Socially Anxious Play: Design, Development, and Evaluation of Game-Based Digital Behavioural Markers for the Assessment of Social Anxiety

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Abstract

Social relationships are essential for humans; neglecting our social needs can cause discomfort or even lead to the development of more severe issues such as loneliness, depression, or substance dependency. Although essential, some individuals face major challenges in forming and maintaining social relationships due to the experience of social anxiety, which is the intense fear of being evaluated by others. The burden of social anxiety can be reduced through accessible assessment that leads to treatment. However, socially anxious individuals who wish to seek help face many barriers stemming from geography, the characteristics of the fear itself, or disparities in access to systems of care. Recent research has suggested digital behavioural markers as a way to deliver cheap and easily accessible digital assessment for social anxiety that may help reduce barriers to care. However, prior work focused mostly on the relationship between social anxiety and the development of problematic gaming behaviours to cope with the potentially severe consequences of social anxiety. In this dissertation, we look at the relationship between social anxiety and digital games from the lens of assessment and analyze whether we can use digital behavioural markers embedded in a gaming task to assess the severity of social anxiety. In manuscript 1, we show that social anxiety may manifest in game and biases the preferences for in-game activities and the reasons why players play Massively Multiplayer Online Role Playing Games (MMORPGs). Further, Manuscript 2 shows that central game mechanics, such as the customization of the self-representation in-game, may affect the experience of social stress in-game. Manuscripts 3 and 4 explore the in-game movement of a player around a non-player character (NPC) and show that certain aspects of the movement path may be used to predict the degree of social anxiety. Further, we show that the camera perspective as well as the self-representation may affect the strength of these behavioural markers of social anxiety. Finally, Manuscript 5 explores how the found behavioral markers, as well as the developed gaming task, may be used to predict self-reported psychopathy—which is negatively related to social anxiety—and further shows that personal character traits manifest in-game and may explain certain phenomena such as the presence of anti-social behaviour in digital games. Overall, the results of this dissertation provide new insights about the relationship between social anxiety and its manifestation in-game, the influence of game mechanics on the experience of social stress, and how social anxiety as well as psychopathic traits may affect in-game behaviours, opening the way towards digital behavioural markers for the assessment of social anxiety.

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To all the wonderful whispering voices in and around my head and to all the wonderful people who understand the bold yet controversial statement that **every person has more or less the desire to mingle (sometimes)**.

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List of Abbreviations

IPD	Interpersonal Distance
GSAS	Gaming Social Anxiety Scale
LSAS	Liebowitz Social Anxiety Scale
MMORPG	Massive Multiplayer Online Role Playing Games
NPC	Non-Player Character
PIS	Player Identification Scale
TSST	Trier Social Stress Test

1 Introduction

Anxiety is mostly described as the negative experience of tension and worries about potential situations, and there are a large variety of products and approaches try to help people to reduce the experience of anxiety [269]. Although unpleasant and sometimes overwhelming [298], anxiety has an important purpose for us: Through the experience of anxiety, we become vigilant to threats from the surrounding environment [209]. Similarly, social anxiety—characterized by a severe fear of social situations in which the individual is exposed to scrutiny by others such as social interactions, being observed, and performing in front of others [13, 491]—serves the same function and helps us to detect social threats: Over the life span we face many situations in which we are exposed to the evaluation by others, like job interviews, trying to find new friends, or dating and finding a potential partner [21]. Experiencing social anxiety can serve as a useful reminder that we need to proceed in these situations with caution to succeed. We become more sensitive to social cues from others and start to adapt our communication strategies to increase our chances for success even further [269].

Socialization with others has been an essential aspect of our existence since the dawn of humankind [44, 43]. Like many animals, early humans developed social characteristics, such as the desire to form social groups, to increase the probability to survive. However, over the time, humans also developed cultural characteristics: Culture relies heavily on information, communication, division of labor, exchange and many more features, all of which rely heavily on social interaction within a formed group [42]. Baumeister [42] argues that many of the distinctively human mental and physical attributes can best be understood when considered as facilitators of culture. Language, for example, requires special physical and mental aspects with a person, but the language itself is only useful within a culture. Therefore, it can be argued that many human attributes and characteristics evolved to facilitate social connections within a culture [43, 269]. Therefore, experiencing social anxiety can be seen as a helpful mechanism that helps an individual to stay within the boundaries of the group and avoid damaging their own reputation and relationship with others [217, 218].

However, social anxiety can also be triggered in non-threatening situations [491, 269]. The tendency of feeling anxious around others in social contexts marks the foundation of trait social anxiety, which presents challenges for these individuals to satisfy their need for social relationships. Social anxiety, one of the most severe mental illnesses worldwide [275, 376], may not only damage the overarching quality of life for the individual [163] but may also have severe consequences for the individual [494, 531, 138, 20] and also for society [135, 316]. The intense fear of being evaluated by others caused by social anxiety means that affected individuals may avoid socializing, which makes them more vulnerable to the severe consequences of neglecting their need to belong, such as more severe mental [107] and physical [227] illnesses. Yet forcing socially-anxious

individuals into social activities can also be quite harmful for their mental and physical health. The harms caused by social anxiety may expand beyond the individual: An increased economic dependency on public support systems may arise due to bigger challenges in entering and navigating the job market as well as through a lack of proper education, because socially-anxious individuals are at a higher risk of dropping out of education programs due to their fear of evaluation by others. When left untreated, social anxiety may increase the risk of related health problems such as depression [199, 494], and substance abuse [531], and in severe cases even elevate the risk for suicide [20, 464].

Fortunately, there are potential solutions for helping individuals with trait social anxiety, as current literature shows the success of powerful approaches like cognitive behavioural therapy (CBT) to help individuals to overcome their social fears [39, 14]. Yet there are several barriers and challenges for socially-anxious individuals who wish to reach out for help. One major barrier is the lack of a quick and effective assessment of social anxiety. As prior work points out, the early detection of social anxiety during adolescence improves the efficacy of potential interventions [385, 354]. However, the assessment of social anxiety is challenging as the social inhibition and withdrawal of affected individuals, which are symptoms of social anxiety, are often mistaken for shyness by others or perceived as a character flaw within the individual [238, 505, 419]. Further, social anxiety shares an overlap of symptoms with other mental illnesses, which makes clear assessment even more challenging [381, 296]. Due to the defining fear of negative or positive evaluation by others, individuals with social anxiety may avoid consulting mental health professional about their mental illness. Prior work emphasizes, that only a small proportion of individuals with social anxiety seek out and receive treatment [454]. Apart from the challenges of the mental illness itself, other barriers, such as sociocultural, economic, or geographical barriers may lower the accessibility of interventions [301, 383, 15].

These limitations in current assessment approaches of social anxiety may not be addressed solely by expanding the existing mental health system [133], as they are not solved only by training more mental health professionals. Instead, the solution needs a variety of approaches, including digital solutions [253, 335], which may enhance existing techniques to increase the efficacy of, reduce the cost of, and lower pre-existing barriers to care. For example, prior research shows that smartphone and internet-based applications may be used to treat a variety of mental health disorders, including social anxiety, through anonymous and easy access [253]. Further, the sensor data of smartphones may be used in the context of assessment [247]. Within the context of interventions, immersive experiences have become a popular way to enhance exposure therapies, which reduce the cost of an intervention and allow the therapist to deliver the intervention within the safe space of their office [520, 111, 145].

However, there are several problems that arise when moving digital health applications out of the clinical context. For example, without guidance, patients may misuse the technology and therefore harm themselves instead of benefiting [274]. Within the context of social anxiety, prior work portrays games as a potential threat for socially anxious individuals because affected individuals are at a higher risk to develop severe problematic gaming behaviour as a coping mechanism for the symptoms of social anxiety [312, 56]. Further,

Gavriloff et al. [192] found that socially-anxious gamers may show less dispositional mindfulness, which is characterized by the mental state of being aware of one's current experience and functioning [89], than non-anxious gamers. They suggest that players use games to self-regulate their social anxiety with mindful awareness of their emotional state in the social aspects of the game. However, a deeper understanding about the potential relationship between social anxiety, gaming preferences, and problematic gaming is missing. Further, researchers in contexts adjunct to social anxiety suggest that digital games may offer ways to deliver easy, flexible, and cost-effective digital approaches for mental health applications [61, 438]. These perspectives on the relationship of games and mental health suggest that games may be efficient overall, but could be harmful within the context of social anxiety. In order to leverage the benefits of digital games without causing any damage to the player, digital approaches need to balance between medical efficacy and ways to utilize games within their treatments [111].

1.1 Goal of this Dissertation

Prior work about utilizing games within the context of mental health interventions reveal novel ways how mental health professionals may deliver easy, flexible, and cost-effective digital interventions and how several digital games components, such as customized avatars, can offer a more engaging experience with mental health interventions [61, 438]. However, within the context of social anxiety, most research focused on mapping existing techniques into immersive replications, such as "in virtuo" exposure techniques [145] as well as the usage of smartphone data [247, 253] and internet based approaches [231, 49].

