failing in the multiplayer version more to themselves [63] than to their partner.

Relatedness and Affiliation

The game was designed to be both cooperative and interdependent in order to facilitate building closer relationships between players. While I did not see a difference in individuals' satisfaction of relatedness as a result of control scheme, I did find that those in the keyboard condition rated their *affiliation* to the other player significantly higher than those in the embodied condition. This may be partially explained by performance, as those in groups who performed worse might have attributed some of their failures to the other person [63, 64], causing negative feelings toward the other player which may have hindered the development of affiliation and social closeness.

Before/After Image Ratings

Images of the dyads playing with the embodied controls were rated as more happy and closer than those who played with the keyboard controls, controlling for the pre-play ratings. The higher happiness ratings may be partially explained by the design intention of making players smile, thus facilitating joy, or perhaps just priming the expression of joy, making them look happier after playing [123]. Additionally, the Disgust expression was seen more as funny and challenging to trigger than a negative emotion, furthering the observed happiness of the dyads. In contrast to the dyads' self-reported affiliation ratings to their partner, which were higher in the keyboard condition, the independent raters interpreted those in the embodied condition as looking visibly closer to one another. This supports the idea that the design of the embodied control scheme emphasizes the aesthetic of making people feel close and connected; which opens up possibilities for future directions. Overall, I show that synchrony as a game mechanic increases closeness felt by players [143, 181, 245]. The results support that using embodied controls as an additional mechanic has the potential to further support people to feel closer and more connected over a distance.

Limitations and Future Work

There were several limitations in the study. Because the informed consent occurred before the photos of the players were taken, participants may have been aware of the intended usage of photos; thus, potentially impacting their facial expressions in the photos. The input delay (i.e., the time it takes for one players' input to be sent to their partner in order to be 'synced': about 1 second) in both conditions of the game seemed challenging to manage. This observed difficulty was supported by the retrospective interviews. To reduce the impact of this delay, all participants had the same setup, which standardized the delay time; however, this did not eliminate the experienced lag. In the future, I will make the game obstacles smaller, therefore more forgiving if the players' timing is not exact. Additionally, in the analysis I did not control for type of relationship between participants. However, there were only 4 groups who knew each other beforehand, and I balanced these groups across conditions. In the current game version, the camera preview on screen is facing the player rather than a live-video of the partner (i.e., players would see their partner's emoji pop up onto the screen—rather than their face—and would be prompted to trigger that same emoji). In support of emotion mirroring [25, 143], it is important for the players to see each other to coordinate their actions through visual feedback. I will add a camera feed on-screen of the other player for future versions of the game to heighten the effects of mirroring. The novelty of physiological control may have influenced the results, so I added a tutorial to help mitigate this effect. Reflected in people's control scores, a 5-minute tutorial might not have been enough to learn a new control scheme (in the embodied condition). Players became accustomed to a certain input timing in the single-player tutorial, and that timing changed in the multiplayer version with the network delay. This might have rendered the tutorial less effective, hindering players' experience with the multiplayer game. In general, people have a baseline familiarity with using a keyboard, so there was an advantage in knowing that control scheme ahead of time. This is in contrast to the embodied controller—which was entirely new for all participants. People played together for only 10 minutes; a longer play session could account for the difficulty of the game as people felt they needed more time playing to improve. It could further foster affiliation as people play longer over time.

Finally, the applications of this work extend beyond what I describe. While I specifically focus on the infinite runner genre and fostering social closeness in distributed dyads, the results indicate the potential for this game to be of use in the broader games community and HCI as well. Game companies could think about using the mechanics of synchrony and embodied controls in their games to foster enjoyment and social closeness. In the broader context of HCI, I see this game as being a useful tool to help many different types of special populations (e.g., people with autism or those who suffer from PTSD). I hope to explore the broader applications of the game in future work.

3.7 Contribution

I created an embodied mirroring game—In the Same Boat—to explore social closeness between players over a distance. The game leverages players' physiological data as input and focuses on the synchrony of this input as the mechanic that realized cooperation and interdependence in the game. Results from a study with 35 dyads (N=70) indicate that this game design does indeed facilitate affiliation amongst distributed players, and that while the embodied controls were less intuitive, people enjoyed them more. Further, photos taken of participants together were rated as happier and closer in the embodied condition, indicating the potential benefits of using embodied controls to foster social closeness. In the Same Boat was designed to promote an intimate interaction, by focusing on embodied interaction using physiological input, mirroring emotions through syncing, and networked play. As a first game to leverage physiological syncing over a distance, ITSB has the potential to help geographically-distributed friends, family, and partners to feel closer through playful interaction.

4 Commons Sense: Design Probe Two

4.1 Motivation

Interacting with others and forming relationships is essential for mental and physical well-being. However, those who love each other, know one another, or work together are not always geographically located near to one another. To help non co-located people stay connected [81], there has been a rise in online platforms that facilitate peer-to-peer synchronous communication—e.g., VoIP messaging services such as WhatsApp[1], live streaming websites such as Twitch[2] and YouTube Live[3], and teleconferencing applications such as Zoom[4] and Google Meet[5]. Recently, in the context of the COVID-19 pandemic and due in part to geographical accessibility, social interactions for both work and leisure take place largely online. The number of people using online platforms to communicate is rising daily, with Zoom currently supporting over 300 million users per day to virtually meet in both work and personal contexts—an increase from 10 million in 2019 [142]. Although progress has been made on supporting working remotely over the last decades (e.g., collaborative authoring tools like Overleaf [6] and myriad communication tools like Slack [7]), less attention has been paid to supporting online leisure activities.

In terms of leisure activities, while the entertainment and sporting domains—that have been primarily live for so many years—have recently shifted online, there are some domains that have existed primarily online since their inception. The competitive video gaming domain (esports) has long used online platforms as the primary way to engage with audiences [295]. Twitch [8] is the leading platform for live streaming video games, with viewership rising each year at 2.9 million average viewers per day [306]. Platforms like Twitch and YouTube Gaming give opportunities for not only competitive players, but also casual gamers from around the world to live stream themselves playing a game. While streaming is famously associated with video games, there are numerous other approaches to streaming content: platforms like Periscope, Twitch Creative, and YouTube cater to the masses, allowing anyone to stream any kind of content they want (e.g., cooking, painting, eating, playing musical instruments) to a larger audience. These virtual 'performances' taking place on these platforms are akin to live theater performances. On Twitch, players/performers live

[1] https://www.whatsapp.com/
[2] https://www.twitch.tv/
[3] https://www.youtube.com/live
[4] https://zoom.us/
[5] https://apps.google.com/meet/
[6] https://www.overleaf.com/
[7] https://slack.com/
[8] www.twitch.tv

stream themselves to their "channel" (a profile that houses all their content). Spectators can navigate to this channel to watch the stream in real time, and communicate with the streamer through a live chat feature. In these online performances, many social cues and signals inherent to face-to-face (f2f) communication (e.g., para-linguistic cues, facial and body language and posture, eye contact) are compromised, including the ability of the performer to 'read the room' or see the audience responses. As communication is largely influenced by the availability of social cues in the interaction, quality of interactions may decrease with fewer available social cues or more impoverished social cues [149]. This not only negatively affects the speaker/performer, but also harms audience engagement—thus devaluing the experience for each party. While some forms of audience response can be translated into the digital domain (e.g., cheering, dancing), others are more difficult to represent (e.g., facial expressions, body posture). Various streaming platforms have integrated some of these features, e.g., the use of 'hearts' on Periscope, and 'reactions' on Facebook and Instagram Live [9]. One widespread method to help bridge this communication gap (used often in platforms like Zoom and Twitch) is a live chat feature, which allows the audience to type messages to communicate with the speaker/performer in real time. These audience reactions are essential to any live performance, as they influence the performer and performance [172].

While many interventions by Human-Computer Interaction (HCI) researchers and designers have found success in engaging distributed audiences [268, 5, 164], the design space of communicating audience response still remains a challenge to translate to online platforms. To help facilitate the expression of audience responses into the digital realm on a live streaming platform like Twitch, this project explores biometric sensing devices that capture and convey physiological data. Sharing physiological signals have long been a way to help people connect [78, 80], with the widespread use of apps that collect and share biometric data with friends through devices like the Fitbit [230], in group exercise contexts where an individual's heart rate is broadcast on a screen at the front of a room [10], in interactive art galleries that change with the audience's response [264], or sharing personal biofeedback on social networks [54]. Similar to sharing interpersonal signals in real life communication contexts, the nature of sharing one's own personal physiological data is an act that is simultaneously intimate and vulnerable—which might be a factor to help create empathy amongst both parties [168, 78] if designed carefully.

In this project, I open up a new design space—facilitating the communication of audience response in an online entertainment context—where these social cues and signals are inherently diminished. I explore this design space by leveraging audience participation through physiological signals (using a tool designed from a database averaging multiple users' heart rates that I call "*Commons Sense*") as a way to heighten audience engagement and effectively capture and communicate the audience experience. As a proof of concept, I created a top-down survival shooter game that—using webcam-based heart rate detection software—takes an average of each spectator's heart rate as input to affect in-game variables such as lighting and sound

[9]https://www.instagram.com/
[10]https://www.orangetheory.com/

design, and game difficulty. I tested this technology probe 'in-the-wild' with four Twitch live streamers and their respective audiences.

Through this in-the-wild deployment, I explore several guiding questions regarding how streamers and spectators leveraged the new interaction: 1) How did the audience interact using Commons Sense? 2) How did streamers respond to Commons Sense? 3) Was the experience of Commons Sense enjoyable? And 4) How did Commons Sense influence the connection between the streamer and their audience? I found that Commons Sense is a communication modality that can both enhance a play experience while offering a novel way to communicate.

4.1.1 Affective Game Loop

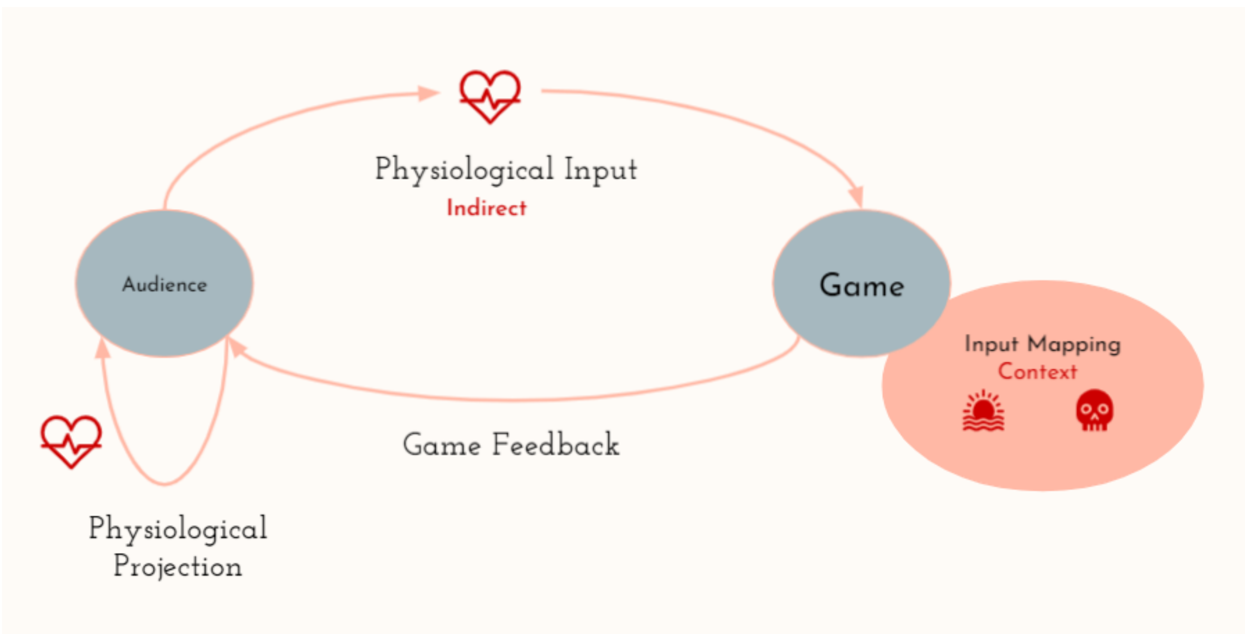

Figure 4.1: Commons Sense contextualized within the Affective Game Loop.

I created Commons Sense as a communication modality intended to engage audiences on Twitch. In the context of the affective game loop (see Figure 4.1), this technology probe explores using an indirectly-controlled physiological signal by the audience (heart rate) as 'difficulty', 'environmental' and 'physiological projection' based mappings (i.e. audio, visual effects) in the game.

The aim of this project was to understand how affective games enhance engagement specifically in the context of live-streaming—an under explored area in the field of affective games. My master's work 'All the Feels' leveraged physiological projection in a live streaming context (an overlay of the streamer's heart rate/GSR/facial expressions on-screen was displayed back to spectators) in order to heighten the connection between Twitch live streamers and their spectators. This project expands on this work, instead taking the *spectators'* physiological signals and using them to influence game events.

In this project, I heighten the communicated audience energy and translate lost in-person social cues onto Twitch using Commons Sense through the outer-space themed audience participation game I created. To operationalize success of the in-the-wild technology probe, I evaluate spectator and streamer interactions and perceptions through four questions of inquiry: 1) How did spectators interact with Commons Sense? 2) How did streamers respond to Commons Sense? 3) Did streamers and spectators enjoy Commons Sense? And 4) How did Commons Sense influence the connection between the streamer and spectators?

This project is the second design probe in the thesis, understanding how a live-streamed affective game can enhance the player/spectator experiences.

4.2 Background

My overarching goal with this project was to explore this new design space on Twitch by designing a novel communication system that facilitates audience engagement—helping to restore some of the social cues and signals that are lost in a digital domain.

4.3 Impoverished Online Communication

Peer-to-peer platforms like Zoom or Twitch support varying forms of communication. Some afford a two-way relationship between users, where everyone participates as both the sender and receiver of messages (e.g., messaging services like WhatsApp); whereas others afford a one-to-many form of communicating, in which there is a single sender at one time with many receivers (e.g., Twitch, or Zoom webinars). This one-to-many form of communication is not only seen in platforms supporting remote work, but also more broadly in leisure domains that emphasize entertainment and play, such as musical concerts, comedy troupes, poetry readings, plays, and even reality television shows. As the size of the audience increases, so do the challenges of communicating [84, 87]. In live physical events with millions of spectators, like concerts or live sporting events, there are many different types of audience reactions that are both linguistic and para-linguistic (referring to communicative modalities such as cheering, booing, waving, screaming [139]) that add to the experience, but are lost in a digital domain. For example, due to restrictions on physical gatherings during the COVID-19 pandemic of 2020, a popular competitive singing show called 'The Voice' (that usually has a live audience) integrated an online audience, demonstrating novel ways of adapting to restrictions on public gathering [131]. To mimic the audience reactions of a live-venue, the show now includes reactions of the virtual audience watching from home in the background by leveraging spectators' webcams. Additionally, sporting events were not able to be held with spectators in attendance, but were instead held in empty stadiums (e.g., NBA, NHL, MBA). For the benefit of audiences watching from home, some leagues used audio tracks of pre-recorded audience reactions to particular points of the game, in addition to displaying spectators' webcam feeds to prompt audience connection with others watching. In f2f communications, mirror neurons—or neurons that activate both when a person acts and when the person observes the same action performed by another—fire when watching facial and gestural cues made by others [25, 326]. In the context of theatre and performance, mirror neurons have been suggested to help the performer read and respond to the audience and vice versa [324]. Thus, translating f2f social cues and signals to the digital domain becomes a priority for researchers in the field of HCI.

4.4 Audience Interactivity and Spectator Experience

Researchers and developers are working toward creating engaging audience experiences [296, 247] that include new para-linguistic communication methods to help better capture and communicate the audience experience [163]. For example, emojis are a para-linguistic modality often used in text-based live chats to insert some form of facial cues into the digital domain [266]. While communicating the audience experience is important, it is most effective at forming a positive feedback loop with the performer when the audience is highly engaged in the experience. Thus, in the entertainment domain it has become a priority to not only develop methods for communicating audience experience, but to make these methods highly engaging as well. For example, the competitive esports title Overwatch recently added a feature that allows tournament audiences to "cheer" from home by pressing a button in an app, which is then sent to the stadium and heard by the competitors [74]. Audience participation is a way to not only engage audiences and performers, but reinforce the liveness of the experience [319]. 'Liveness' is a term appropriated from the theatre arts domain, and represents a key element to capturing the energy of a live performance. Despite a 2012 CHI Workshop that sought to unpack the domain of liveness in HCI [114], and how technology can be better designed to support the subtle dynamics of this space, liveness remains an under-explored topic in HCI domains.

Striner et al. created a spectrum [289] to categorize eight levels of audience interactivity, investigating ways in which an audience (in various entertainment domains) might interact with the performers on 'stage'. Audiences might be afforded multiple possible levels of interactivity from less (observing passively) to more (taking over the performance), depending on the type of entertainment experience. On Twitch, audience members can access the first four levels of the spectrum by: 1) observing passively, 2) personalizing their experience (e.g., listen to music alongside the stream), 3) reacting to the performance (e.g., using the live chat feature, or 'cheering' for the streamer by sending bits), or 4) influencing the performance (e.g., typing things into chat to which the streamer responds); however, the final four levels—including 5) Augmenting the overall experience, 6) Bidirectionally Influence/Get Influenced by Performers, 7) Become a Performer and 8) Take over performance—of audience interactivity are largely unsupported.

Audience participation has long been used in theatre/performance as a way to engage audiences, and is now being adopted into the technological domains. Audience participation games (APGs)—or games that have a "mutually-aware group of audience members who participate in a way that has a meaningful impact on the game" [268]—blurs the lines between streamer and audience. In 2014, an APG called *Twitch Plays Pokémon* gave a global audience control of a game by turning the Twitch live chat into a game controller, allowing audience members to type certain phrases into chat that mapped with game controller inputs in order to advance in the game [239]. Twitch streamers often use home-brew methods to allow audience participation (e.g., chat polls deciding what weapons they should use in-game or what game they should play next), which further demonstrates the value of this mechanic. Despite this, there is still a lack of formal incorporation of audience participation into the Twitch platform [99]. Researchers in the field of Human-Computer Interaction (HCI) have even made tools that enable audience participation including customized emojis for use in the chat [251], interesting heads up display (HUD) elements (e.g., for the spectators to give hints, or vote) [251], and games where the audience plays a role in the game itself [79]. Lessel et al. created an add-on to the video game Hearthstone that enables a new communication channel between streamers and their spectators [164], allowing spectators a hands-on way to engage in the gameplay experience, and Fanzo et al. created an audience-driven horror game that requires audience members to use the live chat to help guide the streamer through the game [79]. Off-the-shelf game titles have likewise attempted to incorporate audience participation—both Tomb Raider (2013) and Choice Chamber (2015) allow spectators to vote on game events, mechanics, and player progression [268].

There have been some initial investigations into supplementing live experiences with physiological sensing. Tennent et al. explored this concept in a project that captured biodata from actors and participants in a pilot television show, giving viewers access to actors' physiological data [297]. The same research team has also implemented a tool for capturing video, audio, heart rate, and acceleration data of those riding a roller coaster, streaming this live to spectators, thus transforming riders into performers and enhancing the experience [265]. Schiphorst et al. created a public art installation called Whisper that—using wearable physiological sensors—displays participants' physiological responses, enabling users to playfully interact with both their own and others' internal data. [264]. However, few researchers have looked into both physiological interaction and how it improves the audience experience, and no projects—to my knowledge—have incorporated physiological reactions of a remote audience in an online context. In this project, I integrate remotely-sensed physiological responses of an audience into a game being streamed live over Twitch.