Although there have been significant efforts in harnessing digital tools for the treatment of social anxiety, the use of digital games—including game-based data and game design elements—is still underrepresented. Furthermore, some individuals, especially adolescents, withdraw from mental health services, because the assessment techniques are inconvenient or even stressful for them [537, 179, 190]. But digital games may bridge the gaps of existing techniques and offer novel ways for affected individuals to find support for their anxiety. However, within the context of social anxiety, digital games have been seen as a potential threat rather than an opportunity, and potential behavioural assessment opportunities haven't been explored. Yet in similar contexts prior work highlights the potential of digital games and game-related applications, such as serious games, or the usage of game design in the development of mental health applications [332]. Therefore, the *goal* of this thesis is to investigate whether we[1] can utilize in-game behaviour to provide additional tools for the evidence-based assessment of social anxiety. This goal requires us to not only investigate how social anxiety manifests in a measurable way in-game but also to better understand how social anxiety affects in-game preferences and activities— essentially building a better understanding about the relationship between *digital games* and *social anxiety*. This includes also a deeper investigation of whether game mechanics may alter the

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[1]Throughout this dissertation, I use 'we' to refer to the work conducted. Although I am the sole author of this dissertation, the research contributions were in collaboration with others. At the beginning of each chapter, I acknowledge who contributed to which aspects of the presented work in that chapter.

experience of social anxiety in-game. Building on this underlying background, we will as a second goal analyze in-game behaviour and investigate which aspects of social interactions in-game may be suitable for assessing social anxiety. As a final goal, we want to explore how other aspects of the player, such as their personal character traits, may affect potential digital behavioural biomarkers of mental health concerns. Building on this set of goals, I formulate for this dissertation the following main research question: *How can we harness in-game behavioural data for the assessment of social anxiety?* To answer this main question, I address the following core research questions:

- **RQ1:** Does social anxiety manifest within the in-game world and affect the player's in-game preferences and activities (Manuscript 1)

- **RQ2:** Do core game design decisions, such as the self-representation and the camera perspective, affect the experience of social anxiety in a gaming task (Manuscript 2 & Manuscript 3)?

- **RQ3:** Which in-game behaviours are consistently affected by social anxiety in a gaming task? (Manuscript 3)?

- **RQ4:** Can we use the found in-game behaviours, grounded in social anxiety biases, as a way to measure the level of social anxiety of the player (Manuscript 4)?

- **RQ5:** How do the found digital behavioural markers react to other social interaction phenomena that are known to relate to social anxiety, such as psychopathic traits (Manuscript 5)?

1.2   Steps towards the Solution

The first step towards this goal is a better understanding of how socially-anxious players behave within games, with a focus on whether behaviours and preferences from the physical world translate into game worlds. Previous research suggested that socially anxious players prefer playing Massively Multiplayer Online Role Playing Games (MMORPG) over other genres [312]. The social focus of MMORPRGs stands in contrast to the behaviour of socially anxious individuals in the physical world where they withdraw from social interactions to reduce the potential exposure to the scrutiny of others. Therefore, a deeper analysis of the reasons as well as the preferred activities within this genre are required to better understand differences and overlaps of in-game and out-of-game behaviour among players with social anxiety. The goal of this first analysis is to confirm that cognitive biases within the out-of-game world are expressed in a similar fashion in the game world. Whenever there is evidence that shows that a cognitive bias exists within the gaming world, the next step towards the assessment of social anxiety within digital games is to analyse how different aspects of the digital game can be included into an evidence-based assessment approach for social anxiety.

Previous literature suggests that social anxiety leads to several defining cognitive and behavioural biases related to attention and memory [235, 435]. For example, prior research shows that individuals with high

levels of social anxiety recalled positive feedback as less positive than it had been [202]. On the other side, socially-anxious individuals show a biased distance estimation when estimating the distance between oneself to a stranger [201]. Such underlying cognitive and behavioural biases can be used as the foundation for the development of digital biomarkers—that is, behaviours that can be observed, measured, and used to identify players with social anxiety. However, previous digital biomarkers for social anxiety were evaluated either in the physical world or by using virtual reality simulations, which recorded physical reactions to virtual stimuli [305]. The usage of digital games is less explored and could provide an inexpensive and accessible approach: By playing video games, users produce a large volume of data, such as behavioural in-game (e.g., movement behaviour), or attention information (e.g., by using special sensors for the analysis of the gaze focus) [335]. Further, many game mechanics mirror memory or cognitive tasks, which are already used for the assessment of the mental state of the individual.

Besides leveraging the in-game data for the assessment of social anxiety, prior work shows that digital games can be helpful for interventions as well [334, 276]: First, games are already used as an intervention within other contexts, such as mood repair [456] and stress recovery [108, 398]. On the basis of the idea that games assist to promote mood equilibrium, research have started to examine these positive effects of digital games. These aspects of games can be helpful for individuals who experienced an anxiety-inducing situation to recover faster from the negative consequences [411]. Second, games allow players to explore various situations safely—similar to how exposure therapy session challenges a patient to face feared situations within a safe space of the therapist's office. Prior work emphasizes that anxiety patients should explore the feared stimulus within different situations to gain resilience against it [35, 111]. With the rise of immersive media platforms, such as virtual reality, researchers have successfully adapted exposition therapy into virtual simulations using mixed reality approaches [111]. Third, games allow players to explore different roles [56, 538, 325]. Prior work about the role of the player's self-representation within games suggests that players can, depending on the level of customization, explore not only their own view on certain aspects, but also explore the perspective of a given character. This is similar in approach to the underlying principle of cognitive restructuring techniques, in which individuals thoughts about anxiety-inducing stimuli are challenged through new and positive experiences within a situation [379, 207, 206]. Fourth, games are a social space: In recent years, digital games became a platform to form and maintain relationships within the game or game related phenomena, such as video game streaming [187]. In video streaming, the player plays the game in front of an audience and can be exposed to the feedback of the audience. But prior research has not provided enough evidence about the benefits of digital games for individuals affected by social anxiety.

1.3   Contextualization of this Research

The following section provides an overview about the core aspects of social anxiety, the existing assessment techniques and the link between social anxiety and digital gaming.