4.5 Probe Design

To investigate the design space of audiences' physiological responses within a livestreamed game, I developed a technology probe [118, 33], consisting of a bespoke 'Alien Shooter' game and Commons Sense, the novel communication modality. Alien Shooter is a top-down survival shooter set in a dark, outer space-like environment, designed to be streamed on the Twitch platform. The player's goal is to survive as long as possible, while being attacked by alien enemies (see Figure 4.2). In Figure 4.2, the left image depicts the environmental effects with low heart rate and the right image shows environmental effects of a high heart rate. For each Twitch audience member tuning in, an individual heart rate value is taken using custom software that detects heart rate through a standard webcam, which is then sent to a database. There, the

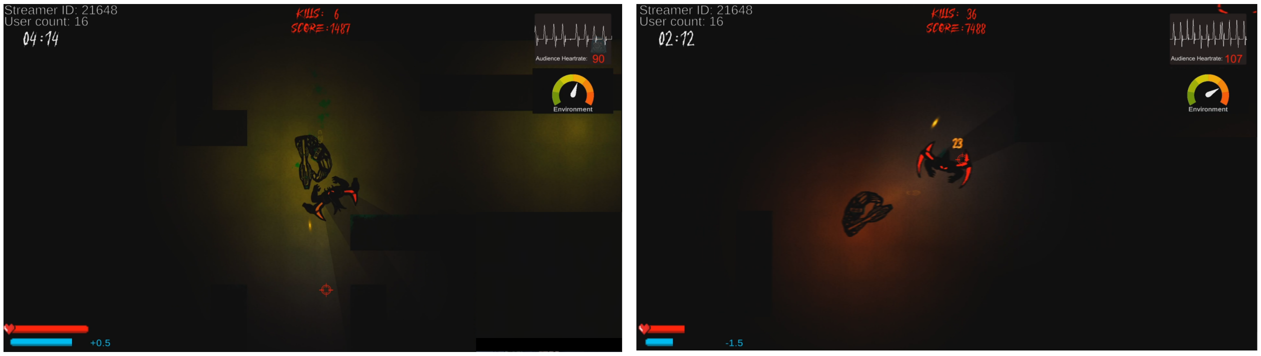

Figure 4.2: Gameplay footage.

heart rate values for all spectators are averaged and this value is sent back to influence the game via three different input mappings—by manipulating the game *environment*, the game *difficulty*, or *both* in a form of novel physiological audience communication that I call 'Commons Sense'.

The Alien Shooter game is designed to take 15 minutes, divided into three 5-minute play sessions, each with a different input mapping. I chose a time-based model (versus score-based) as I wanted the player to experience each version for a standardized amount of time. I decided to design a new game—rather than integrate Commons Sense in a pre-existing game—as the goal was to create a game that not only supported, but highlighted the novel interaction approach that I innovated. Therefore, I wanted to make the game design as simple as possible, while still engaging to the audience. Additionally, I chose to focus on the horror genre as it creates a heightened audience response [79] that could be captured and integrated into the game itself. The game was implemented using the Unity3D game engine, version 2019.3.8f1.

The game design process was an iterative one. I conducted numerous play-testing sessions with university students studying game development and game user research to balance the game difficulty and ensure the heart rate technology was functioning as intended. Playtests were conducted via two approaches: i) throughout the entirety of the design process with the programmer acting as a streamer, and using fake audience HR values in order to balance game systems in Alien Shooter, and ii) by having at least two audience members from the local University participate, to judge sensing accuracy and fix any technical issues with Commons Sense.

4.5.1 Sensing Audience Heart Rate

While it is possible to gather physiological data from a variety of biometric signals (i.e., sweat, temperature, breathing rate), I chose heart rate (HR) for a number of reasons. First, heart rate has been shown to be the most accurate marker of physical and emotional activation in people [41]. Although Galvanic Skin Response (GSR) is a promising marker of arousal/activation as well, and might be a valid analogue of audience response, devices that capture GSR data are not widely accessible or easily tracked in remote environments (i.e., capturing GSR requires the use of expensive wearable devices that must be physically calibrated). Heart rate might be captured from a variety of sources (e.g., electrocardiography—ECG, pulse plethysmography—PPG) using wearables or chest straps, but I wanted the collection method to be broadly accessible for remote audiences. Thus, I decided to focus specifically on using physiological signals that could be captured with a standard webcam.

I chose to collect Blood Volume Pulse (BVP)—which represents the contractions of the heart in local blood vessels, and thus can be extrapolated as a measure of heart rate (HR)—through participants' webcams, as this method was both technologically feasible, and required minimal setup and calibration from the audience. Heart rate is gathered from each spectator watching at home using custom JavaScript software developed by Johanson et al [129]. This software makes use of the headtrackr library [184], which is a library for real-time face tracking and head tracking, tracking the position of a users head in relation to the computer screen. Once the head is successfully tracked, the measurement of heart rate is initialized. This is accomplished by detecting small color changes of the forehead, which are mapped to pulse. An event is triggered every time new heart rate data is available. The HR data contains a boolean if the data is valid, the time of the measured HR (in form of javascript Date.Now() timestamp), the HR in beats per minute (BPM), the quality of the frequency spectrum (represented as kurtosis), and the data quality as a relation between possible number of datapoints and number of datapoints with a minimum standard deviation as well as the status of the detection of the head [184]. While heart rate detection via this method might not be as accurate as other collection methods like wearable biometric devices, for the purposes of collecting an *average* of users' physiological responses, accuracy of the signal was not a primary concern [242]. Further, owing to the nature of this research (that is, the exploration of remote physiological interaction), it was important that I utilised technology feasible for accessible deployment in remote contexts; thus, the ecological validity of the technology was more critical than its comparative accuracy to clinical instrumentation.

Before using Commons Sense, all spectators were required to undergo a calibration phase of the heart rate detection software, to ensure their webcam was working and all conditions were met for consistent tracking of HR throughout the study (e.g., well lit environment, hair out of face, webcam positioned toward face). Spectators were also provided with a notification on-screen when their webcam was not tracking their HR any longer, giving them opportunity to resolve the issue. Each spectator's heart rate value was collected (approximately every 2 seconds) and sent to a Firebase database. Every 2 seconds, the heart rate values for all viewers were averaged and then sent to the game. To preserve audience anonymity and privacy, no webcam footage was streamed, recorded, or stored. Only data from the heart rate monitor (i.e., the calculated beats per minute: BPM) were collected and utilized for the study. I also gathered a status variable that was used to determine whether or not the audience member should be included when calculating the average. For example, if the forehead was not within view of the webcam and was in the process of re-detection, then the audience member would momentarily be excluded from the average until their heart rate could be retrieved by the system once again. The BPM was added to a total BPM for all audience members in the system. A separate back-end system pulled the total BPM and audience member count to calculate the average heart rate among all audience members. Every 500ms the server collected current audience member count as well as the number of audience members, generated an average value by calculating the mean of all the values received, and uploaded it to the Firebase database. The average heart rate (HR) was calculated by dividing the sum of all active participant's heart rates by the number of active participants. In addition, spectators were not able to view their individual heart rate values, which was a design decision meant to highlight the collective efforts of the audience rather than the individual.

When designing the game, I was inspired by work showing that the mechanics of cooperation and interdependence are effective at fostering social connectedness [62]. I designed this game with a high level of interdependence (i.e., how much the streamer relies on their audience and vice versa), and with an option to the audience as to whether they want the game to be cooperative or competitive (i.e., altering their collective heart rate to help the player progress, or impede player progress). It was important that audiences were able to utilise this communication channel how they preferred—whether this be more actively or passively. Meaning, an audience member might view the stream passively simply by letting their heart rate be taken and sent to the game. Alternatively, they can actively manipulate their heart rate (e.g., raising it by exercising or lowering through deep breathing) in order to assist or hamper the player's progress through the game. Because of the options spectators have for how they might interact, Commons Sense might give the audience perceived control over what happens in the game experience.

Representing Audience Heart Rate

The audience's average heart rate was both visible and audible throughout the study in real-time. The visuals for the heart rate were mapped through the heart rate monitor, difficulty gauge, enemy difficulty, and environment color intensity (see Figure 4.2). The audio cues were also mapped with the heart rate monitor, allowing the streamer and audience to hear heartbeat audio representing the averaged audience heart rate. The overall effect of visuals and audio demonstrates to both streamers and their audience how much influence the audience's heart rate had on the play experience at any given moment. Through extensive playtesting, a minimum heart rate value of 40BPM, and a maximum value of 140BPM were selected to represent the low and high cases of the heart rate percentage—as the mean heart rate would most commonly be within the range of the selected cases. Thus, 40bpm would be mapped to represent the heart rate having 0% effect on the game, and 140BPM would be mapped to represent the heart rate having 100% effect on the game.

Mapping the audience's heart rate directly into the game experience (rather than as an overlay on the screen) allows the player to maintain focus on the game itself. Often, streamers' attention is divided, as they are required to split their focus and time between playing the game and reading and responding to Twitch chat comments. This might negatively affect the experience, as attention shifting often is an antecedent for a break in immersion [37]. By integrating the new interaction directly into the game, I reduce the number of items on the stream that the streamer must shift their attention to, reducing cognitive load on the streamer.

4.5.2 Input Mappings and Influence on Game

Although audience heart rate was represented both visually and sonically, I also aimed to use sensed heart rate to directly affect the game. To decide on how audience heart rate should be integrated into the game, I used the affective game loop [252] discussed in chapter 2. The affective game loop framework categorizes physiological input mappings of previous work into three approaches: mechanical, environmental, and difficulty. Mechanical mappings are those that map the physiological signal to a game mechanic (e.g., jumping, running), environmental mappings influence environmental effects (e.g., lighting, weather), and difficulty mappings influence game difficulty (e.g., number of enemies, dynamic difficulty adjustment). These mapping types informed my thinking on how the audience's physiological signals should be integrated into the game. Framing the design in the context of this affective game loop framework, Commons Sense is receiving the audience's heart rate from their webcams (an indirect signal), mapping it to lighting/mood (environment) and enemy spawn rate (difficulty), and feeding this information back to the player in the form of in-game effects.

In 2017, Seering et al.'s work on APGs identified that, "To create a satisfying impact on gameplay, audience participants must be able to understand the game situation, how they might influence it, and how their actions affected the outcome." As this participatory type of audience interaction is still new in digital game contexts, I implemented three mapping approaches to understand which approach was most visible and enjoyable to audience members.

Environment: In this version, the audience's heart rate is mapped to environmental effects, such as lighting intensity and colour. A colour gradient from red to green (see Figure 4.3, bottom left) was mapped to a low (green) or high (red) average heart rate value. Green was selected to represent a calming environment and would be mapped to the minimum heart rate effect percentage (0%). Red was selected to represent the horror-inspired environment and would be mapped to the maximum heart rate effect percentage (100%). As the audience's collective heart rate rose, the backlight on the map dimmed and turned red. A lower heart rate was mapped to a greener, more consistent, and brighter light. The lighting colors were selected to correspond to the intensity of the heart rate. Additionally, the opacity of the lights also corresponded with the audience's average heart rate, with the lights brightening as the heart rate decreases and dimming as the heart rate increases.

Difficulty: In this version, the audience's heart rate was mapped to a variety of variables carefully guided by playtesting game balance, including: speed, damage, and attack range of all enemies, using the present percentage of the heart rate influence, e.g., current damage = base damage + (base damage * heart rate percentage / 100). The base values for the speed, damage, and attack range were obtained through playtesting and were determined to be the most appropriate variable values for a noticeable difficulty increase. The alien enemies' difficulty variable would be set to their baseline when the heart rate was at 0% and would increment towards the max variable as the mean heart rate increased toward 100%. Thus, when the heart rate percentage was at 0% the damage would be set to the base damage; when the heart rate percentage was at 100% the damage would be set to double the base damage.

Both: In this version, the audience's heart rate is mapped to both environment and difficulty, as previously described.

4.5.3 NPC Enemies and Player Health

Choices regarding elements of the game (i.e., design, game balance) were made based on the feedback received from the previously-described iterative playtesting sessions. Challenge in the game was created through the artificial intelligence (AI) non-player character (NPC) alien enemies. I implemented three enemy types in the game to introduce variety: melee, range, and screamer. The melee and range enemies were designed to have most of the general functionality for a top-down shooter, but also aligned with my core design principals of a simple game design to draw focus onto Commons Sense rather than the gameplay. Thus, both melee and range enemies have a simple bi-conditional state manager, with their states corresponding to 'roam' or 'attack'. To make the melee behaviour more engaging, enemies were given a dash mechanic with a cooldown, allowing their movement speed to increase for a short duration and then return to the default until the cooldown had been reached. The screamer enemy remains stationary and instead applies a buff to all active enemies, multiplying the speed and damage of all range and melee enemies by two.

The health-point (HP) gauge and energy gauge were the main two components affecting the player's in-game character. The HP, initially set to the max of 100, would be subtracted from each time the player took damage, resulting in player death once HP reached 0. Upon death, players would be re-spawned after 4 seconds; re-spawns were designed to be unlimited as to make sure the player kept playing for the entire 5-minute play session. The player's energy—which regenerates over time—was inherently the player's most valuable resource. Energy was used to shoot, activate the flashlight, and sprint. The player was given a gun, thus shooting was the only means of killing enemies. Enabling the flashlight would somewhat brighten the room, display a bright cone of light in front of the player, and make the enemies glow—thus serving as an important tool for visualizing enemies and the environment. While moving around the map remained possible without the use of the flashlight, it became difficult to see enemies hiding in the dark, thus making the chance of being overwhelmed by a group of enemies far more likely. Sprinting would allow the player to escape hazardous situations.

4.6 In-The-Wild Deployment

There were several types of 'participants' who engaged with the in-the-wild technology probe: 1) *streamers*, 2) audience members who participated in having their heart rate sensed and completing surveys (*audience*), and 3) audience members who spectated play, potentially contributing to the chat, but who were not sensed and did not have their heart rates sensed (*sense-less spectators*).

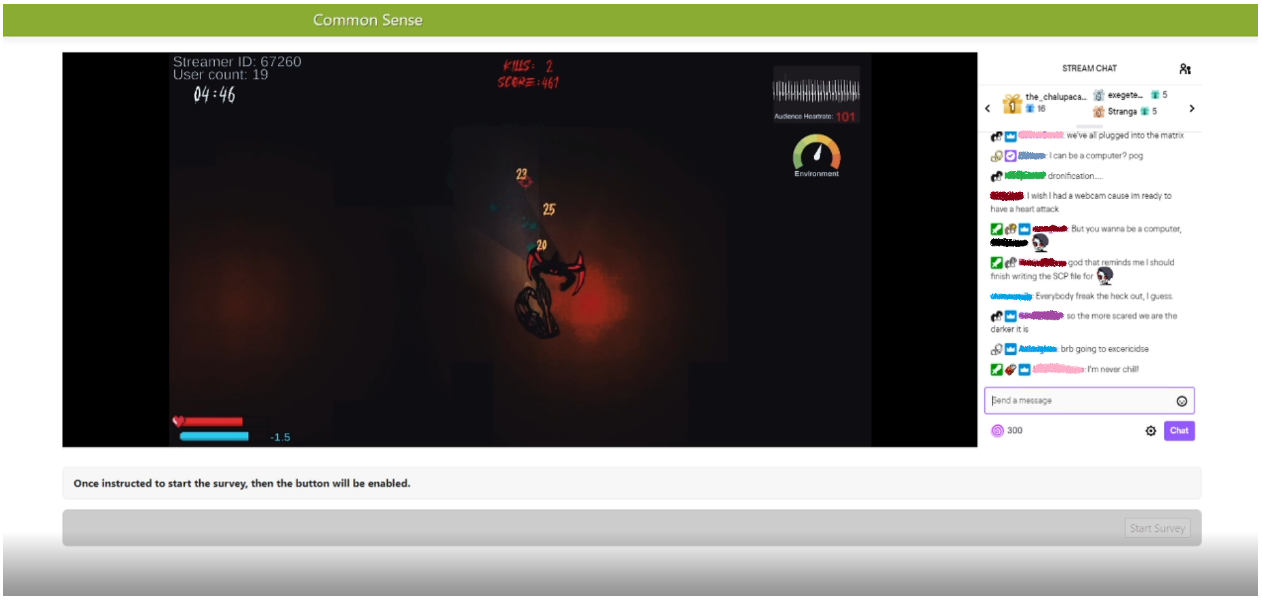

Figure 4.3: Commons Sense

4.6.1 Apparatus and Procedure

The system was divided into two parts: the streamer-specific software—which includes the game executable; and the audience-specific software—which includes the heart rate tracking software, the deployed website, a back-end server, and the database. Both parts were designed to be operated seamlessly, as the deployment involves dozens of participants with varying technical expertise.

Streamers

The streamer was supplied with an informative description for participating, and, upon providing informed consent, was then provided with a link to download the game executable. It was expected that the streamer would already have a set-up for streaming (i.e., internet access, a system and peripherals for gaming, and, preferably, a webcam).

The streamer was greeted with a main menu, with an optional tutorial on game mechanics, the control scheme, and other relevant details. The user count was displayed within the menu to represent the number of audience members participating at any time. Upon clicking the ‘play’ button, the streamer was assigned a unique ID and was then redirected to complete a survey in the browser. Once completed, the streamer was presented with dialog informing them about the three game conditions (i.e., *Difficulty*, *Environment*, or *Both*). Following the starting condition, the other condition was selected, with *Both* being the final round of the study. Each game round was five minutes long, separated by two-minute long survey sessions in which both streamers and participants were asked to complete designated surveys, privately on their computers (i.e., streamers completed it in a separate window than the stream so the viewers would not see their responses). After the final play session and completing the final survey, streamers were shown an overview of their score throughout each session. As this was an 'in-the-wild' deployment, I did not want to tell the streamers to motivate or discourage their audience to alter their heart rate specifically. Thus, I left it up to the particular streamer to decide how they wanted to encourage audience participation.

Audience

The audiences' participation was implemented and managed through a web-based system [129], consisting of a custom Python library built using Flask that assists in deploying online user studies.

On the Twitch stream, viewers were encouraged to participate through a browser (cross-browser compatibility was supported) either through a link provided by the streamer or the link displayed at the top-right of the in-game main menu. Upon accessing the URL, audience participants were met with a consent form, explicitly stating the terms of participating. After providing informed consent, audience participants were redirected to an instructional page to help with the ideal set-up for the webcam's heart rate tracking (e.g., room lighting, body posture, forehead clearance). Audience members were then asked to provide access to their webcam for the heart rate tracking software. Granting access opened the heart rate tracking in a separate window to allow the process to persist throughout the entire session. This window notified the spectator of whether the heart rate detection software was currently tracking their HR or not.

Once the participant's heart rate was being tracked (see Section 4.5.1), participants navigated to an embedded Twitch stream of their designated streamer. The embedded Twitch stream allowed audience participants to login through Twitch's API and continue communication using the Twitch chat. Audience participants were guided through surveys and play sessions while progressing through the session. This process was handled by the game client updating flags within the database and the web client receiving the updates to know where to navigate audience members.

Firebase's Realtime Database was used as the main database of the study due to it's ready-to-use implementation for Javascript and C-sharp, required for both the web client and game client respectively. The database allowed for the storing of variables and for variables to be accessed by the deployed study, as well as the Unity game client. For anonymity, audience members were input as post keys, with only their heart rate, status, and their number of completed surveys being stored.

Sense-less Spectators

There were audience members of the live Twitch streams who were not active participants, in that their heart rate was not sensed, nor did they complete experience surveys. However, these spectators still had the ability to observe and to communicate via Twitch's chat interface. As data were anonymized, there was not an easy way to differentiate those 'sense-less' spectators that exclusively participated in Twitch chat from spectators that had their HR sensed by Commons Sense. Therefore, I refer to sense-less spectators and sensed spectators interchangeably (as 'spectators' or as 'the audience') throughout—as *everyone* discussed in this project was ostensibly engaging with Commons Sense in some way (whether it be through Twitch chat or directly engaging with the heart rate feature). Comments and streams are made publicly available and logged on the site indefinitely, thus I analysed Twitch chat data as open-access public data. As such, senseless spectators did not provide informed consent and there is no data collected from their ‘participation’, other than comments they made in the public chat. To preserve anonymity in this context in which informed consent cannot be provided, I anonymized all public chat data prior to aggregating it for subsequent analyses, and present only anonymized chat data from spectators in this paper.

4.6.2 Measures

As video and chat data were captured from the play sessions, I analysed transcriptions of Twitch chat text along with transcriptions of the streamers’ think-aloud data (their verbalized thoughts during the actual session). Streamers also participated in a brief semi-structured retrospective interview after playing. During and after the play session, the audience and streamer were asked to fill out a set of questionnaires about the experience.

Inclusion of the other in the Self (IOS): This single-item visual scale was developed by social psychologists to understand the relationship between the self and the other [18], and is often used in video gaming contexts to understand the relationship between players. In this context, the “self” is defined as the streamer or audience member filling out the scale, and the “other” is defined as either the audience (for the streamer) or the streamer (for the audience). Participants are given an image that shows pairs of circles ranging from just touching to almost completely overlapping. One circle in each pair is labeled “self,” and the second circle is labeled “other.” Participants are asked to choose one of the seven pairs to answer the question, “Which picture best describes your relationship with [the streamer/your audience]?” Both the streamer and audience completed this scale about each other before and after the gameplay session.

Intrinsic Motivation Inventory (IMI): This questionnaire [185] is often used to understand people’s intrinsic motivation about an activity. This scale, which contains multiple dimensions, is often administered in a video gaming context to understand how enjoyable a gaming experience is (e.g., [254, 62]). Dimensions of this scale in video gaming differ depending on multiplayer or singleplayer experiences. I administered the single-player dimensions to the streamer after the entire play session, which included an assessment of: enjoyment/interest, perceived competence, effort/importance, and tension/pressure. In between each of the three game rounds, both the audience and the streamers additionally filled out the enjoyment subscale of the IMI, to assess potential differences between the implementation approaches. Participants are asked to rate how much they agree or disagree with statements relating to these concepts on a scale from 1 (low) to 7 (high).

Audience Experience Questionnaire (AEQ): After the entire gameplay session, the audience filled out this questionnaire which consists of five dimensions: enjoyment, mood, game engagement, social engagement, and participation [69]. This questionnaire was developed as an instrument to measure the core aspects of the audience experience of social video gaming. Audience members were asked to rate how much they agree or disagree with statements relating to these concepts on a scale from 1 (low) to 7 (high).

Game-Specific Attribution Questionnaire (GSAQ): This scale [63] is derived from attribution scales in psychology [320] that measure how people assign causes to events and how these attributions affect their emotional reactions. In the case of games user research, attribution is often relevant in terms of understanding success and failure in games. The GSAQ has multiple dimensions of attribution including internality (whether they attribute the outcome to themselves or external factors), controllability (whether they felt able to control the outcome), stability (whether their performance would be similar in a different time), and globality (whether their performance extends to other areas). I used only the internality and controllability subscales, as these have been found to correlate most directly with perceived competence [63, 259] and should give an indication of whether the streamer felt responsible and in control over their performance, which was driven in large part by the audience input. Streamers were asked to rate how much they agree or disagree with statements relating to these concepts on a scale from 1 (low) to 7 (high).

Effect of Heart Rate on Game: After playing each round, I surveyed both the audience and the streamer to find out how much they thought the audience's heart rate in that particular condition—either *environment* or *difficulty* for round 2, or both for round 3—affected the game. I asked them to rate this on a sliding scale from 0 to 100.

4.6.3 Participants

Streamers and their audience participants are presented anonymously. Streamers are referred to by (S) and a number (e.g., S1), and the audience of that streamer is referred to by (A) and the same number (e.g., A1).

The number of spectators that participated does not reflect the total number of spectators watching the stream during the sessions, as many spectators either did not have a webcam (preventing participation), showed up late to the experience, or chose not to participate. Twitch live chat also consisted of not only those spectators that participated in the heart rate feature, but also those that did not (sense-less spectators). As the heart rate data collected from the participating audience members was anonymous, there was no way to identify how many participating audience members used the chat feature. There was likewise no way to distinguish between participating and non-participating audience members in the chat.

Four total streamers and 55 total audience members (Age: M=25.81 SD=7.92) completed all surveys in the game sessions, with additional spectators (between 50 to 200 per session) who observed and contributed to text chat, but did not complete surveys or have their heart rate included. Audience members that did not complete all surveys were not included in the data analysis. The initial live deployment on Twitch was using a streamer and 2 audience members, but I do not include this data in the findings due to the small viewer count and changes to the study that were implemented following this initial deployment. This initial streamer provided preliminary feedback that was used to ensure the systems were all functioning as intended.

Table 4.1 shows the composition of the four in-the-wild sessions on Twitch.

Streamer ID	*Twitch Followers*	*Twitch Partner*	*Audience*	*Spectators*
1	23,000	Yes	13	>50
2	66,000	Yes	19	>200
3	64,000	Yes	9	>50
4	53,000	Yes	14	>150

Table 4.1: The composition of the four play sessions. The number of spectators was gathered from the Twitch interface and the size of the audience was based on how many people completed all questionnaires.

4.6.4 Procedure

Due to the unique nature of the Twitch platform, I opted to maximize ecological validity and recruit actual Twitch streamers to test out the game 'in-the-wild' [103]. I recruited streamers through snowball sampling methods, utilizing social media and gaming networks to contact streamers with the requisite spectator bases (at least 20 spectators). Ethics approval was obtained through the local University, and all data were gathered in the summer of 2020. Streamers were asked to pick a one hour time-slot to stream the game with their audience. Myself and a colleague moderated the sessions in order to help with technical difficulties. Streamers were provided with the consent form, game, and study information prior to the play-session, and were asked to encourage their spectators to participate in the heart rate feature of the game. Streamers were compensated a $500 Amazon gift card for their time, and spectators that participated in Commons Sense were entered into a raffle for a $150 Amazon gift card.

I recorded video of each session using Open Broadcasting Software (OBS)[11], and chat data were collected using Chatty[12]. I sent the game files to the streamers, and instructed them to stream using their usual streaming configurations. Streamers waited about 10-20 minutes at the home screen to gather as many audience members as they could to participate before beginning the game.

Before playing, the streamer and audience members using Commons Sense were asked to fill out a consent form as well as the IOS scale. The play-session was divided into three rounds, of five minutes each. The order of the *environment* and *difficulty* game conditions were counterbalanced across streamers to minimize order effects. All streamers played the *both* condition last. Following the play sessions and experience questionnaires, both streamers and audience members filled out general demographics questions (i.e., age, gender) and questions about their streaming or viewing habits/experiences (e.g., active/passive viewer, what game genres they usually stream). I asked streamers five semi-structured questions regarding the game, their enjoyment of the session, and potential avenues for future work. Audience members were also asked to fill out a free-form response regarding their overall experience watching the play session.

[11] https://obsproject.com/
[12] https://chatty.github.io/

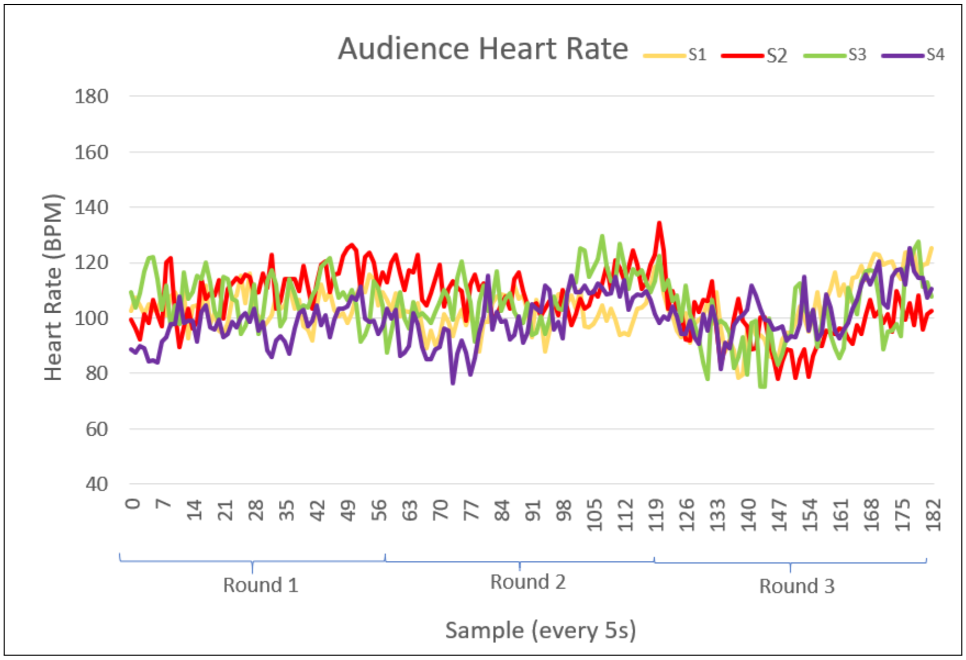

Figure 4.4: Audience heart rate from round 1 to round 3.

4.7 Findings and Reflections

In this section, I present a formative evaluation of this novel design space, using the 'in-the-wild' deployment of the technology probe with four streamers and each of their audiences. While each individual streamer's game session was a unique experience with a separate audience, to observe relationships and trends I aggregate data across streamers and across audience members. However, I take their individual experiences into account with supporting indication from Twitch chat and retrospectives from each. Throughout this section, I present findings, but do not conduct any statistical tests, due to the inherently variable/uncontrolled nature of each Twitch streaming experience/play session, and the exploratory nature of the formative evaluation [314]. I explore the four guiding questions regarding how streamers and spectators leveraged the new interaction, through both qualitative and quantitative data: 1) How did the audience interact using Commons Sense? 2) How did streamers respond to Commons Sense? 3) Was the experience of Commons Sense enjoyable? And 4) How did Commons Sense influence the connection between the streamer and their audience? I conclude with discussing limitations, opportunities, and reflections on how Commons Sense was enjoyable and enhanced engagement amongst both the streamer and members of the audience. Findings are organized by theme from each of these guiding questions, and begin with a key takeaway observation.

4.7.1 Audience Interaction

Key takeaway: Spectators were both engaging with Commons Sense, and were intentionally trying to manipulate their heart rate.

Audience Heart Rate

The average of the audience's heart rate over time from round 1 to round 3 was fairly consistent (see Figure 4.4)—averaging 106BPM throughout all sessions (round 1: 106.9, round 2: 106.6, and round 3: 103). However, the variability of the signal fluctuated throughout the course of the study across all rounds, with a higher threshold of 170BPM and a lower threshold of 70BPM (both reached during round 3). Notably, the average resting heart rate for adults over the age of 20 is between 60 and 100BPM[13]; the mean age of participating audience members was 25.81, suggesting the audience's heart rate was above resting rates for the course of the study.

Throughout each streamer's play session, Twitch chat data suggests that audience members seemed to engage in a coordinated effort to influence their heart rate, usually with the objective of raising it (rather than lowering). See Table 4.2 for excerpts from chat, with examples of some spectators urging others to increase their heart rates, and others encouraging everyone to "chill".

ID	Chat Text
A4;5	we're freaking out man
A4;2	IM LAUGHIGN SO MUCH
A4;6	we need to chill
A4;2	HIGHER AUDEINCE HIGHER hypeE
A2;1	who is the anxious one [emoji]
A2;4	yes
A2;5	With a heart rate this high we know most people doing it are [emoji]
A2;7	chat is too nervous
A2;3	guys chill
A1;1	I have a high resting heart rate [emoji]
A1;2	I live on the edge of a heart attack
A1;3	there is no chill for chat
A1;1	I'm about to do jumping jacks [emoji]

Table 4.2: Chat excerpt. The ID (e.g., A4;2) refers to the streamer group (e.g., A4), then the individual participant (e.g., 2).

Twitch chat logs suggest that spectators were both engaging with Commons Sense, and were intentionally

[13] https://www.heart.org/en/healthy-living/fitness/fitness-basics/target-heart-rates

Word/Emote	*Uses*	*Meaning/Notes*
kekw	137	Laughing, twitch emote
chat	100	referring to the entity of chat
heart	98	often used in conjunction with “rate” or “beat” or “attack”
lul	77	Laughing, twitch emote
[streamer-specific emote]	74	custom twitch emote of a surprised cat
rate	73	used in conjunction with “heart”
game	72	used when referring to the Alien Shooter game OR Commons Sense itself

Table 4.3: Most common words used on Twitch chat across all streamers’ play sessions.

manipulating their heart rate. To evaluate chat sentiment, I identified and defined categories for the 600 most common words or emotes used in all sessions. The categories were: affect, positive emotion, negative emotion, emotes, exercise, physiology/health, calming, aggravating, fear, social/Twitch, study-related, security, inappropriate. Next, myself and a colleague assigned the 600 words to the categories listed above. Words relating to affect were used most commonly (265 times), exercise was discussed 42 times (words like “treadmill”, “exercise”, and other such words associated with raising heart rate), and physiology was discussed 53 times. Feedback from Twitch chat indicates a general drive toward active participation in the experience, as Commons Sense was the most frequently discussed topic of chat.

In addition to these broad categories, I used a Python script that counted the number of times a word was typed into Twitch chat during the game session. After removing pronouns and prepositions from the data set (e.g., “a”, “the”, “at”), I considered the frequency of the top words typed into chat throughout all streamers’ sessions. The top words used are shown in Table 4.3. Additional words related to the game were “webcam”, used 47 times, and “heartrate” (one word), used 41 times. Words relating to both raising HR (e.g., “exercise”, “treadmill”, “work out”) and lowering HR (e.g., “chill”, “calm”, “breathe”) were also common phrases observed in Twitch chat throughout each streamers’ sessions. A sample of chat exchanges containing these words are shown in Table 4.4.

Feedback from audience members on the questionnaires showed that they felt the *environment* and *difficulty* approaches affected the game to a comparable degree (see Figure 4.7), perceiving the *both* condition to affect gameplay the most.

Reflections on Findings

While the average heart rate of the audience stayed consistent through the rounds, the fluctuation of the signal seemed to align with a coordinated effort amongst audience members to raise (or lower) it. Twitch chat logs demonstrate a coordinated effort to manipulate HR data. Marsh et al. state that, “The pull to coordinate with others is fundamental” [181]—as such, designing an interaction that encourages coordination may help to satisfy the fundamental need for social closeness.

In recent years, there has been a drive to understand the viewing habits of those that tune in to live streaming platforms like Twitch [268]. Viewing habits can range anywhere from a more active form of participation (e.g., engaging through Twitch chat or participating in any game features) to a more passive one (e.g., spectators might have the stream running in the background, or might be actively watching but not

ID	Chat Text
A1;1	I wish I had a webcam cause I'm ready to have a heart attack
A1;2	Everybody freak the heck out I guess
A1;3	so the more scared we are the darker it is
A1;3	brb going to exercise
A1;4	I'm never chill!
A4;1	alright everyone start running [emoji]
A4;2	dude i shoudlve worked out before this
A4;2	to raise my BPM [emoji]
A2;10	Not me, I'm just sitting here using my shakeweight
A2;7	i'm just chilling at my desk [emoji]
A2;3	homemade shakeweight
A2;9	I do have a treadmill
A2;3	nice"
A2;2	idk why im sweating lol

Table 4.4: Chat excerpt. The ID (e.g., A4;2) refers to the streamer group (e.g., A4), then the individual participant (e.g., 2).

utilising chat). The design of Commons Sense was left open—allowing the individual to choose how actively they want to engage with the enhanced play experience. In the context of Striner et al.'s spectrum [289], Commons Sense is situated at the 5th/6th dimension (i.e., between the audience influencing the experience and the audience/streamer bidirectionally influencing each other), regardless of how actively an individual chooses to participate.

Commons Sense might allow a broader range of viewers with different preferred styles of communication (e.g., verbal, non-verbal) a chance to participate. Commons Sense expands upon the potential of extant audience interactivity modalities by breaking boundaries of traditional voting or text-based interactions, as it allows for active engagement (through intentionally manipulating HR) or passive engagement (through observation and no active manipulation) with the modality.

4.7.2 Streamers' Response

Key takeaway: Streamers referred to the audiences' collective heart rate often, using it as an opportunity for interaction with their audience.

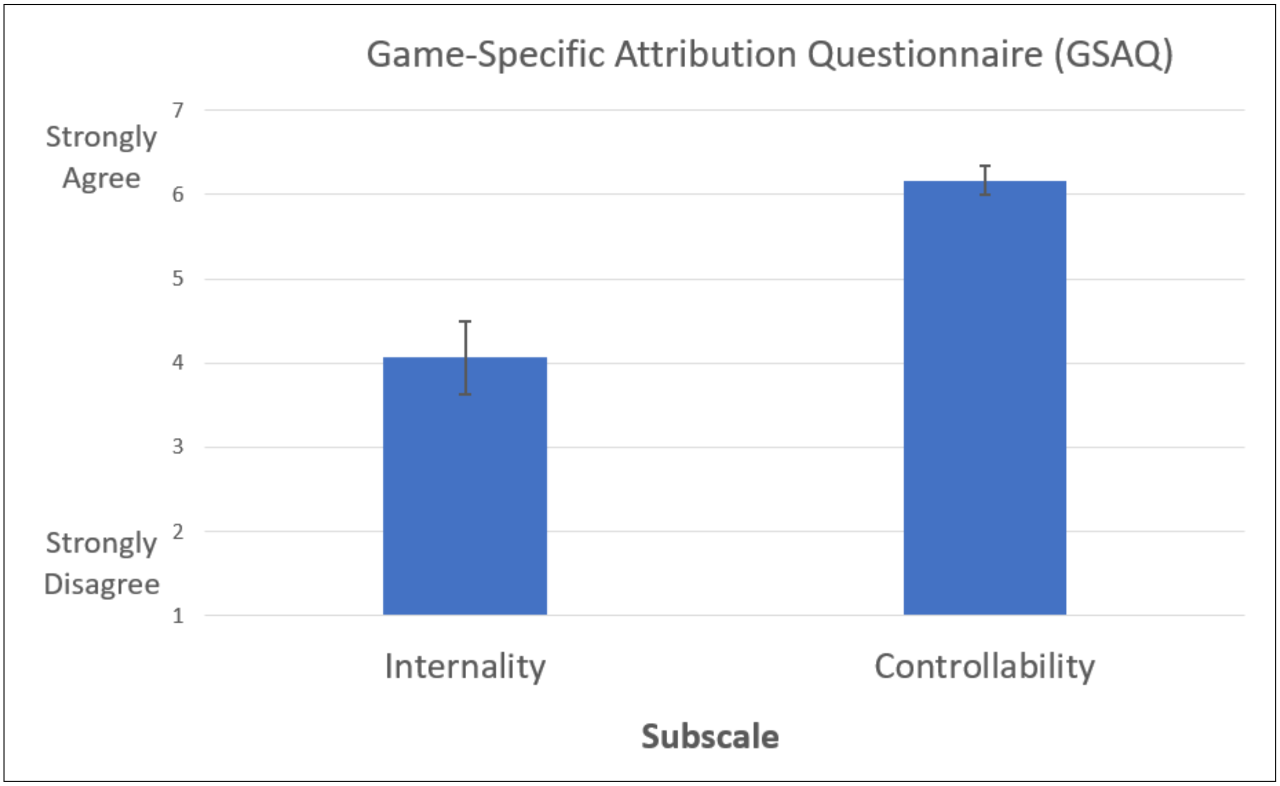

Figure 4.5: GSAQ Bar Graph

Streamer Performance

All streamers engaged directly with their audience throughout the play session, often referring to their audience members as a singular collective entity known as "chat". S1 said the word "*chat*" 34 times, often begging the chat to stay calm, "*Chat, you gotta stay calm, you gotta stay calm, OK?*" or "*Chill out chit chat. You gotta chill out.*". S3 acknowledged spectators engaging with Commons Sense often as well, referring to "*chat*" a total of 20 times. S2 addressed chat directly, saying "*Well done chat. We made it.*" and "*Chat what are you thinking of right now?*". References to exercise were also common: "*Your heart rate chat. Who's running a marathon?*" -S1.