1.3.1 Characterization of Social Anxiety

The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) characterizes social anxiety as an intense fear of social interactions in which an individual gets exposed to potential negative or positive evaluation by other individuals [13]. Therefore, social anxiety biases an individual's behaviour and causes behavioural changes like social withdrawal, or physical symptoms such as blushing, trembling, or sweating. Earlier work [275, 376] about social anxiety describes this anxiety as one of the most common anxiety disorders with a prevalence of 12.1%. To classify social anxiety as a disorder, the experienced fear must be out of proportion relative to the actual threat for more than six months in a row without any influence of other medical or mental conditions. Furthermore, this definition states that the ongoing state of fear must lead to a clinically significant impairment in key social situations to be classified as *Social Anxiety Disorder*. This disorder ranks third among the psychiatric disorders, only following major depression and alcohol abuse [386]. Affected individuals tend to avoid social situations or endure them with significant distress. This avoidance can lead to severe impairment in their daily routine: Compared to healthy peers, socially-anxious individuals are at higher risk to have a lower educational attainment due to their elevated vulnerability for dropping out of school prematurely [554, 271]. Furthermore, this impairment makes it harder for affected individuals to enter the job market [316, 164] due to their reduced productivity [554] as well as reduced access to education [271]. All these factors lead to an overall poorer quality of life [163]. Prior work states that the average onset age for social anxiety is between 14.2 and 14.4 years [144, 468] . This highlights the important role of the experiences during childhood and adolescence for the development of social anxiety [467]. Stein at al. [467] confirms these results: They showed that the age of onset for social anxiety disorder ranges between 11 and 17, depending on the homeland of the participants. Kessler et al. [275] reported a lifetime prevalence rate of up to 12% [376]. Several studies investigated the development of social anxiety over the lifetime of adolescents: These studies conclude that it is a naturally-remitting condition in the absence of treatment [91, 442, 376], where social anxiety had the smallest probability of recovery after 12 years. However, Pine et al. [415] provide some evidence that some socially-anxious adolescents may be able to outgrow the condition. Several investigators, as presented by Koyuncu et al. [296], show a comorbidity between social anxiety disorder and other disorders such as mood disorders, for example, major depression [45, 381, 494] or bipolar disorder [521, 410, 271], as well as alcohol use disorder [208, 384]. Several studies revealed a greater severity in childhood and adolescence than in adulthood [432, 490, 527]. As previously shown, social anxiety has an early onset in one's lifetime. Kodal et al. [284] proposed subtypes of social anxiety in youth populations, in which they identified three defining factors that describe the fear subtypes: performance, observation, and interaction. Cooper et al. [129] conclude that there is evidence that highlights the context sensitivity of social anxiety and needs to be addressed to achieve a more comprehensive diagnosis design. Several researchers proposed explanatory models about social anxiety (disorder), which present the process by which socially-anxious individuals are affected by fear as well as how it is expressed. Most commonly used are the models of Clark and Wells [115] and Rapee [436, 491] and Heimberg [235, 435] (See 1.1):
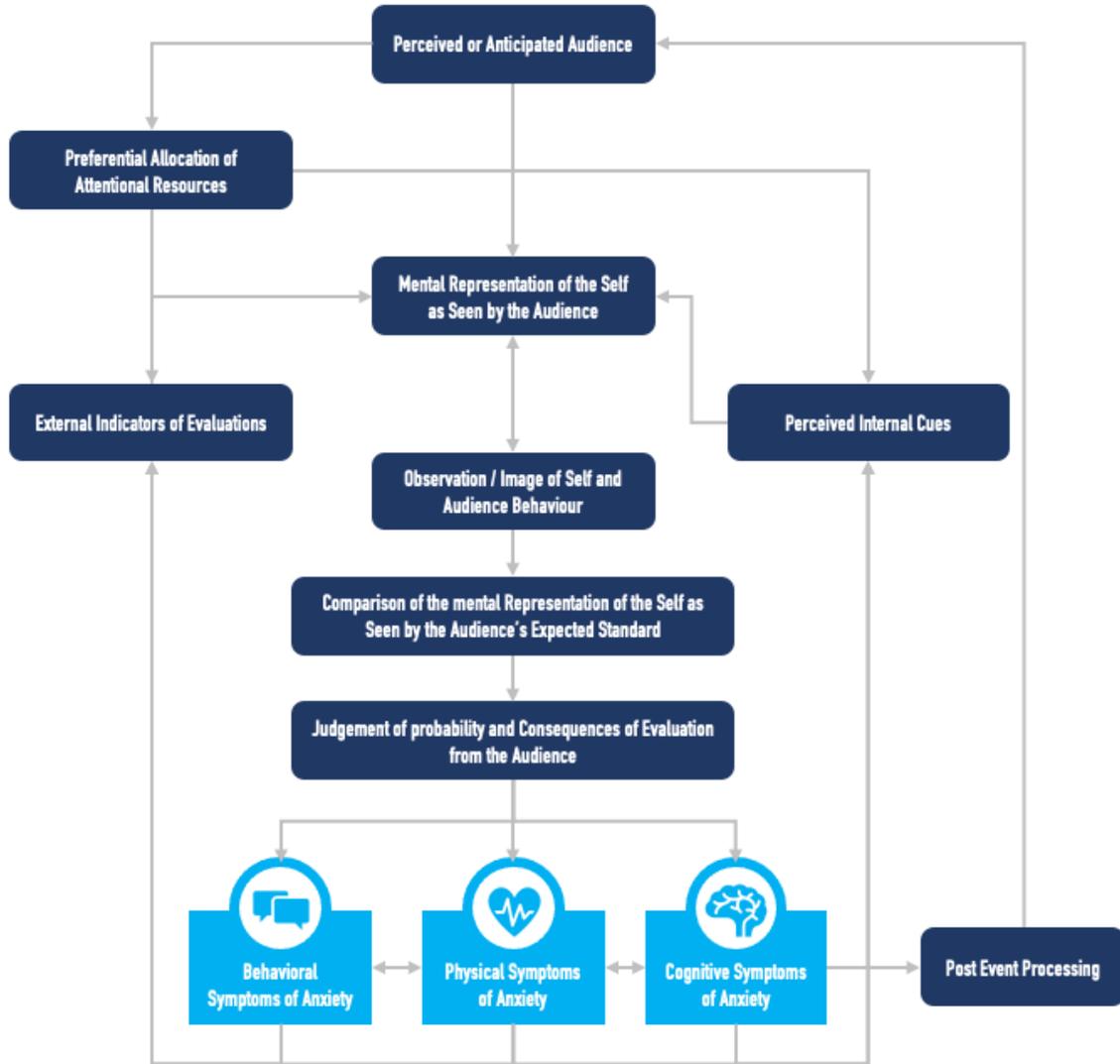
Figure 1.1: A Cognitive Behavioral model of Social Anxiety by Heimberg et al. [235]

As shown in the definition of social anxiety, the social interaction with others plays an important role. This social interaction starts for socially-anxious individuals already with the perception of a potential audience [115]. Depending on the characteristics of the situation, the individual may start to feel anxious. Furthermore, the perceived audience does not have to be physically present, as prior work shows [178], because affected individuals may engage in significant anticipatory processing while awaiting a (feared) social situation, as the model of Heimberg et al suggests [235, 435]. Whenever the individual recognizes the presence of an audience, mental representations of how the individual is perceived within the current social context are either formed or accessed [69]. The mental representation of the self as perceived by the audience is a composite, which is formed and further altered by a number of different internal and external cues [416]. For instance, the image may be informed by a sense of how the individual generally appears to others (e.g., their own image

in a mirror) as well as past difficult experiences in social situations that are consistent with negative core beliefs and self-schema [235, 435]. For this detection of an audience, socially-anxious individuals will allocate attentional resources towards detecting potential threats. This attention bias may play a causal role in for the maintenance of social anxiety [94, 362]. This leads to a "multiple task paradigm", in which socially-anxious individuals monitor their environment for social threats as well as their appearance and behaviour in the current social task [328].

In a second step, socially anxious individuals start to engage in imagery of themselves in social situations, which likely has a negative effect on their mental representation as well as on their predictions of the outcomes of social situations. Specifically, socially-anxious individuals are more likely than healthy individuals to spontaneously recall negatively distorted images of past events [70, 351]. But holding these negative self-images in mind while engaging in a social interaction may lead to heightened anxiety, reduced ratings of performance, and increased physiological arousal [52, 388, 167]. Furthermore, affected individuals show greater difficulties of generating neutral or positive images of themselves [471]. These negative images of negative outcomes of social events are carried forward into new social situations, which heighten anxiety and expectations of further negative outcomes. In addition to monitoring the mental representation of how the individual is perceived by the audience, individuals with social anxiety also project the performance standard expected by the audience. They believe that the perceived audience members have very high standards for the performance of the affected individual. In this distorted image, they fall short and therefore the affected individuals predict negative consequences from the audience. Previous research identified two core fear aspects: The fear of negative evaluation (FNE) and the fear of positive evaluation (FPE) [540, 235, 163]. Fear of negative evaluation is the typical core of social anxiety, in which individuals fear negative consequences from a social situation [125]. But several researchers provide evidence that also the fear of positive evaluation can cause the experience of social anxiety [539, 540]: Here, socially-anxious individuals fear that the initial positive performance in social interactions may raise the standards by which their future performance will be evaluated, yet they do not believe that they are capable of sustaining this positive performance. Therefore, they may predict that initial positive evaluation by others will ultimately result in failure to meet others' elevated expectations [180, 235]. As the model from Heimberg states [235]: Based on these mental images of the self, the audience and the (biased) perception of external and internal cues, the individual estimates the probability and cost of evaluation by the audience. This means, that socially anxious individuals focus on the discrepancy between their own mental representation of self as seen by the audience compared to their perception of the audience's not-achievable standards for their performance (FNE), or they focus on the possibility that they may have drawn unwanted positive attention to themselves that will have its own negative consequences (FPE). In both cases, they are likely to overestimate the social costs of the event. As a result of these negative mental processes, socially-anxious individuals show several behavioural, cognitive, and physical symptoms for social anxiety.

Behavioural Symptoms

The potential experience of negative evaluation or social reprisal may produce overt avoidance behaviour as well as escape from social situations. But if a socially-anxious individual stays within a social situation, they may engage in a broad variety of self-protective strategies to prevent any negative outcomes [347, 463]. These behaviours are typically referred to as "safety behaviour", such as minimizing the participation in group activities [134, 483, 508], or standing farther away from crowds [201]. Prior work [115, 241] groups safety behaviors into avoidance (e.g., avoiding eye contact) and impression-management (e.g., excessive self-monitoring and rehearsal) subtypes. Socially-anxious individuals engage in these behaviours because they feel that these techniques help them to compensate for any perceived social deficit or that safety behaviours help them to be successful in a social interaction [279]. However, quite the opposite is the case, as previous research shows that avoidance behaviour was associated with a negative perception by observers [357, 491]. Furthermore, avoidance behaviours were associated with higher state anxiety during a social interaction and more negative reactions from interaction partners. According to the literature about the relationship between social anxiety and safety behaviours [220], an excessive use of safety behaviours has several problematic consequences, as it increases experienced anxiety and self-focused attention, maintains negative beliefs, and may even contaminate social situations by making these individuals come across as distant or uninterested [435, 115].

Physical Symptoms

Previous studies provide evidence that social anxiety generates physiological arousal, caused by the experience of feared social situations. Compared to healthy individuals [235], socially-anxious individuals are more likely to exhibit physical symptoms that may be observed by others like blushing [533], muscle tension [243], and sweating [376]. Furthermore, recent research revealed that social anxiety may affect the fundamental vocal frequency [541].