S3 referred to audience members in a different manner, querying spectators with phrases such as, "*You guys are really immersed, huh? It's going up when it gets intense. Or does it get intense when it goes up?*". S4 referenced chat often as well, saying things like, "*Chat, can you control your heart rate please?*", "*Chat you killed me or maybe I killed myself.*", "*Chat chill!*", and "*Chat, please stop!*".

Using the Game-Specific Attribution Questionnaire (GSAQ), I looked at perceived attribution to understand to what degree streamers felt responsible for their performance. Responses indicate that streamers felt like they were in control of gameplay (Controllability: M=6.17; SD=0.58), yet also were subject to the control of the audience whim (Internality: M=4.06;SD=1.77)—see Figure 4.5, which shows the mean (+/-SE) of streamers' responses to the internality and controllability subscales, from 1 (strongly disagree) to 7 (strongly

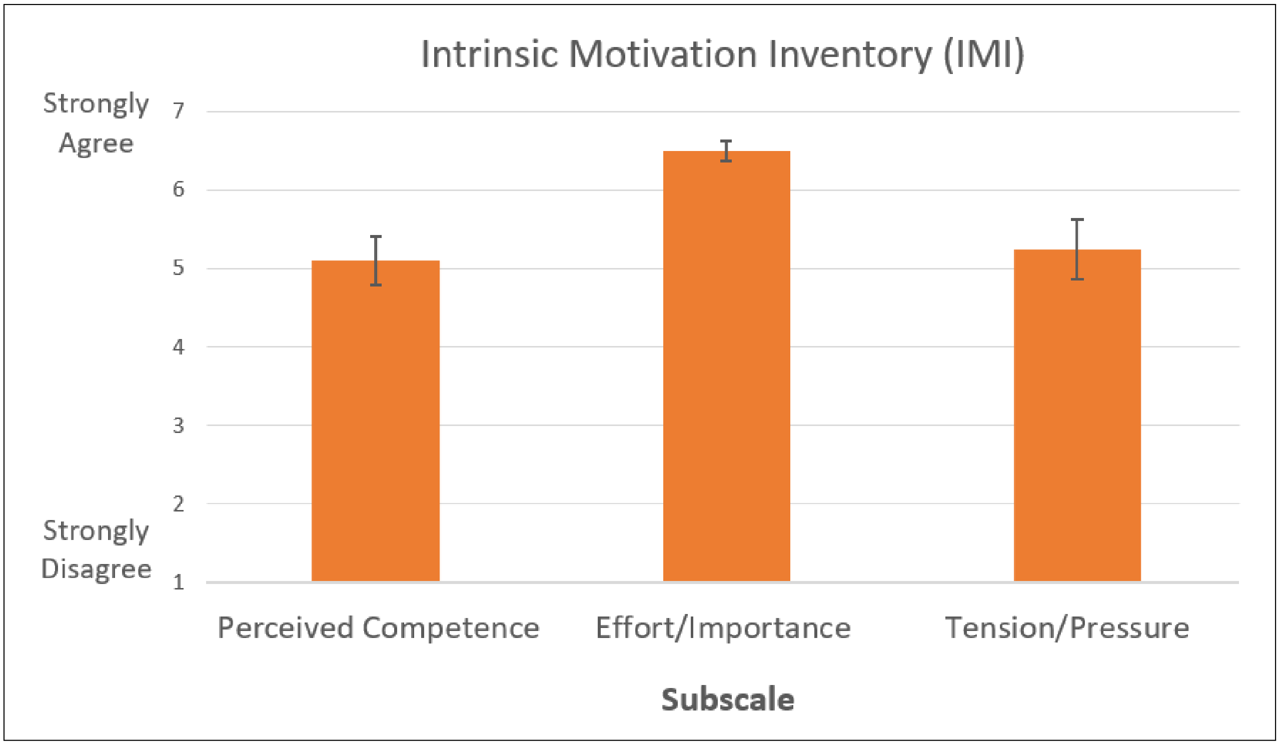

Figure 4.6: IMI Bar Graph

agree)..

I also asked streamers how they felt about their own performance, for the entire play session, using the Intrinsic Motivation Inventory (see Figure 4.6, displaying the mean (+/-SE) of streamers' responses to the Intrinsic Motivation Inventory (IMI), from 1 (strongly disagree) to 7 (strongly agree)). Streamers seemed to feel competent—Perceived Competence (M=5.10;SD=1.37); that they invested a lot of effort—Effort/Importance (M=6.50;SD=0.52); and that there was the overall experience of tension—Tension/Pressure (M=5.25;SD=1.53).

Streamers' Feedback

The streamers noticed the influence of HR on gameplay largely through the impact it had on their individual performance, as audience efforts to raise heart rate frequently corresponded with the streamer's in-game death. S4 noticed this relationship and commented, "*[I] think when it got to over 105-110 I would get overwhelmed sometimes and die.*" In S3's retrospective interview, they note that "*it was really cool to see spectators' heartbeat go up when the game got intense*".

Figure 4.7 shows the mean (+/-SE) of both audience members and streamers' perceived effect of Commons Sense. In terms of how the streamers perceived the effect of HR on the game per implementation approach (from questionnaire data), Figure 4.7 shows that the *both* approach was rated as having the highest effect on gameplay at 83%, with the *difficulty* condition at 78%.

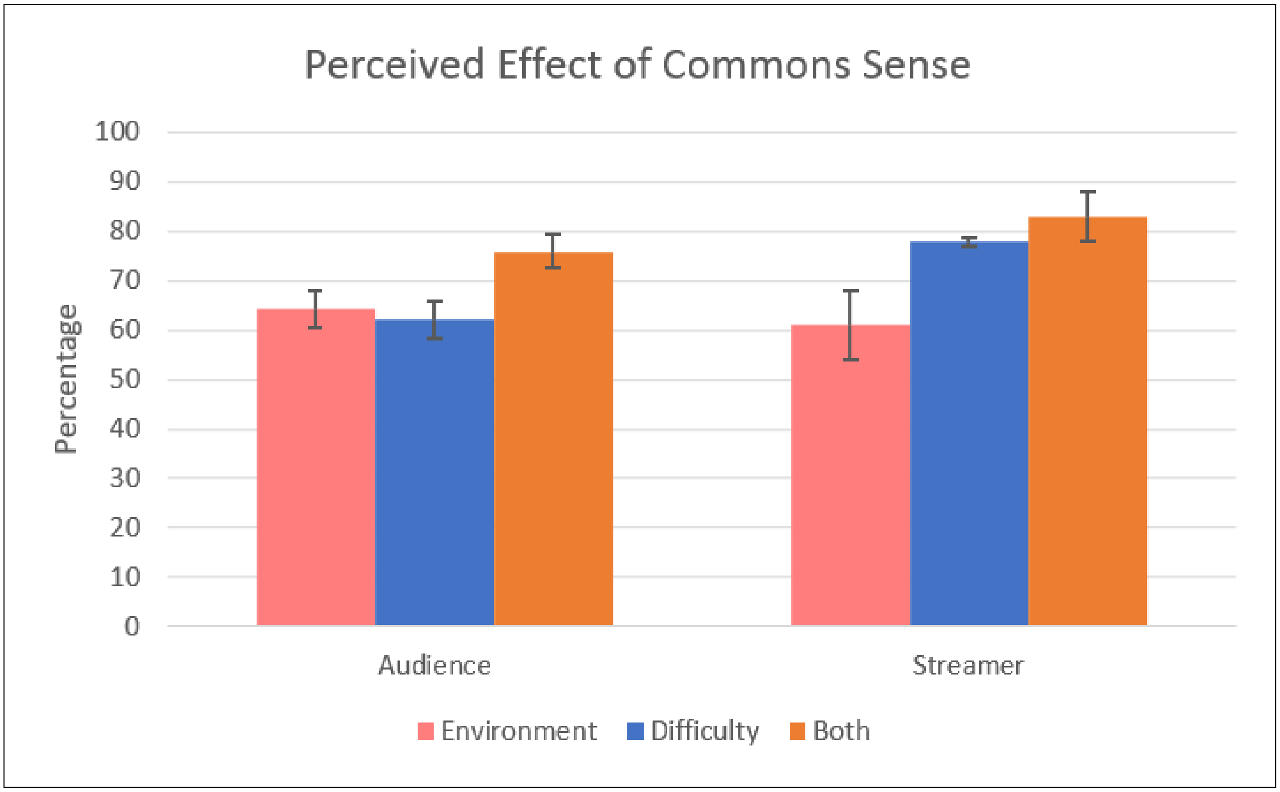

Figure 4.7: Streamers' and spectators' perceived effect of Commons Sense

Reflections on Findings

I designed the play experience such that the streamers' performance in the game would be directly related to the audience's current heart rate; this design's success is supported by the feedback from questionnaires, which suggest that the streamers felt as though the audience had some level of control over their performance. However, streamers also reported an internally high level of control over the experience (scoring high on the controllability dimension). The contrast in scores from each subscale supports the effectiveness of Commons Sense as a balanced interaction: streamers are still able to exert agency and control over the play experience, while at the same time believing the spectators to have a great deal of control as well.

Lower ratings of perceived competence by streamers might be explained by the similarly lowered ratings of internality. A player's causal beliefs and how they attribute their performance are antecedents to feelings of competence and autonomy (e.g., internal and controllable causes for success are more likely to evoke feelings of competence); as such, the streamers' belief that the spectators have a high level of control might lead them to feel less competent about their own performance. As per the design of this enhanced play experience, I intentionally increased spectators' control over game aspects—which will inherently lower the amount of control the streamer has over the experience. In terms of game balance, there is a design trade-off to think about: spectators must have enough control to feel like they are influencing the experience, without making the streamer feel like they have diminished control over the game. S4 notes that "*I enjoyed being able to* *"blame" chat for making things more challenging and joking around with them when their heart rate got high."*.

4.7.3 Enjoyment

Key takeaway: The streamers and the audience enjoyed the experience as a whole, as shown by Figure 4.8 and Figure 4.9.

Streamers

Streamers indicated overall enjoyment of both the game and Commons Sense through their verbal interactions during the play session, retrospective interviews, and post-questionnaires. Streamers expressed positive feelings toward their interactions with the spectators through Commons Sense. S1 says, "*I actually am delighted by this concept in general, I hope I get to play something very similar someday as like a full version.*".

S1 and S3 commented on their interest in the heart rate technology, indicating excitement in regards to seeing this type of physiological interaction integrated into the Twitch platform. In their retrospective interview, S3 states that: "*That was very interesting. That's very cool. I'm really looking forward to a future like this. It makes me excited for the future of streaming because audience interaction is going to like...there's more and more games and new innovations, in regards to streamer interaction. I can't wait to play AAA horror games that are affected by the audience heart rate.*". Further, S2 comments: "*I love technology like this. I think the future is full of possibilities for really interesting participation games like that.*". And another comment regarding affordances of the interaction by S1: "*Can you imagine audience participation but in a passive way like this?*".

In addition to the perceived effect of each implementation approach discussed in the previous section, I was interested in how the implementation approach (*environment* vs. *difficulty* vs. *both*) affected enjoyment of the game by streamers. The post-questionnaires suggest that the *both* implementation approach (third round) was more enjoyable than the prior two rounds (M=6.30 SD=0.92), shown in Figure 4.9. The *environment* rounds (M=5.85, SD=1.42) and *difficulty* rounds (M=6.10, SD=1.02) were similar. S1 notes that they rated the highest enjoyment for the *both* approach because "*it was the most noticeable difference.*"

Audience

Audience members seemed to enjoy engaging with Commons Sense. A member of A1 says that "*the technology is super interesting, and I would enjoy seeing more audience integration like it.*" A member of A3 notes: "*It was a really interesting experience, interacting with the streamer in a way that I've never seen before was real fun. I had never seen a game be controlled by the spectators heart rate, with further development it could become a really neat feature in streams.*"

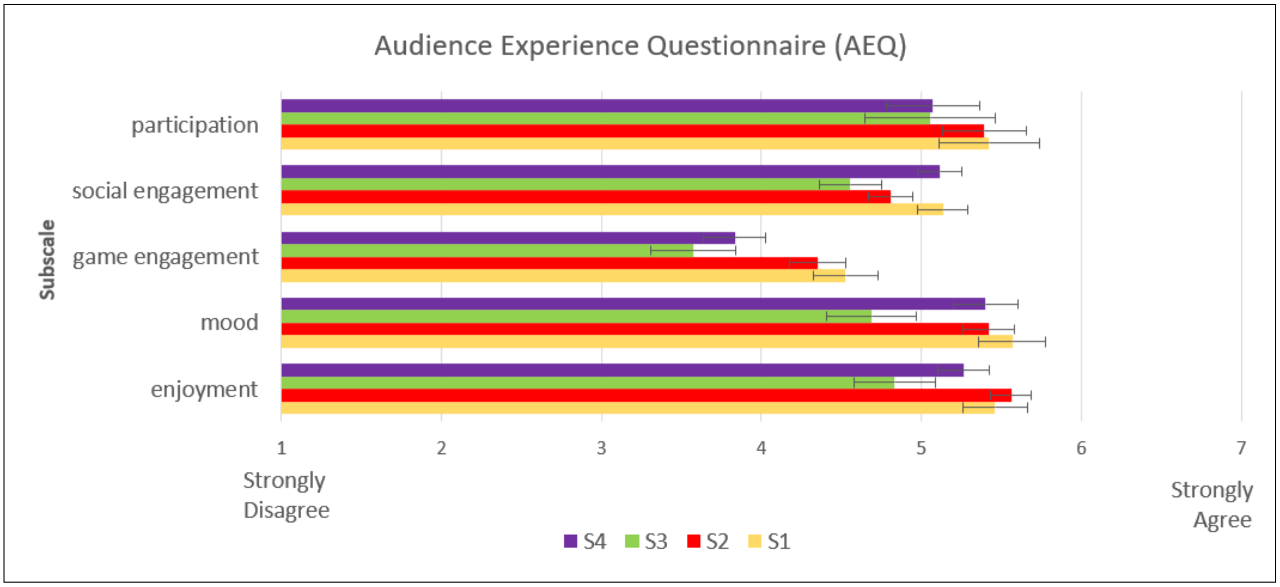

Figure 4.8: AEQ Bar Graph

Scores from the Audience Experience Questionnaire, shown in Figure 4.8 (which displays the mean (+/-SE) of audience members' responses to the Audience Experience Questionnaire (AEQ)) show that audience members enjoyed the interaction. Audience members reported high levels of enjoyment (M=5.34, SD=1.59), a positive mood (M=5.33, SD=1.70), positive levels of social engagement (M=4.92, SD=1.61) and participation (M=5.26, SD=1.60). However, game engagement was lower than the other dimensions across streamers (although still slightly above neutral) (M=4.13, SD=1.86). The game engagement subscale included items measuring constructs such as attention and concentration on the game.

A quote from a member of A1 in reference to a lowered level of engagement with the game: "*it wasn't what I was expecting. Didn't find it personally scary for me, so unless I actively tried to alter my heart rate, it didn't feel like I was affecting anything.*"

In terms of which implementation approach was preferred by the spectators, audience members enjoyed the *both* approach the most as well (M=4.57 SD=1.82), with *environment* (M=4.32 SD=1.82) and *difficulty* close behind (M=4.43 SD=1.79)—see Figure 4.9 (Displaying the mean (+/-SE) of audience and streamer responses to the enjoyment subscale of the Intrinsic Motivation Inventory (IMI), separated by approach from 1 (strongly disagree) to 7 (strongly agree).) As shown, audience ratings of enjoyment were not as high as streamers' ratings, but were only slightly above neutral.

Reflections on Findings

High internality and controllability beliefs appear to be connected with higher interest and enjoyment of a game [63]. Thus, it might be expected to see lower scores on the internality subscale by the streamers to correspond with lowered scores of enjoyment, but this was not the case, suggesting that the unique interaction modalities afforded by Commons Sense adds to the experience, rather than detracts. Streamers

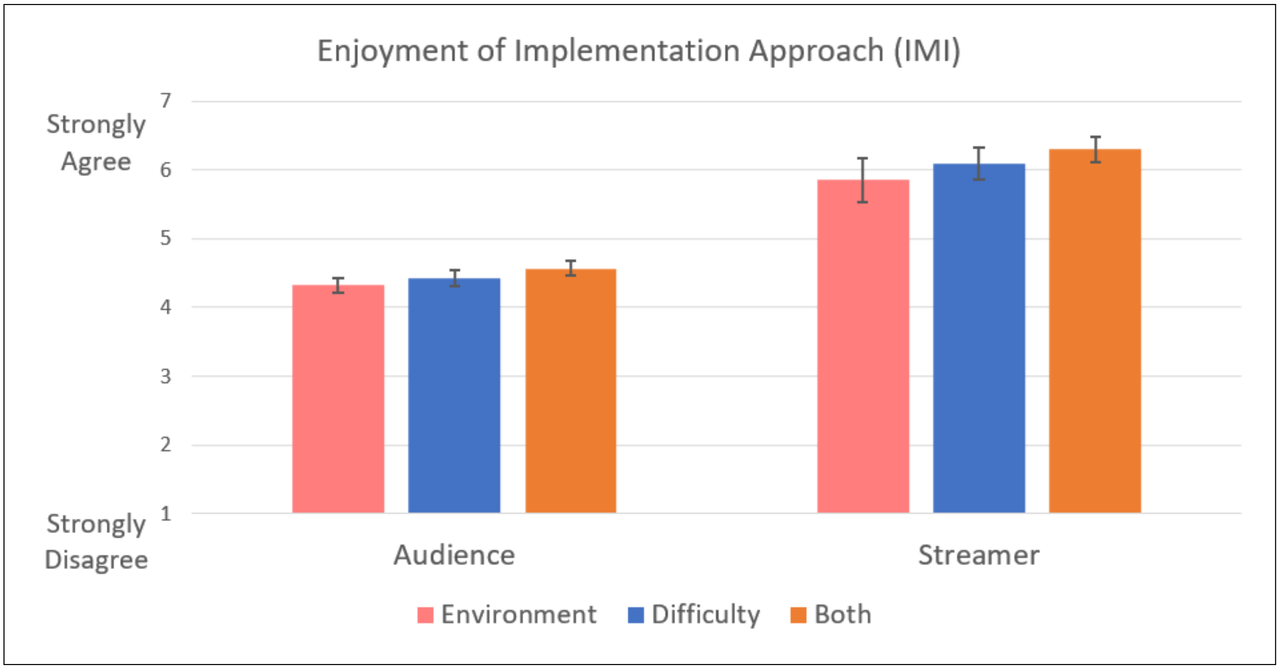

Figure 4.9: Bar Graph of Audience and Streamer Enjoyment

may not have attributed their performance more to themselves than to external influences, but this seemed to be experienced as part of the game's mechanics and challenge.

The lowered levels of audience and streamer-reported game engagement might be explained by the expectancy-disconfirmation theory, which suggests that satisfaction with an experience can be explained by differences between people's expectations and what actually happens [322, 222]. Streamers that took part in the study heavily publicized the event (incentivizing participation with the chance to win money) to draw as much of their audience as possible, which may have increased anticipation. Further, I intentionally deployed the prototype in-the-wild, on Twitch—a platform on which spectators are used to seeing streamers play the top AAA titles. The prototype Alien Shooter game that demonstrates the functionality of Commons Sense is not as complex or aesthetically appealing as games typically streamed on Twitch. Another possible explanation for the neutral game engagement is the repetition of the rounds. In prioritising game simplicity so as to not distract focus from Commons Sense, the game experience may have been rendered less engaging. One audience member from A3 discussed immersion specifically: "*Really fun, I felt if this was integrated into a 3d horror game such as Dead Space, or even some indie titles I would have been even more immersed. But I had fun.*" S3 and S4 refer to the gameplay as "*basic*", and note that their favorite part was the viewer interaction. In the future, adding Commons Sense to an existing commercial game, or designing a game that more closely resembles commercial games, might repair this lowered level of game engagement and heighten the impact of the overall experience.

However, even though game engagement was generally neutral, most audience members did rate the game as enjoyable. An audience member of A3 discusses their personal feelings of neutral game engagement yet

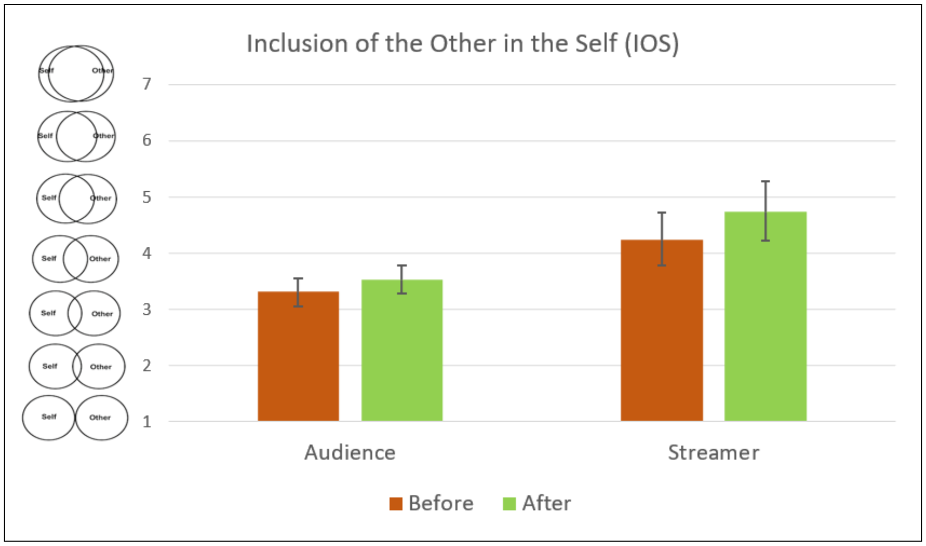

Figure 4.10: Bar Graph of Audience and Streamer Connectedness

high enjoyment: "*for how simple and not impressive the game was on its own, the interactions with the heart rate made a world of difference and really made it more enjoyable.*"

The *both* implementation approach was enjoyed the most by streamers and audience members, supported by the perceived effect of heart rate on the gameplay graph in Figure 4.4, which suggests that both the streamers and audience members feel that the (*both*) approach affects the game to a noticeable degree. S2 says "*I like the challenge and it does make sense to impact both environment and difficulty to me.*". In prior work in affective gaming, many games leverage a combination of both difficulty and environment variables to affect in-game actions (e.g., [207, 231]). However, as more mechanics are added to a game, the game balance might be negatively affected [92], thus it is important as designers to make sure the implemented mechanics create an engaging (and not overwhelming) experience for players.

4.7.4 Connection

Key takeaway: Friendly rapport between audience members and the streamer was taking place throughout the play sessions.

I was interested in how Commons Sense affected mutual feelings of rapport and connection between the streamer and their audience. Twitch chat data supports that friendly rapport between audience members and the streamer was taking place throughout the play sessions.

S4 said during round 1: "*Chat, can you control your heartrate please? Oh my God. Losing that so bad. Dude your guys' heartrates are going up too. No.*" and Twitch chat responded: A4;1: "*cant control what my body do*" A4;2: "*WE WONT STOP [emoji]*" A4;3: "*CHAT STOP HAVING YOUR HEART BEAT* A4;2: "*HIGHER CHAT HYPEE*" A4;4: "*[name redacted] it's not just fear, it's also your level of cardiovascular fitness*"

In response to streamers explicitly asking the chat to calm down, or "*chill*", chat opted for an oppositional approach—instead electing to try to increase their heart rate.

In terms of quantitative data that was collected, the IOS scale (Figure 4.10, displaying Mean (+/-SE) of audience and streamer ratings to the Inclusion of the Other in the Self (IOS) from before to after playing.) shows a slight increase for the streamer from before ($M=4.25; SD=0.96$) to after ($M=4.75; SD=1.26$) and their audience from before ($M=3.31; SD=1.87$) to after ($M=3.53; SD=1.84$); however, these findings were not subjected to statistical tests of difference and cannot be interpreted as such.

Reflections on Findings

While I did not expect to see a notable rise in self-reported feelings of connection in this short of a play session, even these trends of small changes are interesting. Higher-level constructs measured by the IMI relatedness scale—like trust and feelings of closeness—take longer to develop [327, 248], therefore it is possible to see a greater effect over time. While interdependence was high, the level of cooperation vs. competition between the audience and streamers was left open (i.e., the audience could choose to increase their heart rate exponentially, which might hinder the streamers' progress). As interdependent and collaborative mechanics are each shown to positively affect social closeness, the fact that gameplay occasionally became competitive between the streamers and audience members might have hindered this experience. Social interdependence theory [130] suggests that interdependence in combination with competition might lead to oppositional, negative interaction resulting in conflict and distrust. However, because the gameplay had high interdependence, there is still an increase on the IOS scale.

Additionally, the expectancy-disconfirmation theory posits that high expectations of an engaging, immersive, and fun game (by both the streamers/audience) might have actually negatively affected feelings of closeness and rapport—as it has been shown to do in prior research [222]. However, feelings of closeness measured by the IOS slightly increased from before to after, suggesting that Commons Sense might be effective at further increasing social connection in a longer-term study using the modality in a streaming environment.

4.7.5 Limitations and Opportunities

Testing the technology probe out in-the-wild helped me understand what actual Twitch communities both like and dislike about this novel communication method—insights that will inform future design iterations of the probe.

While in-the-wild deployments heighten ecological validity of a technology probe, leading to designs that might better support a particular user group [45], statistical inferences and generalizations might not be as easily drawn as in a standard study. I opted for an in-the-wild approach as this method would help me understand preferences of *actual* Twitch communities, but reduces the controllability, making statistical comparison unreliable. While streamers were asked to encourage spectators to participate (which might have detracted from ecological validity), spectators were still given the option of both taking part in and the degree to which they *interacted* with Commons Sense—which was the more pertinent information in the research context. However—even though I prioritized ecological validity for this particular deployment—it must be noted that this was nevertheless still the context of a research study, therefore participants might have behaved differently than in a non-study context. In future work, I hope to conduct longer term deployments using Commons Sense to minimize this effect and to further explore the benefits of this new form of interaction.

In terms of rewards, as I recruited high-profile Twitch streamers to take part, I felt the compensation offered was a sufficient amount consistent with pay that they would normally be receiving from their employer (Twitch) by streaming a game not in their normal repertoire for one hour (i.e., they took an hour out of their work schedule to participate). This compensation amount is indeed higher than average for this kind of study, thus potentially biasing the self-reported enjoyment of the game by the streamers. I recruited through snowball sampling methods, therefore the group of streamers that participated may be less representative than purely random selection.

Overall, findings suggest that audience members actively attempted to manipulate their heart rate—both the streamer and the audience may have felt the influence of this increased interactivity. However, the elevated heart rates could have also been providing a passively-sensed impression of audience excitement due to their being invested in the play experience, a reflection of an energy akin to one experienced at a live performance. Physiology is not only useful as a one-way indicator of affective state from streamer to audience (as has been previously used on Twitch [250]), but in a bi-directional manner as well [289]. Spectators' reactions can influence the game in a tangible way, differing from most prior work in the APG domain that utilize voting mechanics. This novel communication modality might be useful in other non-gaming online contexts as well, such as digital live performances or presentations.

When deploying affective games at a larger scale, it is important for designers to think about the cost vs. accuracy trade-off. Many physiological sensors require extensive lab setups or expensive hardware. Commons Sense was specifically designed to require no specialized hardware outside of a standard webcam, and emphasized easy calibration, making it a viable option for use by a broad audience (but compromising high-accuracy). For the design, I found that accessibility was top priority: the ability to deploy it to a large audience remotely is essential when working with the Twitch platform. Many of the participants that took part in the in-the-wild evaluation did have a webcam, and had no issues setting up and calibrating it. While this compromised accuracy of the heart rate to a degree, this was not noticeable due to the aggregate nature of the heart rate display (i.e. individual inconsistencies and inaccuracies did not greatly affect the overall average heart rate value). The aggregate nature of the physiological data collected also helped to mitigate privacy concerns, as this is inherently sensitive data. As the data was aggregated amongst all audience members, and individual heart rate values were not saved in the database, no particular HR value can be traced back to an individual; however, commercial systems would need to ensure the privacy of the audience members.

Toxicity on Twitch is a wide concern amongst researchers with regards to methods of interaction, with options for minimizing the impact (e.g. toxicity on Twitch chat is moderated by chat-bots, human moderators and other such techniques like banning user accounts [267]). While there is no way to explicitly control the degree to which spectators interact in a toxic way with Commons Sense, other techniques mentioned to help with moderation can be employed in the same way, to help minimize toxic behaviour as displayed through Commons Sense. In addition, the ability of the audience to interact with Commons Sense in a toxic way is inherently limited by the design of the modality; whichever way the audience chooses to change their heart rate (either increasing/decreasing), it affects the gameplay in an interesting way (e.g. making the game more difficult for the streamer by increasing their heart rate is a part of the game design).

In terms of the Alien Shooter game, the horror genre created the exact type of energy I was hoping for—a positive feedback loop with the audience: as the audience became more excited and their collective heart rate increased, the game reciprocally became more exciting as well. In the future, I will look into further increasing audience engagement with the system, implementing team-based interactions to keep the audience engaged for a longer period of time (through a longitudinal study). As I did not measure controllability/internality of the audience members for this study, I was not able to report how much control audience members may have felt over the enhanced play experience. In future studies, capturing this data may allow for more informed balancing of control each party has over the experience.

In considering the implementation approach, I recommend that future research maps audience input to *both* difficulty and environment, as this approach was perceived by both streamers and audience members to have the most effect on the game, as well as rated to be the most enjoyable of the three approaches. While streamers noted they had seen other audience participatory features or physiological data added to live-streams, none had seen the integration of audience physiology as input on the Twitch platform to date, and were enthusiastic about the concept. This suggests that this enhanced play experience affords a new type of communication channel that was not offered before on the Twitch platform, and using it in future games might be beneficial to help communicate more nuanced emotions.

Unlike in standard online performance contexts (in which little of the audience energy is communicated, or in which the streamer has to re-direct their attention to another display to determine the mood of the audience), the seamless integration of the audience energy into the game's mechanics, graphics, and sound allowed the streamer to feel the audience—not just alongside their performance, but in a way that became part of their performance. Streamers were not only aware of the audience's response, they were—through the gameplay itself—aware that chat had no chill.

4.8 Contribution

In summary, I created Commons Sense as a communication modality intended to engage audiences on Twitch. I aimed to explore a new design space by heightening communicated audience energy and translating lost in-person social cues onto Twitch, through use of Commons Sense and a bespoke audience participation game. To gain insights into this new design space, I evaluated the technology probe in-the-wild, through which I evaluate spectator and streamer interactions and perceptions through four questions of inquiry: 1) How did spectators interact with Commons Sense? 2) How did streamers respond to Commons Sense? 3) Did streamers and spectators enjoy Commons Sense? And 4) How did Commons Sense influence the connection between the streamer and spectators?

From data collected through an in-the-wild deployment with four Twitch streamers and their respective audiences, the formative evaluation suggests that Commons Sense was well-received—streamers and spectators engaged with the addition, and made coordinated efforts to change their collective heart rate to influence the game. Streamers and spectators likewise enjoyed the enhanced play experience, as indicated by feedback provided through retrospective responses and self-reports. I observed that Commons Sense may have begun to facilitate increased connection between the streamer and spectators. Future longitudinal studies using Commons Sense in a variety of gameplay streams across Twitch might better support the development of social connection. Commons Sense is an enhanced play experience that I developed and deployed on the largest game streaming platform, showing it to be a novel approach to engaging streamers and spectators—an interaction approach that warrants further investigation. This formative work helps to situate future work on affective audience participation games, opening up a new design space and providing insights and lessons learned from a technology probe deployed in-the-wild on the Twitch platform. Sharing physiological signals as a way to communicate audience response shows promise not only as an engaging and robust form of communication in an impoverished digital domain like Twitch, but also in the broader landscape of HCI. HCI researchers and audience participation game designers should consider this new design space, using physiological signals as a way to enhance communication and engagement within large-scale digital platforms.

5 General Discussion

In this chapter, I discuss lessons-learned from conducting the systematic review and creating the two design probes, In the Same Boat and Commons Sense.

In terms of the Self-Determination theory [260], in order to foster the highest sense of intrinsic motivation in individuals, three needs must be met: competence (i.e., the need to feel good at the task), autonomy (i.e., the need to feel in control), and relatedness (i.e., the need to feel close to others). Thus, it follows, to heighten player experience, it is necessary to focus on heightening these three pillars of SDT as well, particularly with special attention paid to the *relatedness* dimension. In this work, I focus specifically on heightening engagement through enhancing *relatedness* amongst players.

5.1 Systematic Review

In the systematic review, I asked the question, "Has the promise of affective gaming to enhance player experience been realized?" My goal was to explore this question by discussing if, how, and why affective gaming enhances player experience.

5.1.1 "IF" Affective Gaming Enhances Player Experience

Key takeaway 1: There are few formalized evaluations within the field of affective gaming, making it difficult to answer the question of "if" affective gaming enhances player experience.

Generally, the outcomes of the reviewed papers showed that most studies achieved their goals, indicating that the field of affective gaming has promise to enhancing player engagement. Constructs such as flow, enjoyment, fun, immersion, and usability were examined, and physiologically-adaptive games improved the player experience compared to non-adaptive games. However, the focus on novelty in contribution may have led to a lack of formal evaluations. Without these formal evaluations of the games, it is difficult to give a solid answer as to whether affective gaming enhances player experience. While most studies generally yielded the desired outcomes, about 10% of studies explicitly stated that aspects of their goals were not realized. Most reasons were due to either the intrusiveness of the physiological sensors interfering with gameplay, resulting in decreased enjoyment, flow, and immersion in the game, or the sensor functionality as a primary issue, which translated to lowered game control responsiveness.

Most researchers who used physiological devices customized them to their particular need; as both development and calibration of these devices can be time-consuming, I posit that the time spent conducting a user study for research in this domain is high and may slow the research cycle down significantly, meaning it might be less feasible to publish papers at the same rate as other fields, adding to the potential reasons why the field is still not advancing. I recommend affective gaming researchers leverage hardware with pre-existing Unity integration (e.g., Affdex, Fitbit) or devices with extensive documentation (e.g., Adafruit Circuit playground, Microbit) to help ease a few of the challenges presented when developing affective games. Additionally, these affordable, compact devices allow for efficient setup and calibration, making it easier to acquire a larger number of them in order to run multiple studies in parallel.

5.1.2 "HOW" Affective Gaming Enhances Player Experience

Key takeaway 2: it is important to carefully consider the affordances of the physiological signal when mapping the signal into gameplay, in order to effectively enhance player experience.

To understand the nuances of how affective gaming enhances player experience, there needs to be a classification system to understand the physiological sensors/signals used, and how they are mapped into the gameplay experience. In designing the affective game loop, my goal was to make a system for classifying literature within the field in terms of the particular physiological sensors used, and how that signal is used within the game experience. In terms of the affective game loop, indirect physiological inputs (heart activity, EDA) were most commonly used to adapt context-based in-game activities, while direct physiological inputs (breath, facial expressions) were used mostly to control action-based mechanics. When designing affective games, it is important to take into consideration the affordances of the particular physiological sensing modality when making input mapping recommendations. For example, action-based input mappings, such as jumping or shooting, require immediate and on-command responses, which is the most feasible when using a directly-controlled input. On the other hand, context-based input mappings such as difficulty and environmental changes are often subtle, gradual, and implicit game occurrences, making indirect physiological inputs a suitable match. While this indirect-context/direct-action mapping was the most common and intuitive, there seems to be promise in the opposite: context-based mapping of direct signals and action-based mapping of indirect ones. Studies showed that this pairing of physiological input with game mapping is not only feasible [228], but can enhance player engagement and arousal [32, 173, 212].

5.1.3 "WHY" Affective Gaming Enhances Player Experience

Key Takeaway 3: "Why" is the most under-explored question of the three, due to the preliminary nature of the field as a whole.

The interdisciplinary nature of affective gaming research means that each game is designed based on a wide range of literature from diverse fields (e.g., medicine, gaming, psychology, sociology, and theatre arts). In addition, each application area discussed in the systematic review (general engagement, mental health, physical assistance) draws from a different subset of literature from a different field. Future work might capitalize on synthesizing this literature into a database in order to help understand what contributes to making an effective physiological game experience. Before the field can truly understand "why" affective games enhance player experience, there needs to be more understanding about "how" the designs contribute to an engaging play experience. In future years as the field progresses and more formal evaluations of the games are conducted, there will be a need to conduct a meta-analysis of this work to explore this question. However, at this time the field is too new and exploratory in nature to answer this question.

In summary, there are numerous barriers in the field of affective gaming preventing the promise of enhancing player experience to be realized. In the next sections, I discuss how I apply the key takeaways of this systematic review to the design of each probe.

5.2 In the Same Boat: Design Probe One

In this first design probe, I explored how using an affective control scheme (using action-based direct physiological signals) might enhance player experience. My goal was to explore this by creating a design probe called 'In the Same Boat' and testing this new embodied control scheme in a formalized evaluation (*Key takeaway 1*) against the same game using keyboard controls. In the Same Boat explore themes of social closeness between players over a distance. The game leverages players' physiological data (facial expressions and breathing rate) as input to the game and focuses on the synchrony of physiological input as the mechanic that realized cooperation and interdependence in the game. The direct-physiological signals were mapped to action-based mechanical input (movement of the canoe). In the Same Boat was designed to promote an intimate interaction, by focusing on embodied interaction using physiological input, mirroring emotions through syncing, and networked play. This game is the first to leverage physiological syncing over a distance and has the potential to help geographically-distributed friends, family, and partners to feel closer through playful interaction. The analysis of control scheme (embodied vs. keyboard) showed that embodied controls were less intuitive; however, participants using the embodied controls enjoyed playing more than those using the keyboard. Those who played with the tutorial enjoyed the game less overall, which suggests that joint discovery of the controls was more desirable. Affiliation scores after play were higher in the keyboard condition, which might be partially explained by the significant difference in game performance: people who played embodied controls performed worse in terms of high score than those who played with keyboard. Finally, to corroborate the player-centric analyses, I had 105 independent participants rate before and after images of the dyads together. Participants rated photos of the dyads that played with the embodied controls as significantly happier and closer to one another than those who played with keyboard controls.