Cognitive Symptoms

As shown earlier, socially-anxious individuals engage in safety behaviours to prevent potential negative consequences from social interactions. The engagement in these behaviours can be seen as the product of cognitive biases. Previous work of Spence and colleagues provides evidence that socially-anxious individuals (in comparison to non-socially anxious peers) show the following cognitive characteristics [436, 491]:

- More negative anticipated outcomes from social tasks and more negative expectations regarding the quality of one's own performance [356, 6, 69]

- A greater level of self-focused attention [69, 244, 470]

- More negative evaluation of one's performance and during a social interaction [355]

- More negative pre-event [244] and post-event processing and rumination [466, 252]

- Greater likelihood of negative interpretation of social situations and information, such as negative perception of audience behaviour and negative observer-perspective images as well as the distance to others [431, 69]

- Increased frequency and vividness of negative distorted self-images, associated with greater distress relating to social situations [471]

Prior work shows that these effects are still evident after controlling for depression [244] and therefore cannot be attributed solely to a general cognitive bias associated with negative affect [436, 491]. Based on the previously described symptoms, mental health professionals started to develop different approaches for the assessment of social anxiety.

1.3.2 (Digital) Assessment of Social Anxiety

One of the most influential paradigms in the clinical psychology domain is the evidence-based approach [385, 249, 16]. This paradigm consists of two asymmetric branches: Evidence-based treatment and evidence-based assessment. Evidence-based assessment is describes as "assessment methods and processes that are based on empirical evidence in terms of both their reliability and validity as well as their clinical usefulness" [338]. However, the high comorbidity among mental disorders, including mood disorders or ADHD [295], poses a challenge for clinicians who try to achieve an accurate and detailed assessment. To overcome this challenge, the assessment requires to assess for the possible presence of potential comorbid disorders [249]. Antony et al. [16] recommend that evidence-based assessment for anxiety disorders should target anxiety cues and triggers, avoidance behaviours, compulsions and overprotective behaviours, physical symptoms and response, comorbidity, skill deficits, (social) environment factors, and associated health issues including the disorder and treatment history. However, there are concerns about how well one measurement correlates with another [16, 481]. The endless expanding of different measures [34], ironically called the big bang of assessment [273], makes it hard to select the optimal assessment tool for a specific problem. Tulbure et al. [516] state that evidence-based assessment represents an integral part of the overall evidence-based paradigm. It provides a meaningful way to filter a large number of measurements and facilitates the selection of appropriate instruments. Furthermore, evidence-based assessment expands the scientific basis of psychotherapy, by providing empirical support of psychological services in general, and of psychotherapy in particular.

Within the context of social anxiety, Schneier et al. [467] suggest to evaluate the scope of social anxiety across a broad variety of social situations. There are several scales that may be helpful to make assessments as well as for a patient's progress evaluations, such as the Liebowitz Social Anxiety Scale [322], the Social Interaction Anxiety Scale (SIAS) [340], and the Social Phobia Inventory (SPIN) [126]. De Los Reyes et al. [142] state that mental health professionals require a variety of instruments to fully understand the adolescents' level of social anxiety within and across contexts in which they may display symptoms. A common approach

to cross-contextual assessment of adolescent social anxiety involves collecting clinical reports from multiple sources, such as parents, teachers, and peers [249]. The unique perspectives from others about anxious individuals yields a richer picture of clinical presentation of the patient [297]. Besides the assessment via self-reported questionnaires to measure the personal effects as well as cognitive symptoms of social anxiety, also the additional assessment of behavioural as well as physical symptoms are recommended for a full evidence-based assessment. Ecological Momentary Assessment (EMA)[196] can be used to assess the reaction of socially-anxious individuals to positive or negative situations.

One promising solution for assessing behaviour in social situations is the usage of biomarkers. Biomarkers are defined as measurable responses which can be utilized to predict the incidence of a disease [424]. Digital biomarkers —objective and quantifiable data collected via digital devices [198]—may even further strengthen the assessment by increasing the temporal and spatial resolution of captured behaviour during an assessment [162]. Furthermore, digital biomarkers may be more resilient against human bias , and may be less stressful for participants [476]. They represent a rich source of insights about the user's mental and physical state, gathered with minimal effort from both health experts and patients alike [512]: With the rise of mobile platforms as well as the additional inclusion of mobile sensors in such devices, a growing number of studies have been conducted by leveraging personal phones or wearable sensors [215, 103] to gain more insights about the state-of-mind as well as the risk of experiencing mental illnesses, such as social anxiety [253].

Besides the usage of GPS information [247], several researchers analysed the benefits of sensor data, such as gaze data, for the assessment of social anxiety. Several studies provide evidence that socially-anxious individuals avoid the eye region of faces [371, 549]. Furthermore, Chen et al. [110] reported that socially-anxious individuals fixate longer on non-social regions while giving presentations. Kret et al. [299] provide evidence for the hypothesis that socially-anxious individuals rely on other measures of detecting the emotional state of others, such as observing their body language, including specific poses [23] or hand gestures [366, 140]. These are perceived as a rich source of information regarding someone's emotional state for the observer. Besides gaze data, some researchers investigated whether skin conductance may be usable for the assessment of social anxiety [304, 157] by demonstrating that slower habituation and the amplitude of skin conductance were positively correlated with the severity of social anxiety. Furthermore, higher skin conductance levels were reported for highly socially-anxious individuals during the imagining of threatening stimuli [350].

As previously shown, there are multiple sources of data for digital biomarkers. However, the usage of digital games for the assessment of social anxiety has not been properly explored within the context of social anxiety. But in 2019, two-thirds of the online population play digital games, including players of all ages, genders, and races/ethnicities [172]. When people play digital games, they produce a large volume of data that can be used as digital biomarkers to assess mental health concerns. Mandryk et al. [335] outline two complementary approaches for developing game-based biomarkers: harnessing the traces left behind through natural interactions with digital games; and developing custom games that place a player in a situation and monitor their response or performance using known behavioural correlates of mental health. Furthermore,

previous research provides evidence for a relationship between social anxiety and the player's (in)-game behaviour.

1.3.3 Why digital Games?

A dominant theme within research about the relationship between social anxiety and immersive digital worlds focuses on the interplay between social anxiety and problematic game usage: Gaming behaviour has been argued to exist on a *"continuum ranging from non-problematic occasional and regular gaming at one end of the scale through to problematic excessive and additive gaming at the other" [213].* The term *"problematic gaming"* is used by Griffiths et al. [213] as *"an umbrella term to describe the phenomenon of problematic video game use"*, which has a spectrum of severity, ranging from lightly disordered patterns of play through *gaming disorder*, defined by the WHO IDC-11 as being *"characterized by impaired control over gaming, increasing priority given to gaming over other activities to the extent that gaming takes precedence over other interests and daily activities, and continuation or escalation of gaming despite the occurrence of negative consequences"* [557].

Cole et al. [123] found that gamers measuring high in problematic internet usage due to online gaming were more likely to experience higher levels of social anxiety. Furthermore, a study of problematic online gaming by Park et al. [395] suggests that of four genres (MMORPG, First Person Shooter (FPS), Real Time Strategy (RTS), and "Others"), players with higher levels of social anxiety were more likely to play MMORPGs than other genres and less likely to play FPS games. Also, Gavriloff et al. [192] found that in comparison to non-anxious players, socially-anxious gamers show less dispositional mindfulness, which is characterized by the mental state of being aware of one's current experience and functioning. They suggest that players use games to self-regulate their social anxiety with mindful awareness of their emotional state by participating in the social aspects of the game. Taken together, we still lack a deeper understanding of why socially-anxious players are drawn to or avoid particular genres, especially the preference towards MMORPGs.

In summary, prior work about the usage of digital assessment for social anxiety outline great potential for novel ways to help patients to overcome barriers and limitations of existing solutions. Further, internet- and mobile-based solutions help patients to connect more easily to mental health professionals through the devices, which reduces geographical as well as logistical limitations. Furthermore, both approaches allow experts to gain more behavioural data of the individual, which may help to assess the severity of social anxiety through behavioral data. However, prior research about the benefits of games within the context of social anxiety is still very limited.

1.4 Methodological Considerations

For the formulated question whether we can use in-game behaviour for the assessment of social anxiety, we first must discuss several methodological approaches.