5.3 Commons Sense: Design Probe Two

In this second design probe, I explored how using an affective communication modality (affecting gameplay through context-based indirect physiological signals) might be implemented into a game to enhance player/audience experience. My goal was to explore this by creating Commons Sense and testing this new communication modality in-the-wild with real streamers and their respective audiences. Commons Sense expands upon the potential of extant audience interactivity modalities by breaking boundaries of traditional voting or text-based interactions, as it allows for active engagement (through intentionally manipulating HR) or passive engagement (through observation and no active manipulation) with the modality.

I tested out three different implementation approaches to see which was the most well-received by the audience and streamer (*Key Takeaway 2)*. In considering the implementation approach, I recommend that future research maps audience input to *both* difficulty and environment, as this approach was perceived by both streamers and audience members to have the most effect on the game, as well as rated to be the most enjoyable of the three approaches. While streamers noted they had seen other audience participatory features or physiological data added to live-streams, none had seen the integration of audience physiology as input on the Twitch platform to date, and were enthusiastic about the concept. This suggests that this enhanced play experience affords a new type of communication channel that was not offered before on the Twitch platform, and using it in future games might be beneficial to help communicate more nuanced emotions.

One key findings suggested that audience members actively attempted to manipulate their heart rate—both the streamer and the audience may have felt the influence of this increased interactivity. For this particular design, I found that accessibility was top priority: the ability to deploy it to a large audience remotely is essential when working with the Twitch platform. In terms of the Alien Shooter game, the horror genre created a positive feedback loop with the audience: as the audience became more excited and their collective heart rate increased, the game reciprocally became more exciting and horrifying as well. Unlike in standard online performance contexts (in which little of the audience energy is communicated, or in which the streamer has to re-direct their attention to another display to determine the mood of the audience), the seamless integration of the audience energy into the game's mechanics, graphics, and sound allowed the streamer to feel the audience—not just alongside their performance, but in a way that became part of their performance. Streamers were not only aware of the audience's response, they were—through the gameplay itself—aware that chat had no chill.

5.4 Physiological Sensors

In the realm of using physiological signals to enhance player experience, it is of the utmost importance to design the systems utilizing physiology in such a way that does not detract from the play experience, but rather, enhances it. In terms of choosing the right physiological sensors for the particular research, there are trade-offs in the realm of cost, accuracy, and accessibility. Throughout my research, I have noticed some critical points to consider when designing affective games: *Accessibility, Intrusiveness, Accuracy*, and *Privacy.*

a) *Accessibility*: In terms of accessibility, off-the-shelf sensors at a lower price point are usually best when designing an affective game that will go to market or eventually be played outside a lab-based environment (e.g., Fitbit, Apple Watch, Circuit Playground, webcam). Usually, these sensors are also non-intrusive as well, making them ideal choices for commercial games. The Arduino Circuit playground in particular is cheap ($30), widely available for shipping to anywhere in the world, and has inexpensive attachments for heart rate tracking (either through a wristband or ear attachment), GSR (through finger sensors), and breathing rate (using the on-board microphone).

b) *Intrusiveness*: Using an off-the-shelf device usually also means that the device is less intrusive (e.g., Muse headband, Fitbit). Cumbersome or bulky physiological sensors that are often used in a lab based setting (e.g., chest straps, wrist cuffs) runs the risk of detracting from the overall play experience, immersion, and flow state [53]. Considering using a less-intrusive device will increase the real world applicability of the design. Unfortunately the less intrusive and off-the-shelf wearables usually also come at the cost of accuracy; i.e., wrist-worn sensors will generally not be as accurate as a chest strap for collecting heart rate. Devices like the Fitbit or Apple Watch have improved their accuracy in recent years, making them preferable choices for affective gaming research. Heart rate detection via webcam (like the custom one used in design probe two) is the least accurate of the techniques that capture heart rate. However, in the case of affective gaming, the physiological signals are used to enhance the overall experience (not accurately track the fine details of the signal), thus the accuracy only need to be above a certain minimum threshold so as not to detract from the experience. Therefore, for most affective gaming research, less-intrusive devices is more a more important consideration than accuracy.

c) *Accuracy*: As mentioned previously, using non-intrusive and widely accessible devices often means a compromise in terms of accuracy. However for affective gaming (where the purpose is for enhancing engagement rather than using the sensors to track the detailed reactions to the game)—accuracy is less of a concern for users. The data simply needs to be accurate enough to make sense (be responsive enough to not cause a disconnect between the controls and the responses, which breaks immersion). This means that high quality lab equipment is not necessary for most research in this domain. In general, for affective gaming research, I have found accuracy to matter only in so much as it does not detract from the users' ability to play the game. Thus, it follows that there are ways of mitigating the accuracy issues, so that less accurate (but more accessible; less intrusive) devices may be used. In Design Probe Two, by making the heart rate an *average* value of many users rather than one user, the heart rate value becomes less reliant on individual values, therefore any mis-detections of the heart rate for any one participant go unnoticed. For Design Probe One, the less accurate device (breathing rate detection on the Circuit playground) was a non-critical piece of the design (i.e., if the users failed to learn how to control this aspect of the game, they would not fail the game altogether). The more accurate detection method (affect recognition) was made to be the primary mechanic in the gameplay.

d) *Privacy*: When collecting user data, it is of course always important to keep it confidential and private. However, when working with additionally sensitive data—such as physiological data—this importance to keep the data private increases multi-fold. Concerns relating to the misuse of people's physiological data (e.g., taking this data and using it to improve advertisements, or in a way the user did not consent) is widespread.

Thus, collecting this data is often a challenge due to concerns related to privacy—users are often are afraid to use the system when they think their data might be used in a way they did not consent to it being used. Using physiological data in HCI work is a careful balance, and requires much discussion, consent, and debriefs with participants—researchers must keep this data private, secure, and obtain consent to use this information. Users are often quite hesitant about participating in studies concerning physiological data, therefore it is quite important to be upfront in the particular lengths to which you will keep their data private. In the two design probes in this thesis, I did not save any participant physiological data after the studies were run. The data was simply used as a technique to augment the gameplay experience, and not collected for use afterwards.

5.5 Inclusive Designs

In discussing accuracy and accessibility of affective gaming, there needs to be discussion surrounding the compromised accuracy in relation to certain demographics using these devices. In particular, facial expression software is known to consistently mis-classify or completely fail to identify black individuals [6]. This discrimination (and bias of the technology) is both due to non-standardized development methods, and a failure to test the technology with a broad range of participants before it is deployed. It is necessary in this field (which is so dependent on technology with these inherent biases) to explore the limitations and drawbacks of the particular hardware. Extensively testing the hardware with different user groups and demographics, and commenting on the particular biases is an important aspect of all affective gaming work.

In these projects over the course of my thesis, I extensively playtested the physiological sensors I used with different skin tones to understand the limitations of the hardware I was using. Affdex [186] worked quite well on all different skin tones, however, struggled to discern lighter skin colors in extremely bright environments (i.e., the harsh, bright lights in a lab setting). To mitigate this impact on the study, I had participants sit in closets, or rooms with less harsh lighting during the study. The custom heart rate detection software used in design probe two used a face detection software that struggles to read the heart rate of people with darker skin tones, people with hair covering their foreheads, and people wearing glasses. To lessen the impact of this, I gave instructions to users to help calibrate the software correctly (e.g., sit in a well lit area with hair moved away from your forehead). However, this did not completely mitigate the effects; especially for participants with darker skin tones. I addressed this deficit by aggregating all spectator heart rates as input, so no one viewer would be singled out for having the hardware fail to track their heart rate at any given time.

In addition to these hardware issues with perceiving darker skin tones, sensors are usually calibrated based on an ‘average’ value, which does not represent a large portion of the population with higher or lower values. For example, people with high production of sweat are not able to use many wrist-based heart sensors on the market, as this disrupts the contact of the device to the skin to accurately track the signal. In general, physiological sensors that are able to be calibrated first by the particular user, and adjust the ‘average’ with the calibration, are the best and most promising options to use in affective game designs. While there are sometimes ways to mitigate these limitations, not all hardware allows for this. Often times, the hardware itself is designed in such a way that lighting or calibration is not able to compensate. As these devices become more widespread, what does that mean in terms of inclusivity for the field of affective gaming, and should we really let this hardware become the gold standard?

In terms of accessibility of the field, as evidenced by my systematic review, one of the ways that affective games stand out as being most beneficial is when made to help populations with diverse abilities. There is not a "one size fits all" approach to training, thus affective games can personalize the game experience by adapting to player state in real-time, which is particularly useful when designing systems for the purposes of training. The system is able to adapt by listening and responding to the needs of the player, helping them learn or train abilities such as facial expression recognition for children with ASD [94], reducing anxiety through heightening control of physiological signals [240], or for enhancing or adapting existing rehabilitation programs [38].

I urge designers in the field of affective gaming (and wider, physiological sensing in general) to take a critical look at the accessibility and inclusivity of the physiological devices being used. In turn, designers of these physiological sensing devices should also prioritize accessibility and inclusivity of the hardware. Everyone should have access to affective gaming. Designing more inclusive, accessible physiological sensing technology should be a future research priority for those in the domain of affective gaming.

In addition to accessibility concerns, there is also the potential that as users become better at playing certain affective games (and therefore become better at controlling their physiological signals), they might also open themselves up to a variety of health concerns (e.g. tachycardia, addiction). Designers of affective games need to be cognizant of these potential adverse effects, making design decisions with player's health in mind. For example, designing a more dynamic gameplay experience (giving players goals to both raise and reduce their signals) might be one way to help mitigate these effects.

Lastly, in this thesis the largest self-identified race was caucasian/white—which inherently biases the interpretation of the results. Thus, this begs the question as to whether people for whom the software didn't work as well would still have had similar levels of self-reported enjoyment. As physiological sensing technology carries these biases, it is important to consider that the technology might be primarily tested with the specific user group it also works best. It will be important to consider this and design with marginalized groups in mind, to help us understand how to improve the next iterations of physiological sensing devices, as well as the affective games that utilize these devices.

5.6 Opportunities and Future Directions

In the larger landscape of the field, the previous sections can be synthesized to include a number of limitations and opportunities for the field to consider and address when designing future affective game systems. Each of these areas detail an important opportunity for advancement that I have found throughout conducting the work as part of my dissertation. These opportunities explore how to advance the field of affective gaming, throughout the design and implementation process.

First, my work opens opportunities in accessibility. Researchers and designers should always work to understand the particular limitations of the physiological sensing device in use. Testing the device on a variety of users in different environments in order to understand variables that impact accuracy and accessibility, are imperative to create designs that address or account for these limitations. In addition, customizable options added to the sensing devices will allow for a wider range of participants to engage with the game. For example, incorporating varying lighting options (e.g. colors, intensity) for users into studies involving facial recognition technology will help account for potential variations in detection. Another option is to provide users with a few different choices of sensing technologies to use (allowing integration with multiple signals) in the case that one doesn't work particularly well for them. For example, if tracking galvanic skin response doesn't work for one user, a heart rate wearable can be another preexisting option.

Next, methods of integrating physiological sensing devices into game creation tools requires further development. Designing and developing off-the-shelf physiological sensing design *toolkits* that integrate with various game creation tools will help ease challenges in the domain relating to "reinventing the wheel", providing designers a framework to support the integration as well as customization to support their particular needs. This will give researchers and designers the opportunity to access a collection of technology and knowledge from other researchers that might be working on developing similar integration. The toolkits should be customizable, and able to be tailored to meet the specific design goals and needs of the researcher. While this integration is already offered already to some degree on the Unity platform with certain sensing technologies (e.g. Tobii Unity SDK or Affectiva), this is still not widespread. These toolkits might be internally by researchers in the field, or by increasing communication with manufacturers of physiological sensing technology, to inform them of the needs of the field directly.

In terms of future research directions, the field could benefit from more work specifically focusing on designing affective games to support a particular application area. While most systems currently are designed more generally to enhance user engagement, this field seems to be particularly useful when applied to help certain populations. Applied games that adapt to the player's physiological state have the potential to heighten learning, progress, and engagement. In these cases, the sensor technology needs to be more robust and accurate in order to adapt the game to the affective state of the player in real time.

Privacy is one of the most important topics to discuss when thinking about and understanding the design space of affective games. Discussions and debriefs surrounding privacy both in the documentation of the work as well as integrated into the design of the games will be useful for players to feel more comfortable using the technology. For example, not collecting or saving any physiological data will make users generally feel more comfortable, as well as creating a way that other players are not able to see the data of other players participating.

Lastly, there is much opportunity to learn from other domains of HCI, and appropriate best practices and lessons learned to the field of affective gaming. The physiological signals focused on in this thesis present their own unique set of affordances and design challenges when integrating them into affective games. However, much can be learned from other "physiological" signals, namely the field of movement and bodily engagement. This field has a rich history, and can provide many design requirements and potential lessons learned that can be applied to the affective games designed using the particular physiological signals focused on in this thesis.

6 Conclusion

The rise in the field of affective gaming over the last 30 years is shown by the increasing number of papers published on the topic. Beginning in 2004, the number of papers published on the topic began to accelerate, which coincided with the release of the Unity 3D Real-Time Development Platform [308], published in 2005. Early papers on affective gaming [158, 159] discussed technological limitations of their work in detail. A paper published in 1992 [159] discussed the specifics of port connectivity between a heart monitor and the computer, as well as indicating the programming that was involved to send a 5-volt DC current from the monitor to the computer when heart rate exceeded a threshold. Even today, as a range of off-the-shelf physiological devices exist (and are more accessible than ever), they either take a lot of work and customization to integrate into digital games, or are produced by major technology companies that only gave researchers access to their Software Development Kits in the past few years—the Apple watch SDK became available in 2015 and Fitbit SDK in 2017.

Affective games—with the benefit of heightened user engagement—have shown the potential for improved outcomes over other types of therapeutic methods. Research has seen success in using affective gaming not only for enhancing player engagement, but for rehab and treatment of both physical and mental health problems. However, many studies were preliminary in nature and there has not been gold standard physiological devices or biofeedback games that have emerged for affective gaming within GUR. This gap between research and adoption could be due to the difficulty to customize sensors for each individual research need. Another reason might be that the GUR community is still a relatively small field; researchers might instead be focused on other domains such as brain-computer interfaces, gesture/movement, or using physiological devices for player experience measurement.

Overall, while the field of affective gaming is still preliminary in nature, researchers who have explored the topic have overwhelmingly found success in their use of physiological input to enhance the player experience. However, formal evaluations are rare and attempts to replicate previous findings almost entirely absent, suggesting that the field is still in its infancy, relative to other domains with established evaluation protocols and standards.

Creating the affective game loop through the systematic review helped me understand the landscape of affective gaming. Each design probe, 'In the Same Boat' and 'Commons Sense' explored a certain aspect of the loop, but expanding on prior work in key ways. 'In the Same Boat' leveraged the social synchrony of physiological responses—a novel approach to designing an affective game. 'Common Sense' put the physiological responses in the hands of the audience—rather than the streamer/player—taking audience participation games to a new level.

In this dissertation, I asked the question “Does affective gaming enhance player engagement?” To answer this question, I explore how affective gaming enhances engagement—game play that is influenced by the affective state of the player [97]—by conducting a design exploration of the field. I first conducted a systematic review of the field to understand how prior work demonstrates if the promise of affective gaming to enhance player experience has been realized. I found that while researchers have produced much seminal work over the years, the field is still in relative infancy compared to other domains, not delivering on the promise of enhancing player experience (possibly due to lack of standardized physiological devices). I created the ‘Affective Game Loop’, which is a framework I created to classify prior work based on which physiological input category they fall into: Mechanical, Environmental, and Difficulty.

To explore how one might go about realizing this goal of creating engaging player experiences with affective games, I create two novel design probes, ‘In the Same Boat’ and ‘Commons Sense’, as case studies to explore varying aspects of the Affective Game Loop. ‘In the Same Boat’ explores direct physiological interaction mapped to mechanical, action-based input. I learned that while a cooperative, interdependent, and synchronized game design heightens player experience, adding an embodied control scheme heightens this experience to an even greater degree. ‘Commons Sense’ is an affective communication modality intended to capture and communicate audience response on Twitch. Heart rate is taken from the audience members, averaged, and fed into the game to affect in-game variables (indirect physiological interaction mapped to environment/difficulty, context-based input). I learned that this affective communication modality heightens both the experience of the audience, as well as the live streamer/player. Affective gaming has quite a broad reach in terms of domain; each probe not only focused on a particular aspect of the affective game loop, but two completely different contexts (strangers over a distance and Twitch audiences). This thesis explored this new and unique design space of affective gaming, opening up future avenues for exploration by examining the different ways of heightening player experience. Affective games, when designed effectively, can deliver a rich gameplay experience for all users. Future research will capitalize on the findings of this thesis, first understanding the landscape of the field from the systematic review and then taking the design recommendations from the two probes and applying it to future affective game designs.

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Appendix A

Design Probe One Materials

A.1 Scripts and Consent Forms

A.2 Questionnaires

Setup

First, make sure you have both computers on, and discord working and connected. Laptop needs to be plugged into power. Make sure if it's the biofeedback controls version, there is a webcam setup on the computer in the A lab. Both games need to be up and running and the hardware plugged in. Make sure it's the correct version of the game (com5 for A lab, and com6 for laptop in broom closet). If it's keyboard, just make sure you open the keyboard version of the game. It is easier if you just get them to the screen where they press "start" so follow my table paper instructions. BOF should be open and running as well with a tab open for them on each computer. Have a sticky note of their participant id on the table in front of them as well.

Script

- Thank the participants for coming in.
- Bring them both into the back room in the A lab. Sit them down to explain the study to them.

Idea for script: "Thank you for participating! You will be playing a game together where you will need to synchronize your facial expressions with one another in order to dodge obstacles.

First, you can take turns getting familiar with the facial expressions you will need to make. You will need to make joy, disgust, and surprise. I will give you time to practice making these expressions for the software, you will fill out some pre-questionnaires, and then play the game for 10 minutes in separate rooms communicating with each other over voice chat. Once you are finished, you will fill out another set of questionnaires about your experience. Then, I will interview both of you in the same room about your experience. Any questions for me?"

- Ask the participants to turn off sound or vibrate notifications on their cell phone, and not to answer or use their phone for the duration of the study.
- **Describe the study** task:
    - **For emotion/biofeedback controls:**
        - Your job is to play an infinite runner game with each other. You will be working together to control a canoe riding down a river and communicating over voice chat.
        - To control the canoe's movements, both of you must synchronize your breath rate to move left and right (give an example of breathing into the Circuit playground) with a quick breath into the top of the device, and facial expressions (disgust, surprise, joy) to jump and duck under obstacles. These controls will help you dodge obstacles and collect coins in the river.
        - A sign which displays an emoji of the facial expression will appear to the right of the river. When you reach it, you make the face at the same time as your partner.
    - **For keyboard controls:**

        - Your job is to play an infinite runner game with each other. You will be working together to control a canoe riding down a river and communicating over voice chat.
        - To control the canoe's movements, both of you must synchronize your key presses (left arrow key to move left), (right arrow key to move right), (up arrow key to jump), (down arrow key to duck) in order to dodge obstacles and collect coins in the river.
    - **Biofeedback:** For biofeedback version, participants will both take turns becoming familiar with the AffdexMe software and practice making disgust, surprise, and joyful faces which the facial recognition software can best pick up. Do this in the same room and record this in a separate recording.
    - Explain to participants how to restart the game once they lose. (There will be a "game over" screen, at the bottom there is a "home button". just press that and it'll take you back to a screen where you press "start". If they accidentally disconnect altogether, there is instructions on a piece of paper on the table explaining how to reconnect for each player.
    - They must play with each other for 10 minutes. Tell them to notify you if they have any problems reconnecting during the session or, if the game stops being responsive for some reason. (That's when you just close the game and re-open it, like I said). Also tell them when they are done to let you know.
- Then, tell them part of the experiment involves taking a photo of both of you together before it starts, so take a photo of them.
- Separate the two participants into different rooms of the lab. Explain that they will be connected via voice chat to communicate and coordinate with the other player. Tell them once they are done filling out the questionnaire, they can begin to play the game.
- They will fill then fill out the TIPI, general trust and trust state questionnaires on BOF before beginning the experiment. (**Jeremy:** stay in the area to start timing them for 10 minutes if they begin playing, or don't know how to start playing)
- Start OBS to record the screen.
- While participant performs study task
    - Avoid distracting them with noise or talk
    - Go out of the room. Inform them that they can come get me if they are having technical issues.
    - Time them 10 minutes of play
    - Go in the room and tell them they are done when they are done.
- **Post-study Questionnaire**:
    - After the session, ask participants to fill out the PENS, IMI, demographics, games, trust state, and general trust questionnaires. Then tell the player in the broom closet to come back into the A lab room once done.
    - Take a photo of both of them together, once again.

- Retrospective interview with both participants sitting in same room (record in separate audio file)
    - Walk me through the memorable points of the game. What did you like the most? What did you like the least?
    - Describe to me how it felt to play with each other. Do you feel you communicated well? What are some examples you can remember?
    - Did you feel closer to one another after playing?
    - Do you have any other comments or feedback on the experience, controls, or the game?
- Give participants remuneration and fill out honorarium form.

Figure A.1: Study Script

UNIVERSITY OF SASKATCHEWAN

Department of Computer Science
176 Thorvaldson Building
110 Science Place Saskatoon SK S7N 5C9 Canada
Telephone: (306) 966-4886 Facsimile: (306) 966-4884

Participant Consent Form

You are invited to participate in a research study entitled:
In the Same Boat

Researchers:
Dr. Regan Mandryk (Faculty), Department of Computer Science, University of Saskatchewan
(306) 966-4888 regan@cs.usask.ca
Raquel Robinson (Research Assistant), Department of Computer Science, Univ. of Saskatchewan
(306) 966-4886 raquel.robinson @usask.ca

Purposes and Objectives of the Research:
The purpose of this research is to determine the effects of a synchronization-based controller. There are two objectives:

- Determine how the synchrony of various kinds of input controls affect multiple dependent variables.
- Determine how much participants enjoy the game.

Procedures:

- Please feel free to ask any questions regarding the procedures and goals of the study or your role.
- The study takes place in the Interaction Lab at the University of Saskatchewan.
- After discussing this consent form with the experimenter, you will be introduced to the study tasks, the controls, and the goal of the game.
- Then, a photo of the both of you will be taken which will be used later for online emotion classifications and data analysis.
- After, you and your partner will be separated into different rooms and asked to fill out a set of trust questionnaires.
- Then, you and your partner will then be instructed to play the game for 10 minutes.
- At the end of the 10-minute period, both of you will be asked to complete a set of questionnaires asking about enjoyment of the game, trust, satisfaction in relationships, demographics, and personality information.
- Following the questionnaires, you will participate in a retrospective interview together in the same room with your partner.
- Your responses to questionnaires and your gameplay footage will be recorded by the computer.
- The session will take about 30-45 minutes.
-

Funded by:
This research is funded by the Natural Sciences and Engineering Research Council of Canada.

Potential Risks:

- There are minimal known or anticipated risks to you by participating in this research.
- There is always a risk of minor anxiety or stress associated with participating in an experiment.

Potential Benefits:

- The potential benefits of this research are in a better understanding of how video games can help strengthen existing long-distance relationships and start new ones.
- Your participation will also help us design games and contribute to the scientific understanding of player experience.

Compensation:

- You will receive a $10 honorarium for your participation in this study.

Confidentiality:

- To protect your confidentiality, all data gathered during this study will be associated only with a participant number, and not with your real name or any personally-identifiable information.
- Although the data from this research project will be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify individuals.
- Consent forms will be stored separately from all other data gathered during the study, so that it will not be possible to associate a name with any given session. There will be no record of which participant number is associated with which participant
- To protect confidentiality, data collected from this study (log data from the computer system, and questionnaire data) will be stored on a password-protected secure computer
- Data will be stored for five years and then deleted.
- The researcher will undertake to safeguard the confidentiality of the discussion but cannot guarantee that other members of the group will do so. Please respect the confidentiality of the other members of the group by not disclosing the contents of this discussion outside the group, and be aware that others may not respect your confidentiality.

Right to Withdraw:

- Your participation is voluntary, and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Whether you choose to participate or not will have no effect on any position you hold at the University (e.g., employment, class standing, or access to services).
- If you withdraw from the study, you will still receive the honorarium.
- Should you wish to withdraw, inform the experimenter verbally; all data collected to that point will be deleted.
- Your right to withdraw data from the study will continue until the data is pooled with other participants. At this point there is no way to know which data is yours.

Follow up:

- Results from this study will be written up in articles for publication, and will be publically available in approximately three months. These articles can be obtained from the laboratory website of the principal investigator (Dr. Regan Mandryk – http://hci.usask.ca), or by contacting Dr. Mandryk by email (regan@cs.usask.ca).

Questions or Concerns:

- If you have any questions or concerns, please contact the researcher listed at the top of page 1 of this form
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent

Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

______________________	______________________	____________
Name of Participant	*Signature*	*Date*

______________________ ____________

Researcher's Signature *Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Figure A.2: Consent form for participants in the *keyboard controls* condition.

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Participant Consent Form

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In the Same Boat

Researchers:

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Raquel Robinson (Research Assistant), Department of Computer Science, Univ. of Saskatchewan
(306) 966-4886 raquel.robinson @usask.ca

Purposes and Objectives of the Research:

The purpose of this research is to determine the effects of a synchronization-based controller. There are two objectives:

- Determine how the synchrony of various kinds of input controls (heart rate, breath rate, facial expressions) affect multiple dependent variables.
- Determine strengths and weaknesses of using certain physiological signals (breath rate vs. heart rate) as controls for the game.

Procedures:

- Please feel free to ask any questions regarding the procedures and goals of the study or your role.
- The study takes place in the Interaction Lab at the University of Saskatchewan.
- After discussing this consent form with the experimenter, you will be introduced to the study tasks, the controls, and the goal of the game.
- Then, a photo of the both of you will be taken which will be used later for online emotion classifications and data analysis.
- After, you and your partner will be separated into different rooms and asked to fill out a set of questionnaires.
- Then, you and your partner will then be instructed to play the game for 10 minutes.
- At the end of the 10-minute period, both of you will be asked to complete a set of questionnaires asking about enjoyment of the game, trust, satisfaction in relationships, demographics, and personality information.
- Following the questionnaires, you will participate in a retrospective interview together in the same room with your partner.
- Your responses to questionnaires and your gameplay footage will be recorded by the computer.
- The session will take about 30-45 minutes.

Funded by:

This research is funded by the Natural Sciences and Engineering Research Council of Canada.

Potential Risks:

- There are minimal known or anticipated risks to you by participating in this research.
- There is always a risk of minor anxiety or stress associated with participating in an experiment.

Potential Benefits:

- The potential benefits of this research are in a better understanding of how video games can help strengthen existing long-distance relationships and start new ones. We also hope to have a better understanding of how physiological data can act as an engaging social communication channel between people.
- Your participation will also help us design games and contribute to the scientific understanding of player experience.

Compensation:

- You will receive a $10 honorarium for your participation in this study.

Confidentiality:

- To protect your confidentiality, all data gathered during this study will be associated only with a participant number, and not with your real name or any personally-identifiable information.
- Although the data from this research project will be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify individuals.
- Consent forms will be stored separately from all other data gathered during the study, so that it will not be possible to associate a name with any given session. There will be no record of which participant number is associated with which participant
- To protect confidentiality, data collected from this study (log data from the computer system, and questionnaire data) will be stored on a password-protected secure computer
- Data will be stored for five years and then deleted.
- The researcher will undertake to safeguard the confidentiality of the discussion but cannot guarantee that other members of the group will do so. Please respect the confidentiality of the other members of the group by not disclosing the contents of this discussion outside the group, and be aware that others may not respect your confidentiality.

Right to Withdraw:

- Your participation is voluntary, and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Whether you choose to participate or not will have no effect on any position you hold at the University (e.g., employment, class standing, or access to services).
- If you withdraw from the study, you will still receive the honorarium.
- Should you wish to withdraw, inform the experimenter verbally; all data collected to that point will be deleted.
- Your right to withdraw data from the study will continue until the data is pooled with other participants. At this point there is no way to know which data is yours.

Follow up:

- Results from this study will be written up in articles for publication, and will be publically available in approximately three months. These articles can be obtained from the laboratory website of the principal investigator (Dr. Regan Mandryk – http://hci.usask.ca), or by contacting Dr. Mandryk by email (regan@cs.usask.ca).

Questions or Concerns:

- If you have any questions or concerns, please contact the researcher listed at the top of page 1 of this form
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office

ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent

Your signature below indicates that you have read and understand the description provided; I have had an opportunity to ask questions and my/our questions have been answered. I consent to participate in the research project. A copy of this Consent Form has been given to me for my records.

Name of Participant	*Signature*	*Date*

Researcher's Signature	*Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Figure A.3: Consent form for participants in the *embodied controls* condition.

Consent Form

Title: In the Same Boat

Researcher(s): Raquel Robinson, PhD Student, University of Saskatchewan Human-Computer Interaction Lab, 1 306 966 4888, raquel.robinson@usask.ca

Purpose and Objectives of the Research: The purpose of this research is to determine how close and happy people are in images.

Procedures:

- The study takes place online.
- You will then be instructed to look at a series of images and rate them.

Funded by: The Natural Sciences and Engineering Research Council of Canada (NSERC).

Potential Risks and Benfits: There are minimal known or anticipated risks to you by participating in this research. There is always a risk of minor anxiety or stress associated with participating in an experiment. Your participation will help us design games and contribute to the scientific understanding of player experience.

Confidentiality:

- To protect your anonymity, all data gathered during this study will be associated only with a participant number, and not with your real name or any personally-identifiable information.
- Although the data from this research project will be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify individuals.
- Consent forms will be stored separately from all other data gathered during the study, so that it will not be possible to associate a name with any given session. There will be no record of which participant number is associated with which participant.
- To protect confidentiality, data collected from this study (log data from the computer system, and questionnaire data) will be stored on a password-protected secure computer.
- Data will be stored for five years and then deleted.
- Only the principal researcher and her research assistants will have access to the data to ensure that your confidentiality is protected.

Right to Withdraw:

- Your participation is voluntary. You may withdraw from the research project for any reason, at any time without explanation.
- Should you wish to withdraw, you may do so at any point, and we will not use your data; we will destroy all records of your data.
- Your right to withdraw data from the study will apply until the data have been aggregated (one week after study completion). After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data

Follow up: To obtain results from the study, please contact Raquel Robinson(raquel.robinson@usask.ca).

Compensation: You will receive a $1.50 honorarium for participating.

Questions or Concerns:

- Contact the researcher(s) using the information at the top.
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Figure A.4: Consent form for independent participants that were asked to rate before and after images of the players.

Please answer the following questions regarding your teammate.

Below you can read a number of statements about the other player. Read each statement and rate how much you agree or disagree with it.

	Strongly disagree	Disagree	Somewhat disagree	Neutral	Somewhat agree	Agree	Strongly agree
I could rely on my teammate to react in a positive way if I exposed my weaknesses to them.	○	○	○	○	○	○	○
I feel like I could trust my teammate completely.	○	○	○	○	○	○	○
I could rely on my teammate to keep the promises they make.	○	○	○	○	○	○	○
I would expect my teammate to play fair.	○	○	○	○	○	○	○
My teammate would be honest and truthful with me.	○	○	○	○	○	○	○
I would feel very uncomfortable if my teammate had to make decisions, which would affect me personally.	○	○	○	○	○	○	○
I feel that my teammate could be counted on to help me.	○	○	○	○	○	○	○
I could count on my teammate to be concerned about my welfare.	○	○	○	○	○	○	○
I would be willing to let my teammate make decisions for me.	○	○	○	○	○	○	○
I could expect my teammate to tell the truth.	○	○	○	○	○	○	○
My teammate would treat me fairly and justly.	○	○	○	○	○	○	○

Figure A.5: Affiliation Questionnaire

A number of statements which people have used to describe the previous task are given below. Read each statement and indicate your agreement with that statement. There are no right or wrong answers. Do not spend too much time on any one statement. Remember, give the answer which seems to describe how you thought during the game.

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I didnâ€™t try very hard at playing the game.	○	○	○	○	○	○	○
I would describe this game as very interesting.	○	○	○	○	○	○	○
I think I am pretty good at this game.	○	○	○	○	○	○	○
I couldn't play this game very well.	○	○	○	○	○	○	○
This game did not hold my attention.	○	○	○	○	○	○	○
I was very relaxed while playing the game.	○	○	○	○	○	○	○
I felt tense while playing the game.	○	○	○	○	○	○	○
I put a lot of effort into this game.	○	○	○	○	○	○	○
I enjoyed this game very much.	○	○	○	○	○	○	○
I am pretty skilled at the game.	○	○	○	○	○	○	○
While playing the game, I was thinking about how much I enjoyed it.	○	○	○	○	○	○	○
After playing the game for a while, I felt pretty competent.	○	○	○	○	○	○	○
It was important to me to do well at this game.	○	○	○	○	○	○	○
I am satisfied with my performance at this game.	○	○	○	○	○	○	○
I felt pressured while playing the game.	○	○	○	○	○	○	○
Playing the game was fun.	○	○	○	○	○	○	○
I was anxious while playing the game.	○	○	○	○	○	○	○
I tried very hard while playing the game.	○	○	○	○	○	○	○

Figure A.6: Intrinsic Motivation Inventory (IMI)

Reflect on your experiences and rate your agreement with the following statements.

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I found the relationship I formed in this game important.	○	○	○	○	○	○	○
When I wanted to do something in the game, it was easy to remember the corresponding control.	○	○	○	○	○	○	○
I don't feel close to the other player.	○	○	○	○	○	○	○
Learning the game controls was easy.	○	○	○	○	○	○	○
The game controls are intuitive.	○	○	○	○	○	○	○
I found the relationship I formed in this game fulfilling.	○	○	○	○	○	○	○

Figure A.7: Player Experience of Needs Satisfaction (PENS); relatedness and intuitiveness of controls subscales

Please answer the following questions.

Using the following scale, please indicate how much you agree or disagree with the following statements:

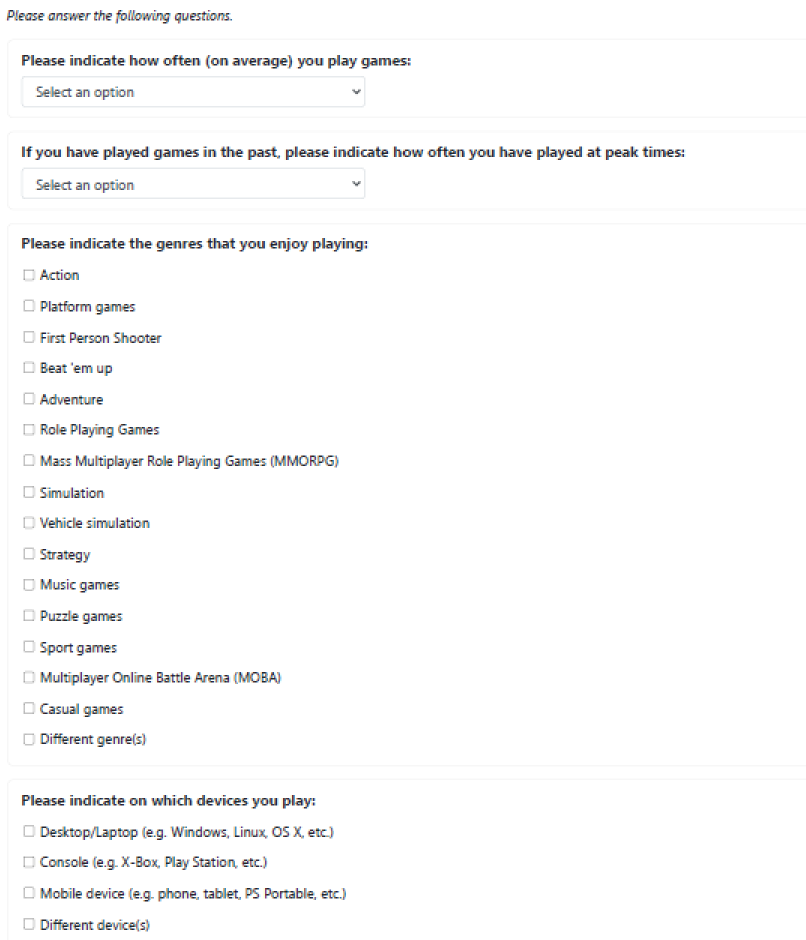
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Most people are basically honest.	○	○	○	○	○
Most people are trustworthy.	○	○	○	○	○
Most people are basically good and kind.	○	○	○	○	○
Most people are trustful of others.	○	○	○	○	○
I am trustful.	○	○	○	○	○
Most people will respond in kind when they are trusted by others.	○	○	○	○	○

Figure A.8: Propensity to Trust

I see myself as:

	Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly
Conventional, uncreative.	○	○	○	○	○	○	○
Anxious, easily upset.	○	○	○	○	○	○	○
Critical, quarrelsome.	○	○	○	○	○	○	○
Reserved, quiet.	○	○	○	○	○	○	○
Dependable, self-disciplined.	○	○	○	○	○	○	○
Extraverted, enthusiastic.	○	○	○	○	○	○	○
Sympathetic, warm.	○	○	○	○	○	○	○
Calm, emotionally stable.	○	○	○	○	○	○	○
Disorganized, careless.	○	○	○	○	○	○	○
Open to new experiences, complex.	○	○	○	○	○	○	○

Figure A.9: Ten Item Personality Inventory



Please answer the following questions.

Please indicate how often (on average) you play games:

Select an option

If you have played games in the past, please indicate how often you have played at peak times:

Select an option

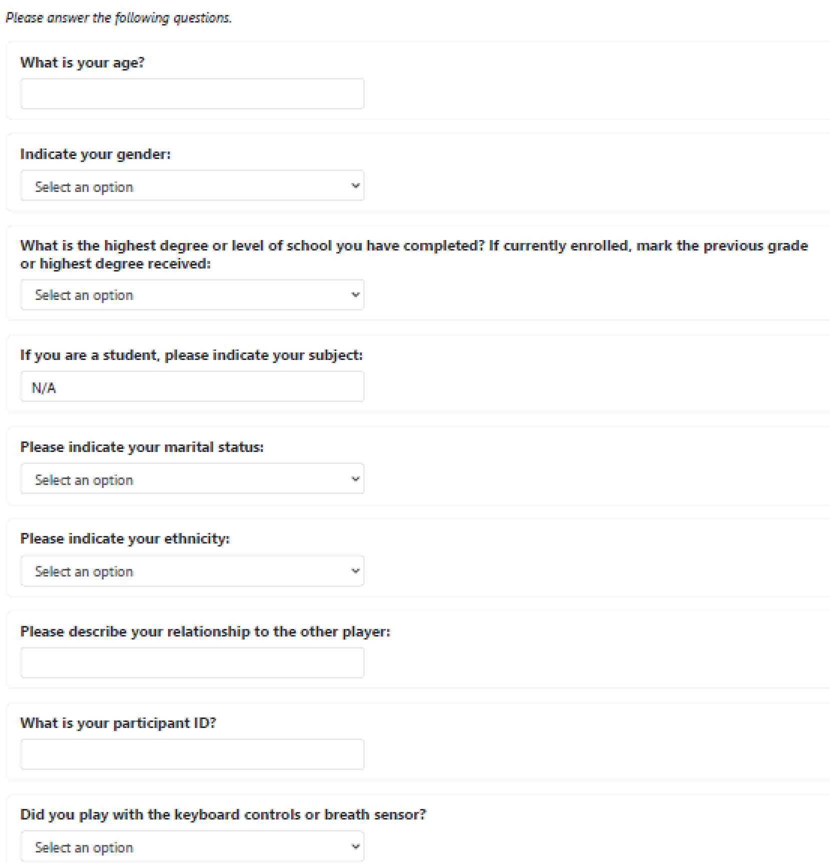
Please indicate the genres that you enjoy playing:

- ☐ Action
- ☐ Platform games
- ☐ First Person Shooter
- ☐ Beat 'em up
- ☐ Adventure
- ☐ Role Playing Games
- ☐ Mass Multiplayer Role Playing Games (MMORPG)
- ☐ Simulation
- ☐ Vehicle simulation
- ☐ Strategy
- ☐ Music games
- ☐ Puzzle games
- ☐ Sport games
- ☐ Multiplayer Online Battle Arena (MOBA)
- ☐ Casual games
- ☐ Different genre(s)

Please indicate on which devices you play:

- ☐ Desktop/Laptop (e.g. Windows, Linux, OS X, etc.)
- ☐ Console (e.g. X-Box, Play Station, etc.)
- ☐ Mobile device (e.g. phone, tablet, PS Portable, etc.)
- ☐ Different device(s)

Figure A.10: Gameplay Questionnaire



Please answer the following questions.