1.4.1 Off-The-Shelf versus Assessment Games

As Mandryk et al. [335] outline in their work, there are several ways to employ digital games as a tool within the context of mental health. On one side researchers may use off-the-shelf games. When playing commercial games, various types of digital data such as in-game performance, play frequency, certain aspects about the cognition and the motor skills of the player, and social information about relationships, mood, and affect in-game. Building on this rich data stream, researchers may be interested in harnessing these data directly and build on the game itself. One major advantage is the "in-the-wild" aspect of this approach: Players engage with the game already naturally and for most players, this approach provides easy access compared to other approaches for assessing the player's current state of mental health. As many sources outline, digital commercial games became a core of modern pop culture and many players engage with them on a daily basis. However, these off-the-shelf games advantages have some limitations: Although there is a growing popularity of modification support for commercial games, many core aspects of the game remain untouchable for third parties. Researchers are bound to the underlying game mechanics and must adapt their research around that (e.g., the camera perspective and the underlying self-representation in-game). Furthermore, commercial games (thankfully) limit the access to behavioural data of players in their games to third parties, which makes it harder for researchers to harness them in the context of mental health. Further, commercial games do not give full control over mechanics, story and aesthetics, which can bias the player's assessment. For example: Players may be forced to move to certain points or behave in certain ways in-game, due to the given rules of the game.

In the context of this dissertation we decided to go with the alternative approach: The usage of custom-made games gives full control over the in-game world and mechanics, and allows full access to the in-game behaviour. As prior work shows, there are many custom-made games which have been successfully adapted in the context of assessment and mental health in broader terms. However, we must be aware of the limitations of the custom game approach, similar to the ones of the off-the-shelf-games. But in order to better understand the relationship between social anxiety and the in-game behaviour we argue that a clear and more controlled game environment is more helpful to better understand how social anxiety may manifest in-game and affect how players behave and act in-game.

1.4.2 Technological Framework

This dissertation builds on two major technologies: Digital games, and the usage of crowd-sourced experiments. In order to facilitate this research we relied on two technical tools which have been used in prior work in the context of Human-Computer Interaction research.

Game Engine

First we decided to use Unity as a framework for the development of our gaming tasks. Compared to other platforms, Unity[518] is still one of the most commonly-used platforms for mobile and web-based digital games. Further, over the years, Unity became a rich platform for third party developers, who offer assets on the integrated asset store, which reduces the production time for developing a game-based experiment. This flexibility allows us to adapt the gaming tasks easily for different contexts. Furthermore, Unity has been successfully been used for experiments using the "Bride of Frankensystem" [257] system for developing and deploying online experiments.

Online Environment

Building on prior work, we used the "Bride of Frankensystem" framework, which allows us to record questionnaire data and link them with online gaming tasks [257]. This framework allows researchers to deploy online questionnaires using JSON Files and combine these questionnaires with online web-based applications, for example Web-GL based gaming tasks. Furthermore, this framework allows us to stay independent from commercial applications such as SurveyMonkey or Google Forms, and allows us to store data on our own server infrastructure rather than storing them on third-party servers, where others may have access.

1.4.3 Online Recruitment

Within the context of Human-Computer Interaction, many researchers rely on data recordings using online platforms such as Amazon Mechanical Turk (MTurk)[12] or Prolific [425]. Both platforms work in a similar way: Users can either sign up as a worker/participant or as requester/researcher. Researchers may place their experiments, such as questionnaires or web-based applications, on these platforms and pay participants through these platforms. Participants can sign up, participate in the studies, and get paid through these platforms. Platforms like Prolific and MTurk allow researchers to reach out to a large audience. For example, Prolific [425] advertises that their sample size is around 140,000 participants with several pre-screened demographics, such as age and gender, but also preferences and health information. Furthermore, these platforms allow an easy payment and participant management system as well as a safe way to communicate with participants in the case of problems during the experiment. Besides the easy access to a large audience, the usage of online crowd-sourcing platforms like Prolific and MTurk allow us to reach out to a more diverse user base, compared to traditional in-lab experiments. Furthermore, it may allow us to reach out easier to participants affected by the effects of social anxiety, which causes them to avoid in-person meetings.

However, in recent years, a debate about the data quality of data recorded on these platforms rose. As prior work outlines, there are several limitations and threats, researchers must be aware of to ensure quality data. First, we do not have full control over the participants' environments. While Prolific, for example, allows researchers to limit the experiment to certain platforms (e.g., desktop or mobile), we don't know the

full technical setup and the surrounding environment in which the user participates. These aspects could affect the data quality (e.g., participants get distracted from a task or don't pay attention because they get distracted by something in their environment) [153]. Second, Mturk as well as Prolific offer researchers to limit the access to studies to certain countries (e.g., due to cultural and language barriers, we focus only on the US and English-speaking countries). However, recent work suggests that users may easily breach these barriers and participate in such studies anyways, although they are not eligible for them (e.g., through using VPNs). Further, the platforms have no clear way to identify whether the worker account is actually a real person or a secondary account of one user. As an result, one user may get over represented in a study because they used multiple accounts for the same study [153]. Therefore, researchers must implement ways to identify fraudulent behaviour in the study to protect the data quality, such as attention checks or the usage of web-cams to identify whether the same participant signed up multiple times [358]. However, we must be aware that participants on these platforms are human beings. Therefore, also external events and trends may affect the data recordings on these platforms. For example: During the summer of 2021, researchers on Prolific saw a massive imbalance of their demographics. This imbalance was caused by the online video platform TikTok, where one video producer recommended Prolific as a way to earn additional money online [317] causing a huge influx of young female participants on the platform. However, when taking these potential risks into account, online experiments are a powerful tool that allow us to reach out to a large and diverse user group with easy access to the experiment and who can participate within their own comfort zone, similar to other web-based assessments for mental health. Therefore we decided to use online platforms as our main platform for conducting all of our experiments.

1.5   Dissertation Outline

This dissertation presents five manuscripts, which are organized into the three parts: **Foundation**, **Design and Implementation**, and an **Application** in which the found digital behaviour markers are applied outside of the context of social anxiety.

The first part, **the foundation** of this thesis, builds on the prior introduced work about the relationship between social anxiety and digital games. Manuscript 1 investigates whether social anxiety affects the motivation and preferences of players in Massively Multiplayer Online Roleplaying Games (MMORPGs), a genre, which has been suggested to be preferred by socially-anxious players. The results of Manuscript 1 reveal that social anxiety manifests within immersive applications, such as gaming, but in a less prominent way. Manuscript 2 extends our understanding how the customization of the self-representation may affect the experience of social anxiety in-game. Customized avatars have been used in prior work to enhance digital games as well as digital health interventions. The results of Manuscript 2 show that players with elevated levels of social anxiety rate their expected and experienced fear higher in a gaming task if they were allowed to create a customized self-representation. These two manuscripts form the foundation for the development of

more elaborated games, which we use to support assessing social anxiety through digital biomarkers.

Part Two focuses on the **design and the implementation of digital biomarkers** for the assessment of social anxiety: Manuscript 3 investigates whether avoidance patterns that are characteristic of social anxiety manifest within a digital gaming task and analyzes whether the player's self-representation as well as the camera perspective, two core design aspects of games, affect the manifestation of these avoidance patterns. The results show that social anxiety manifests within the gaming task, in which socially-anxious players avoid other players' representations. Further, Manuscript 4 expands on these findings and proposes the interpersonal distance (IPD) measure as an additional evaluation tool for detecting social anxiety within a gaming task. The results of Manuscript 4 confirm the findings of prior work and show that social anxiety may be detectable by the analysis of in-game behaviour.

Part Three finalizes the dissertation with an **extension** of the found digital biomarkers and the prior developed social interaction task and applies these findings to a context beyond the assessment of social anxiety. Manuscript 5 focuses on the hypothesized opposite of social anxiety—psychopathy [245]. Similar to Manuscripts 3 and 4, Manuscript 5 utilises an adapted version of the gaming task and adds communication as well as emotion perception aspects as a new measurement. The results of Manuscript 5 show that players with psychopathic traits show the inverted behaviour to socially-anxious individuals, which my be an indication that the opposite behaviour of social anxiety leads to an opposite behaviour in-game.

Each chapter starts with an overarching introduction of the problems for this step in the development of digital biomarkers for the assessment of social anxiety followed by a solution statement and the taken steps to answer the previously-introduced research questions. After the presentation of the actual manuscripts, each chapter provides a summary of the results and the gained insights. Aspects about the characteristics of social anxiety were previously summarized. Each chapter closes with a short discussion about the relevance of the presented manuscripts within the overarching context of the thesis. After the presentation of the three parts, We discuss the findings in the light of the overall problem statement of the thesis and present the gained insights and outline future work building on this thesis. The dissertation finishes with a conclusion statement. Supplementary material, such as questionnaires and material used for the thesis, can be found in the appendices. Figure 1.2 summarizes the outline.