What is your age?

Indicate your gender:

Select an option

What is the highest degree or level of school you have completed? If currently enrolled, mark the previous grade or highest degree received:

Select an option

If you are a student, please indicate your subject:

N/A

Please indicate your marital status:

Select an option

Please indicate your ethnicity:

Select an option

Please describe your relationship to the other player:

What is your participant ID?

Did you play with the keyboard controls or breath sensor?

Select an option

Figure A.11: Demographics Questionnaire

Appendix B

Design Probe Two Materials

B.1 Recruitment and Consent Forms

B.2 Questionnaires

Credit info or other:

Raquel Robinson, PhD Candidate, University of Saskatchewan
rbreejon@gmail.com; Raquel.robinson@usask.ca

Details of User Study/Consent Form

Purpose and Objectives of the Research: This objective of this research is to understand the effect of integrating interactive physiological elements into the Twitch stream/game on viewer and streamer engagement.

Procedures: The study should take a total of 45 minutes. In this study, you will watch the streamer play a custom game we have developed which will be streamed on Twitch. The game uses your heart rate data (taken via webcam) to affect elements of the game the streamer will be playing. While video data will be collected for the purposes of heart rate functionality, it will not be saved after it is collected. There will be no personally identifying information collected from you.

The interesting mechanic of the game is the audience participation feature. You will navigate to a webpage we have set up which has the Twitch stream and Twitch chat embedded. From here, after consenting, your heart rate will be taken via webcam and sent to a database, averaged with all the other viewers who participate, and sent back to the game in real time to affect various game elements (lighting effects, mood, difficulty, etc.). If you do not want to participate in this feature and just watch, you can watch as normal on the twitch stream without navigating to the webpage.

The game is a top-down survival shooter. There are 3 rounds which are 5 minutes long with a few different game mechanics in each. For you, the study will mainly be watching each round (with your heart rate fed into the game), with a few questionnaires between rounds.

Compensation: Once the 3 rounds are over, you can enter your email for a chance to win a $150 CAD (converted to your currency) Amazon gift card for participation.

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Figure B.1: Recruitment handout for potential audience-participants

Twitch Audience Interactivity User Study

Credit info or other:

Raquel Robinson, PhD Candidate, University of Saskatchewan
rbreejon@gmail.com; Raquel.robinson@usask.ca

Details of User Study/Consent Form

Purpose and Objectives of the Research: This objective of this research is to understand the effect of integrating interactive physiological elements into the stream/game on viewer/streamer engagement.

Procedures: The study should take a total of 45 minutes. In this study, you will play a custom game we have developed which will be streamed on Twitch. The game uses your Twitch audience's heart rate data (taken via webcam) to affect elements of the game you are playing (mood/environmental effects, difficulty).

First, we will send you a zip folder to download the game. Extract the files from the file and place it anywhere on your computer. Then you will set it up how you normally would stream any game on Twitch (OBS, Twitch Studio, etc.)

The game is a top-down survival shooter. There are 3 rounds which are 5 minutes long with a few different game mechanics in each. For you, the study will mainly be playing each round with your audience as usual on Twitch, with a few questionnaires between rounds. The audience will watch the stream and fill out a few questionnaires between rounds as well. At the end, if you are comfortable, we will also do a short interview to ask questions about the experience.

The interesting mechanic of the game is the audience participation feature. The Twitch audience will navigate to a webpage we've set up which has the stream/chat embedded. From here, after consenting, their heart rate will be taken via webcam and sent to a database, averaged with all the other viewers who participate, and sent back to the game in real time to affect various game elements (lighting effects, mood, difficulty, etc.). For the viewers, the webcam will ONLY collect heart rate and feed it into the game. The viewers' video data will not be collected or saved anywhere. Viewers who don't want to participate in this feature and just watch you play can watch as normal on your twitch stream without going to the webpage. Generally, it would be great if you could try to have as many of your viewers participate in the heart rate feature as possibe.

Compensation: You will receive a $500 Amazon gift card for participation. Your viewers will be entered into a drawing for a chance to win an $150 gift card if they choose.

After Playing

After playing, we ask for you to send us a couple csv files of gameplay data. You can find this in the “CommonSense_Data” > “Resources” folder. There should be two csv files with your username/name in the title. Email these csv files to rbreejon@gmail.com

Doodle Poll for Availability

Fill out this doodle poll to let us know when next week the best time is to run the study:

https://doodle.com/poll/i6rzb9ks2peeesr5

Figure B.2: Recruitment and sample consent form handout for potential streamer-participants

UNIVERSITY OF SASKATCHEWAN

Department of Computer Science
176 Thorvaldson Building
110 Science Place Saskatoon SK S7N 5C9 Canada
Telephone: (306) 966-4886 Facsimile: (306) 966-4884

Participant Consent Form

You are invited to participate in a research study entitled:
Commons Sense

Researchers:

Dr. Regan Mandryk (Faculty), Department of Computer Science, University of Saskatchewan
(306) 966-4888 regan@cs.usask.ca
Raquel Robinson (Research Assistant), Department of Computer Science, Univ. of Saskatchewan
(306) 966-4886 raquel.robinson @usask.ca

Purposes and Objectives of the Research:

The purpose of this research is to determine the how much streamers enjoy playing a game using the audience's physiology.

Procedures:

- This study will take place entirely online.
- In this study, you will play a custom game we have developed which will be streamed on Twitch for approximately 20 minutes. The game uses your Twitch audience's heart rate data (taken via webcam) to affect elements of the game you are playing (mood/environmental effects, difficulty).
- The study session will take approximately 30 minutes to complete including questionnaires.
- After consenting, you will be asked to fill out a questionnaire regarding the nature of your relationship to your audience, as well as general demographic information about yourself. In between rounds, you will be asked to fill out a questionnaire asking how you enjoyed the prior round.
- At the end of the study, you will be asked a few more questions about the experience, your enjoyment, engagement, and interest in the game.
- You will then be asked to participate in a quick 5-minute online interview asking some more free-form questions about the experience in general.

Funded by:

This research is funded by the Natural Sciences and Engineering Research Council of Canada.

Potential Risks:

- There are minimal known or anticipated risks to you by participating in this research.
- There is always a risk of minor anxiety or stress associated with participating in an experiment.

Potential Benefits:

- Your participation will help us design games and contribute to the scientific understanding of player experience.

Compensation:

- You will receive a $500 Amazon giftcard for your participation in this study.

Confidentiality:

- To protect your confidentiality, all data gathered during this study will be associated only with a participant number, and not with your real name or any personally-identifiable information.
- Although the data from this research project will be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify individuals.
- Consent forms will be stored separately from all other data gathered during the study, so that it will not be possible to associate a name with any given session. There will be no record of which participant number is associated with which participant
- To protect confidentiality, data collected from this study (log data from the computer system, and questionnaire data) will be stored on a password-protected secure computer.
- Data will be stored for a minimum of five years post-publication.

Right to Withdraw:

- Your participation is voluntary, and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Whether you choose to participate or not will have no effect on any position you hold at the University (e.g., employment, class standing, or access to services).
- If you withdraw from the study, you will still receive the honorarium.
- Should you wish to withdraw, inform the experimenter verbally; all data collected to that point will be deleted.
- Your right to withdraw data from the study will continue until the data is pooled with other participants. At this point there is no way to know which data is yours.

Follow up:

- Results from this study will be written up in articles for publication, and will be publically available in approximately three months. These articles can be obtained from the laboratory website of the principal investigator (Dr. Regan Mandryk – http://hci.usask.ca), or by contacting Dr. Mandryk by email (regan@cs.usask.ca).

Questions or Concerns:

- If you have any questions or concerns, please contact the researcher listed at the top of page 1 of this form
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent

By participating in this study, your free and informed consent is implied and indicates that you understand the above conditions of participation in this study. __ I agree; __ I disagree.

Figure B.3: Consent form for streamers

UNIVERSITY OF SASKATCHEWAN

Department of Computer Science
176 Thorvaldson Building
110 Science Place Saskatoon SK S7N 5C9 Canada
Telephone: (306) 966-4886 Facsimile: (306) 966-4884

Participant Consent Form

You are invited to participate in a research study entitled:
Commons Sense

Researchers:
Dr. Regan Mandryk (Faculty), Department of Computer Science, University of Saskatchewan
(306) 966-4888 regan@cs.usask.ca
Raquel Robinson (Research Assistant), Department of Computer Science, Univ. of Saskatchewan
(306) 966-4886 raquel.robinson @usask.ca

Purposes and Objectives of the Research:
The purpose of this research is to determine the how much streamers enjoy playing a game using the audience's physiology.

Procedures:

- This study takes place completely online.
- In this study, you will watch the streamer play a custom game we have developed which will be streamed on Twitch. The game uses your heart rate data (taken via webcam) to affect elements of the game the streamer is playing (mood/environmental effects, difficulty). No video data will be collected, and your individual heart rate data will be anonymous. Heart rate data will be taken, averaged with other participants, and sent directly to the game.
- The session will take approximately 30 minutes (3 rounds of 5 minutes each plus questionnaires).
- Before watching the stream, you will be asked to fill out a few questionnaires including general information regarding your relationship to the streamer and general demographics questions. Between rounds, you will fill out a questionnaire about your enjoyment of the previous round.
- After watching, you will be asked a few more questions about how you enjoyed the overall experience.

Funded by:
This research is funded by the Natural Sciences and Engineering Research Council of Canada.

Potential Risks:

- There are minimal known or anticipated risks to you by participating in this research.
- There is always a risk of minor anxiety or stress associated with participating in an experiment.

Potential Benefits:

- Your participation will help us design games and contribute to the scientific understanding of player experience.

Compensation:

- You will have an opportunity to enter a raffle for a chance to win a $150 amazon giftcard upon providing us with a valid email address after participating,

Confidentiality:

- To protect your confidentiality, all data gathered during this study will be associated only with a participant number, and not with your real name or any personally-identifiable information.
- Although the data from this research project will be published and presented at conferences, the data will be reported in aggregate form, so that it will not be possible to identify individuals.
- Consent forms will be stored separately from all other data gathered during the study, so that it will not be possible to associate a name with any given session. There will be no record of which participant number is associated with which participant
- To protect confidentiality, data collected from this study (log data from the computer system, and questionnaire data) will be stored on a password-protected secure computer
- Data will be stored for a minimum of five years post-publication.

Right to Withdraw:

- Your participation is voluntary, and you can answer only those questions that you are comfortable with. You may withdraw from the research project for any reason, at any time without explanation or penalty of any sort.
- Whether you choose to participate or not will have no effect on any position you hold at the University (e.g., employment, class standing, or access to services).
- If you withdraw from the study, you will still receive the honorarium.
- Should you wish to withdraw, inform the experimenter verbally; all data collected to that point will be deleted.
- Your right to withdraw data from the study will continue until the data is pooled with other participants. At this point there is no way to know which data is yours.

Follow up:

- Results from this study will be written up in articles for publication, and will be publically available in approximately three months. These articles can be obtained from the laboratory website of the principal investigator (Dr. Regan Mandryk – http://hci.usask.ca), or by contacting Dr. Mandryk by email (regan@cs.usask.ca).

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- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Consent

By participating in this study, your free and informed consent is implied and indicates that you understand the above conditions of participation in this study. __ I agree; __ I disagree.

Figure B.4: Consent form for spectators

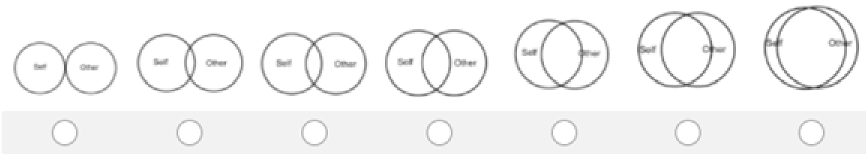


Figure B.5: Inclusion of the other in the Self (IOS)

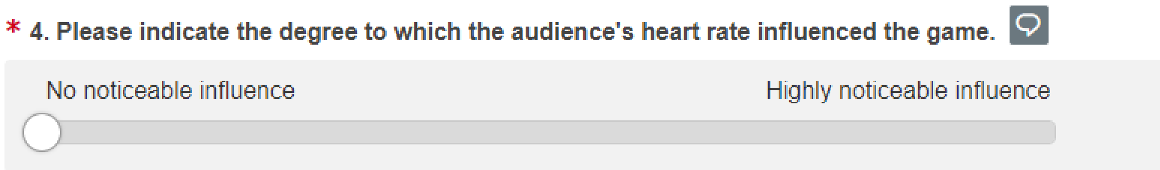
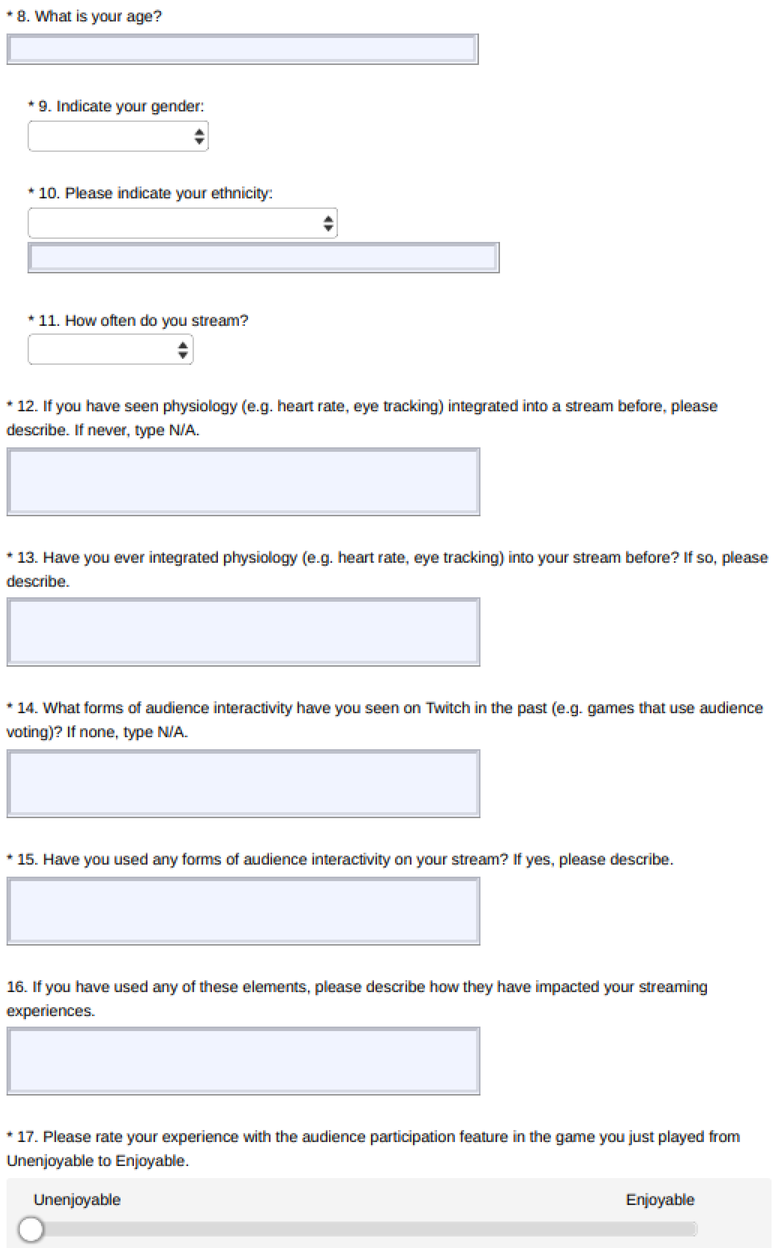


Figure B.6: Perceived effect of audience heart rate on game

Reflect on your experience watching the stream and rate your agreement with the following statements.

	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree
I paid close attention to the player.	○	○	○	○	○	○	○
I felt happy.	○	○	○	○	○	○	○
I enjoyed my part in the game session.	○	○	○	○	○	○	○
I felt embarrassed.	○	○	○	○	○	○	○
I lost track of time.	○	○	○	○	○	○	○
I felt involved.	○	○	○	○	○	○	○
I felt connected to the player.	○	○	○	○	○	○	○
I had fun.	○	○	○	○	○	○	○
I felt like I interacted with the player.	○	○	○	○	○	○	○
I found the game enjoyable.	○	○	○	○	○	○	○
I was completely engaged in the game.	○	○	○	○	○	○	○
I felt like part of a team.	○	○	○	○	○	○	○
I felt good.	○	○	○	○	○	○	○
I found the content and theme of this game enjoyable.	○	○	○	○	○	○	○
I forgot everything around me except the game session.	○	○	○	○	○	○	○
What the player did/said affected me.	○	○	○	○	○	○	○
I felt like I participated in the game session	○	○	○	○	○	○	○
The player paid close attention to me.	○	○	○	○	○	○	○
I enjoyed watching the game.	○	○	○	○	○	○	○
I thought about things other than the game session.	○	○	○	○	○	○	○
What I did/said affected the player.	○	○	○	○	○	○	○
I was fully occupied with the game.	○	○	○	○	○	○	○
I was deeply concentrating in the game.	○	○	○	○	○	○	○
I felt annoyed.	○	○	○	○	○	○	○
I felt bored.	○	○	○	○	○	○	○
I enjoyed watching the player.	○	○	○	○	○	○	○
I felt like an active participant.	○	○	○	○	○	○	○

Figure B.7: Audience Experience Questionnaire (AEQ)



* 8. What is your age?

* 9. Indicate your gender:

* 10. Please indicate your ethnicity:

* 11. How often do you stream?

* 12. If you have seen physiology (e.g. heart rate, eye tracking) integrated into a stream before, please describe. If never, type N/A.

* 13. Have you ever integrated physiology (e.g. heart rate, eye tracking) into your stream before? If so, please describe.

* 14. What forms of audience interactivity have you seen on Twitch in the past (e.g. games that use audience voting)? If none, type N/A.

* 15. Have you used any forms of audience interactivity on your stream? If yes, please describe.

16. If you have used any of these elements, please describe how they have impacted your streaming experiences.

* 17. Please rate your experience with the audience participation feature in the game you just played from Unenjoyable to Enjoyable.

Unenjoyable Enjoyable

Figure B.8: Streamer Demographics Questionnaire