Application

Manuscript 5
(Don't) stand by me: How trait psychopathy and NPC emotion influence player perceptions, verbal responses, and movement behaviours in a gaming task

Design & Implementation

Manuscript 3:
Assessing social anxiety through digital biomarkers embedded in a gaming task

Manuscript 4:
Development of explicit and implicit game-based digital biomarkers for the assessment of social anxiety

Foundation

Manuscript 1
In-game and out-of-game social anxiety of MMORPG players

Manuscript 2
The effects of avatar customization on the experience of social anxiety

Figure 1.2: Overview of the five manuscripts

2 Foundation

In order to develop digital biomarkers and harness digital games for the assessment of social anxiety, we first need to better understand the relationship between social anxiety and digital games, how it manifests within digital games, and whether central game mechanics, such as the chosen self-representation may affect the manifestation of social anxiety in-game. Therefore the goal of part one is to provide an answer for the first research questions: *Does social anxiety manifest within the in-game world? If it does manifest, does the self-representation affect the experience of social anxiety in-game?*

2.1 Problem and Motivation

Prior work shows that socializing is one of the major motivators for play, with 65 % of adult players reporting that they engage in video games, in part because gaming together with others helps to maintain a social connection with friends and family around the world [172]. Yet these benefits may not accessible for all players. Socially-anxious players may experience effects of their mental burden not only on the physical, but also in the digital realm. Prior work shows that socially-anxious players are drawn to online interactions like online chats and social media platforms [423]. However, the literature also draws a relationship between problematic gaming usage related to social anxiety and the potential (ab)use of digital games to satisfy social needs [312, 395]. As this prior work shows, socially-anxious players are more drawn to MMORPGs, which focus more on socializing with others than any other game genre, and less drawn to performance focused games, such as First-Person Shooter games [395]. Yet the question of *why* players with elevated social anxiety are drawn towards games with a strong socializing component remains unclear. It may be possible that people who experience fear and anxiety around socializing are drawn to MMORPGs to satisfy their social needs. However, it is not clear whether social anxiety translates from the physical realm into the digital realm, or whether socially-anxious players leverage the fantasy of the gamer world and the affordances within it to represent themselves as they wish to fulfill their social needs with reduced anxiety. Manuscript 1 addresses this question by providing a better understanding through investigating the relationship between social anxiety and its influence on the in-game preferences of players.

Besides understanding the reasons for play as well as the preferences in-game, we also need to better understand how game mechanics may affect the experience of social anxiety in-game. As outlined earlier, mental health interventions such as CBT approaches, face several limitations stemming from various sources like geographical access to therapy, and the available resources but also individual requirements of the mental

burden (e.g., a common nuance of social anxiety is the fear of presenting in front of a large audience). While prior work shows that Internet-Mobile-Based Interventions (IMIs) may be a powerful tool to overcome these problems, one challenge remains: As with all interventions, IMIs rely on the user's motivation to participate and to follow through the whole process. Game designers as well as researchers have been investigating how game mechanics may affect an individual's beliefs, behaviours, and their motivation to play to increase the adherence to the game but also to the (mental) health intervention [461].

One prominently discussed aspect is the customization of the player's self-representation, referred to as avatars. As prior work shows, socially-anxious participants experienced higher levels of social anxiety if they saw an in-game representation with a mapped photo of their own face as a facial texture [25]. This shows that the usage of customized avatars may help to increase the experience of social anxiety in the assessment while predefined avatars may reduce the efficacy of an intervention. However, current work was not able to represent the participant at a high fidelity, so the question remains: Does customization of self-representation increase expected and experienced fear within an in-virtuo exposure task for social anxiety? Manuscript 2 answers this question and contributes a better understanding how core game mechanics, such as the self-representation in-game, affects the experience of social anxiety, which can be useful for the development of assessment strategies through games. In order to fully understand the manifestation of social anxiety in game, as well as how self-representation in-game affects social anxiety, two crowd sourced online studies were developed to gain insights about these two aspects.

2.2 The relationship between social anxiety in-game and out-of-game

2.2.1 Research Questions

In order to better understand the reasons and preferred activities as well as whether social anxiety transfers into the gaming context, Manuscript 1 provides answers to the following research questions:

- **RQ 1.1:** In MMORPG players, is there an expression of in-game social anxiety?

- **RQ 1.2:** For what reasons are players with social anxiety and in-game social anxiety playing MMORPGs?

- **RQ 1.3:** In what kinds of MMORPG activities are players with in-game and out-of-game social anxiety engaging?

- **RQ 1.4:** Does social anxiety or in-game anxiety predict how threatening events in the game world are as compared to the physical world?

- **RQ 1.5:** Does social anxiety or in-game anxiety predict MMORPG enjoyment?

2.2.2   Design Rationale

To answer the previously introduced research questions, we were confronted with the following aspects and limitations suggested by prior work. First we need to be aware of the context sensitivity of social anxiety. As the literature suggests, social anxiety may manifest for players in various ways and cause different expressions in-game. Therefore we decided to adapt the LSAS, the golden standard of assessing social anxiety in the clinical context, in order to capture the experience of social anxiety within this specific context of social interaction.

Second, we need to consider the range of genres and player composition in-game. Games offer a large variety of game mechanics, based on various goals and skill sets of players. For example: First person shooter games focus more on the performance, tactical skills, and accuracy rather than the social skills of the player. Following the example and the first evidence we decided to focus only on MMORPGs to better understand whether the socialization in-game is the main driver for the increased attractiveness of this genre.

Third, there are a variety of activities in which players may engage when playing MMORPGs. Games of this genre tend to offer a large variety of interaction in-game, ranging from simple socializing activities like group chats and in-game dance events up to highly-challenging activities like solving complex riddles in-game. To grasp the breadth of these activities, we asked game user researchers who play and research MMORPGs to deconstruct and group these activities into title-independent items using a custom scale. Similarly to the activities, also the reasons to play may be as diverse as the players themselves, as prior work suggests. Therefore we reviewed prior work and constructed potential reasons of why players may engage especially in MMORPGs.

Fourth, the perception of threat: One potential yet unexplored explanation of why players prefer MMORPGs to socialize is the perception of social threats online. As shown in earlier work, socially-anxious individuals feel more confident and socially competent online [423]. However, recent work about toxic in-game behaviour shows that problematic antisocial behaviour manifests in-game and harms not only the game-experience [517, 460] but also the in-game performance [367] and the mental health due to the exposure of maladaptive behaviour by others in-game [391, 302], which may affect the player beyond the gaming context [59].

2.2.3   Steps towards the solution

We approached the translation of social anxiety into the gaming context. As prior work shows, social anxiety may be context dependent [37, 491]. However, prior used standardized tools for the assessment of social anxiety focus either on general interactions in the physical realm or on certain contexts, such as social media usage [9]. Therefore we adapted the Liebowitz Social Anxiety Scale [322] for the MMORPG context, referred to as the Game Social Anxiety Scale (GSAS). Next we conducted a crowd sourced online study: because we were only interested in MMORPG players, we first used a screening task in which participants had to indicate their game genre preferences. Participants who indicated that they play MMORPGs were invited

to a follow-up study. In this study we asked participants to indicate their preferences and reasons to play an MMORPGs, and answer the original LSAS as well as the GSAS. Furthermore we assessed the perceived threat of situations in the digital versus the physical realm. The manuscript in its published form follows.

2.3   Manuscript 1:   In-game and Out-of-game Social Anxiety of MMORPG Players

2.3.1   Abstract

Socializing is an important part of why people choose to play games and is at the core of many game mechanics. Anxiety and fear about social interactions can lead to withdrawal from socializing in the physical world, yet players with social anxiety preferentially choose MMORPGs — a highly social genre — raising questions of whether social anxiety expresses differently during in-game interactions. In the present study (N=181), we explore whether and how social anxiety translates into MMORPGs. By developing a measure of in-game social anxiety, we find that although fear and apprehension of socializing in the physical and game worlds are related, they differently affect preferences, behaviours, and experiences. Social anxiety in the physical world

drives reasons for playing, whereas in-game anxiety affects behaviours, reducing participation in activities related to socializing and difficult in-game challenges. Our findings can inform the design of social games and the links between social anxiety and social gaming.

2.3.2   Introduction

People have a fundamental need to form and maintain meaningful relationships [44], which is increasingly being met through socialization with others in the digital realm [170, 551, 321, 486], and in particular through digital games. Socializing within games is a primary motivator for play [141], with 63% of adult gamers reporting that they play with others, in part because gaming helps them connect with their friends and family [172]. While there is still debate as to whether socialization in games is as effective at satisfying social needs as interacting offline (e.g. [289, 251, 496]), recent work shows that stereotypes about the lonely gamer are inaccurate [291, 465]. Players view games as a social medium through which they socially interact [293, 496, 515], and for typical players, there are benefits to well-being [294, 337, 132, 154].

However, the benefits of socializing through games might not be accessible to all players. In the physical world, people differ in how challenging they find socializing, due to fear and anxiety experienced in social interactions [491]. This fear causes socially anxious individuals to withdraw from social situations and isolate themselves [134, 508, 483]. On the other hand, there is evidence that the same people who experience fear around socializing in the physical world are drawn to online interactions, such as online chats and social media platforms [543, 423, 475]. Further, some research suggests that gamers high in social anxiety are preferentially choosing to play Massively Multiplayer Online Role-Playing Games (MMORPGs) over other types of multiplayer games [395, 560]. MMORPGs are a highly social game genre [552, 109, 380], in which players interact with others in a persistent virtual world, and are used to maintain existing relationships, form new ones, and even find romantic partners [552]. It is possible that people who experience fear and anxiety around social interactions (i.e., social anxiety) are drawn to MMORPGs to satisfy their social needs. However, we do not know if social anxiety experienced in the physical world translates into an MMORPG context, or whether socially anxious players leverage the fantasy of the game world and the affordances within it to represent themselves as they wish and engage in social interactions with reduced fear.

To determine how social anxiety affects people's access to, behaviours in, and experiences of social games, we surveyed 181 MMORPG players about their experienced social anxiety in the physical world and the game world, along with their MMORPG preferences, motivations, and activities. Because previous approaches focused on physical world contexts or social media contexts [9], we had to develop our own tool to measure social anxiety in the context of online gaming. We based this tool on the gold standard of social anxiety assessment through self-report, the Liebowitz Social Anxiety Scale [322]. Our measurement tool showed high internal consistency and descriptive characteristics in line with existing measurements of social anxiety for use in the physical world. We used this tool to assess whether social anxiety expresses differently in the game world than in the physical world (RQ1, RQ2). We question whether the degree of social anxiety

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(both out-of-game and in-game) affects seven identified reasons why players choose MMORPGs (RQ3), their preferences for six different in-game activities (RQ4), and their resulting game experiences (RQ5, RQ6).

Our results show that social anxiety in the physical world and social anxiety in the game world are related but differently affect players preferences and behaviours. Social anxiety in the physical world significantly predicted the reasons for playing, with players reporting that it is easier to connect with others in-game, that the MMORPG world is less broken, and that they feel more socially competent within it. On the other hand, in-game anxiety predicted reduced participation in activities related to socializing and difficult in-game challenges. These differences in play behaviour did not affect overall enjoyment of the MMORPG genre, which was very high in our sample. Regardless of anxiety type or level, players found events in the physical world to be more threatening than the same events in the game world.

We discuss how game designers can leverage our results, possible implications for therapeutic use, and add relevance to current debates around problematic game usage. Social anxiety is a major mental health issue globally [275] and our results provide deeper insights about how it expresses in the world of online game interactions.

2.3.3 Related work

We present related work from three perspectives (inspired by Björk's framework [63]): The game (MMORPGs), the gamer (and social anxiety), and gaming (socializing in MMORPGs).

The game: The MMORPG genre

MMORPGs are a popular game genre—the most popular game in the genre, World of Warcraft, had an estimated 5 million active players in 2019 [492], and at its peak (2010) it had 12 million players [404]. MMORPGs feature fully simulated multiplayer game worlds in which players can create their own in-game representations, known as a "character" or "avatar" [211, 122]. Players use these characters to interact with the digital world as well as with other players. Players can express themselves by customizing their character's appearance, personality, and skills. By facing in-game challenges, players can advance their character, unlock new abilities, and acquire new equipment.

Many MMORPGs feature built-in systems to associate with other players, e.g., factions, guilds, and clans. Additionally, they provide activities that can be broadly classified as either Player vs. Environment (PvE; players fight together against virtual enemies) or Player vs. Player (PvP; players fight each other). These can be played in a group, or solo, and players can selectively engage in or ignore these different aspects of the game. The long-term success of MMORPGs has been attributed to these features [114, 27, 497], as well as to the rich social interactions available within the game [510].

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The Gamer: Characteristics of Social Anxiety

For some people, socializing can be frightening or anxiety-inducing to a level where they experience "social anxiety", which is characterized by a persistent fear of situations in which they are exposed to unfamiliar people or to possible scrutiny and negative evaluation by others [13, 5]. As a result, they tend to avoid social situations or endure them with significant distress. Social anxiety is most accurately expressed along a severity continuum [436], where one can experience a high degree of social anxiety yet not reach the threshold for clinical diagnosis. The degree of social anxiety is affected by several individual and environmental [491] risk factors, which lead to different expressions of social anxiety [190]. Further, individuals may experience high social anxiety only within specific contexts, such as giving a presentation [71], while other situations are less distressing.

Previous studies show that individuals with social anxiety may have greater difficulties forming relationships with others [354]. As a result, they tend to have fewer close friends [511], and are less accepted or even ignored by their peers [303]. They may also be victimized by others due to differences in social competence [430, 429], and are at higher risk of being bullied [120]. Individuals who experience social anxiety can develop unhealthy coping strategies, including substance abuse [95] and problematic gaming behavior [212]. Gaming behaviour has been argued to exist on a "continuum ranging from non-problematic occasional and regular gaming at one end of the scale through to problematic excessive and addictive gaming at the other." [213]. The term "problematic gaming" is used by Griffiths et al. as "an umbrella term to describe the phenomenon of problematic video game use" [212], which has a spectrum of severity, ranging from lightly disordered patterns of play through gaming disorder, defined by the WHO IDC-11 as being "characterized by impaired control over gaming, increasing priority given to gaming over other activities to the extent that gaming takes precedence over other interests and daily activities, and continuation or escalation of gaming despite the occurrence of negative consequences." [557]. Cole et al. (S. H. Cole and Hooley 2013) found that gamers measuring high in problematic internet use due to MMORPG gaming were more likely to experience higher levels of social anxiety. A study of problematic online gaming by Park et al. [395] suggests that of four genres (MMORPG, First Person Shooter, Real Time Strategy, and "Others"), players with higher levels of social anxiety were more likely to play MMORPGs than other genres, and less likely to play FPS games. Furthermore, Gavriloff et al. [192] found that socially anxious gamers show less dispositional mindfulness—which is characterized by the mental state of being aware of one's current experience and functioning (Brown and Ryan 2003)—than non-anxious gamers. They suggest that players use games to self-regulate their social anxiety with mindful awareness of their emotional state by participating in the social aspects of the game. Despite past work, we still lack understanding of why socially anxious players are drawn to play MMORPGs.

The interaction: Socializing in games and MMORPGs

Forming and maintaining relationships and feelings of belonging are fundamental needs [44] that are increasingly being fulfilled by using online games for social interaction [159, 293, 172]. There is some debate as to whether

this is desirable (e.g., [291]), possibly stemming from the stereotype of the lonely, socially-isolated gamer [289, 465]. Particular concerns include the possibility that in-game relationships are low-quality in terms of providing social support [83] or that they displace physical-world ties [496, 289]. Investigations into social displacement theories have found support for the idea that in-game ties are negatively associated with physical-world ties [289]; however, in-game relationships are not necessarily "lesser" than physical-world relationships [160, 154]. When measures of well-being are considered, in-game social interactions are positively associated with a player's sense of self-esteem [294], perceptions of social competence [294], reductions in loneliness [337, 132, 154], and increased relatedness [154]. A factor when investigating these concerns is that the line between game-world and physical-world friendship is blurred—many players use online games to maintain pre-existing relationships [159, 154]; conversely, many friendships that start in the game-world eventually get taken to the physical-world [515, 154].

MMORPGs feature multiple ways to socialize. Players usually have access to many different chat channels at any point in time; for example, guild or clan chats, team chats, faction chats, open world chats, nearby chats that only the players in a specific area can see, and direct chats in which one can privately whisper with a certain player. Additionally, non-verbal communication techniques allow players to communicate strategies by drawing instructions on the in-game map, alert others by pinging, or guide novices through a difficult part of the game, which can help players to improve their performance and foster relationships with other players [513, 310, 7].

Many in-game activities require teamwork, and therefore a group of players will unite to achieve a common goal. Players can further benefit from cooperation by making use of the complementary abilities of their characters. Individual MMORPGs also feature unique interaction mechanics, but common examples include role-playing, player emotes and dance moves. Some MMORPGs allow players to start a family or even marry another player in-game.

Even though in-game socialization can result in positive outcomes, there are risks involved. In particular, in-game social interactions can be negative or "toxic". In online games, this takes the form of one player harassing another [185], which in extreme cases can lead to bullying [302]. A 2015 study found that 52% of MMO players had been victims of cyberbullying [33]. Many in-game tasks are challenging and players who are judged as "weak" may be socially excluded from groups or from joining the strongest guilds [302]. Overall, previous research draws a strong link between social anxiety, game genre preferences, and problematic game usage. However, explanations are still missing for why socially anxious players enjoy—and perhaps even prefer—MMORPGs.

2.3.4 Methods

To provide a better understanding of this link between social anxiety and MMORPG play, we conducted an online survey with MMORPG players. Our goals were to investigate if social anxiety translates into the digital world and if so, how it affects reasons for choosing MMORPGs, the MMORPG activities players engage in,

and their play experience. Further, we were curious if social anxiety affects perception of the game as a safer space relative to the physical world.

Procedure and participants

We deployed an online survey to participants recruited using Amazon's Mechanical Turk (MTurk). MTurk is an online platform where "requesters" can post Human Intelligence Tasks (HITs) that workers can opt-in to complete. Data collected from MTurk has been successfully used for research in the area of human-computer interaction (HCI) [79, 259, 399, 477], although some care must be given to ensure that bots or negligent workers are excluded from consideration in the final analyses [226, 393]. Ethical approval for the study was provided by the ethics board of the University of Saskatchewan and all participants first provided informed consent.

As we were interested in recruiting MMORPG players, we first deployed a "screening" HIT, asking participants about the game genres they play. Participants who indicated they played MMORPGs were then assigned a "qualification" that would allow them to see the HIT for our survey. Participants were paid $3 USD for completing the survey, which took approximately 15 minutes to complete.

We recruited 181 participants (74 female, 107 male, 0 non-binary) aged 19–66 (mean=33.6, SD=8.7). One participant was not able to complete the questionnaire due to technical difficulties. We asked participants to check off whether they played particular popular MMORPG games, and found the most popular MMORPGs among our participants to be World of Warcraft (N=144), Final Fantasy XIV (N=92), The Elder Scrolls Online (N=81), Guild Wars 2 (N=81), and Final Fantasy 11 (N=60). To identify negligent participants (or bots) who did not answer the survey with consideration, we removed participants who moved through the questions very quickly (¡1.5 seconds per item, N=6) [80], leaving 174 participants in all subsequent analyses.

Measures

In addition to standard demographic information, we asked a variety of questions related to social anxiety and MMORPG motivations, preferences, and behaviours. As some of these scales were constructed for the purpose of this study, we describe them in detail.

Assessment of social anxiety: We used the self-report version [186, 232] of the LSAS [322], which estimates the severity of social anxiety. It consists of 24 items, measuring both fear and avoidance (separately) of a range of social situations, with instructions to consider experienced fear and anxiety over the past week. There are 11 items related to social interactions (SI) and 13 items linked to public performance (PP). Each item is rated on two 4-point Likert scales: the fear rating ranges from 0 (none) to 3 (severe) and the avoidance rating ranges from 0 (never; 0%) to 3 (usually; 68-100%). All scores are summed together.

Assessment of in-game social anxiety: As previous research showed, social anxiety may be experienced differently depending on the context of the social interaction [190], which leads to the concept of in-game social anxiety – anxiety experienced during social game contexts. While in other contexts, such as social

media usage [9], specialized assessments have been developed, there is no tool to measure the social anxiety experienced during MMORPG. To understand how social anxiety translates into the game world, we created a new scale of in-game social anxiety, basing its design on the LSAS. As LSAS focuses on the experience in the physical world, not all items could be directly translated into an MMORPG context. We reviewed the 24 items and classified them into three categories: the first category contained six items (5 SI and 1 PP), which could be used without further adjustments, such as "Participating in small groups". The second category consisted of 13 (4 SI and 9 PP) items, which required a recontextualization into the in-game world. For example, "Telephoning in public", was changed to "Talking in a group voice chat while gaming with other players". The last category contained five items (2 SI and 3 PP) items, which were not applicable to the digital world, due to their focus on being physically near others (e.g., "Drinking with others in public places"). We replaced these items with new items unrelated to the original LSAS items but containing typical situations players might fear in games, such as "Comparing your performance with that of other players (e.g., leaderboards)", and we kept the same proportion of SI and PP items. The instructions were changed to be clear that participants should rate how much they fear and avoid these situations in the game world of an MMORPG. Individual items in this Gaming Social Anxiety Scale (GSAS) can be seen in Table 2.1. As with the LSAS, each item was rated on two 4-point Likert scales: The fear rating ranges from 0 (none) to 3 (severe) and the avoidance rating ranges from 0 (never; 0%) to 3 (usually; 68-100%), and then all scores are summed. The GSAS showed high internal consistency (Cronbach's α =.978; Guttman λ-2 =.979).

Assessment of MMORPG enjoyment: To evaluate personal enjoyment of playing MMORPGs, we asked our participants to rate their enjoyment on a 5-pt scale (with 1= Not at All; 5=Very Much).

Assessment of reasons the game world: To determine the reasons that people play MMORPGs, we asked a set of questions. Four experts, each with a decade of experience in MMORPG play and games user research backgrounds, created 30 items intended to fit into seven categories of reasons why players play MMORPGs. After data collection, two items with low correlations to their intended scale were removed (e.g., "I feel less affected by what happens in an MMORPG than by what happens in the physical world" – Feelings of Safety). Table 2.2 describes the seven reason categories and their internal consistencies. Participants were instructed to rate, on a 5-point Likert scale, how often they have thoughts similar or equal to the presented item while playing an MMORPG, ranging from "Never" (1) to "All the time" (5).

Assessment of activities inside the game world: To investigate which activities players engage in within MMORPGs, we followed a similar approach to the one taken to characterize reasons. The same four experts determined six categories of frequent MMORPG activities and created 37 items to reflect typical examples of in-game activities. Participants were instructed to rate how likely they would be to engage in these activities while playing an MMORPG on a 5-point Likert scale ranging from "Very unlikely" (1) to "Very likely" (5). Three items (e.g., "Pay for an advantage or to make up for your shortcomings" – Low Challenge) were removed because of a low correlation with their intended scale. Table 2.2 describes the six categories of activity items and their internal consistencies.

Public Performance Items	Talking in a group voice chat while gaming with other players.
	Participating in small groups.
	Finding out that somebody on your team is streaming.
	Comparing your performance with that of other players (e.g. leader-boards).
	Performing a special task while other players rely on you.
	Being observed in the game world.
	Having someone in the game world watch you perform a task.
	Making a mistake in a raid.
	Losing connection during a group activity.
	Speaking up in a group.
	Contributing to an in-game group discussion.
	Trying to flirt with another player.
Social Interaction	Talking to people in authority
	Joining a group of other players in a fun activity in the open world (e.g. dance parties).
	Contacting another player, you don't know well.
	Talking with people you don't know well.
	Meeting strangers.
	Being the center of of attention.
	Expressing a disagreement or disapproval to people you don't know very well.
	Starting or joining a voice chat to socialize.
	Joining a group where everyone already knows each other.
	Starting your own group or guild.
	Resisting a high-pressure recruitment.

Table 2.1: The Gaming Social Anxiety Scale (GSAS) items

Relative threat assessment: We asked participants to rate their relative anxiety in eight specific social interactions (e.g., "Someone criticizing your choices") between the physical world and the game world. They were asked to respond on a 50-pt slider ranging from "physical world" (-25) to "digital world" (25). We instructed participants to set the slider to the middle (0) if they were "equally anxious or non-anxious about both contexts". Individual items can be seen in Table 2.4.

2.3.5   Results

RQ0: In a sample of MMORPG players, what is the distribution of social anxiety?

Figure 2.1 shows the distribution of scores for the LSAS (Cronbach's α=.974: Guttman λ-2 =.976). People can be considered socially anxious if their score exceeds 30 and are likely to have generalized social anxiety disorder if their score exceeds 60, subject to clinical diagnosis [459]. Our score distribution reveals that our sample did include many MMORPG players that experience social anxiety.

						1 2 3 4 5
Reason	1	**Better World**	Feelings that the digital world is less broken and makes more sense than the physical world.	"In an MMORPG, social structures make more sense to me than those in the physical world."	4 items α=.837	
	2	**Easy Exit**	Thoughts about how easy it is to quit or withdraw from the game environment when it is becoming unpleasant.	"If anything goes wrong in an MMORPG, I can easily quit and be done with it."	4 items α=.744	
	3	**Content Volition**	Appreciation that less interesting or fun game content can be easily ignored.	"In an MMORPG, I can avoid activities that I don't like."	2 items α=.749	
	4	**Feelings of Safety**	Security that social interactions in the digital world feel safer, for example because 'ignore' buttons exist.	"In an MMORPG, I feel less judged by others than in the physical world."	8 items α=.899	
	5	**Self-Worth**	Higher feelings of competence and social competence in the digital than in the physical world.	"In an MMORPG, I feel more competent than I do in the physical world."	3 items α=.848	
	6	**Social Access**	Easier access to social interactions in the game world; Finding it easier to meet new people in-games.	"In an MMORPG, I can explore social interactions in a safe way."	4 items α=.800	
	7	**Transition**	The wish to take in-game friendships to another context by meeting physically or playing multiple games.	"I feel good about taking MMORPG friendships to an out-of-game context."	3 items α=.744	
Activity	8	**Advancement**	Completing activities to level or improve the in-game character, such as acquiring equipment or doing daily quests.	"Complete as many daily and weekly quests as possible."	3 items α=.722	
	9	**Collection**	Collecting vanity items that do not improve character strength, such as fashion, mounts, pets or achievements.	"Collect outfits and accessories for your avatar."	6 items α=.823	
	10	**High Challenge**	Engaging in high challenge in-game activites, e.g., difficult raids and dungeons or PvP activities.	"Join a random group for a difficult dungeon."	5 items α=.778	
	11	**Low Challenge**	Engaging in easy activities such as completing low-level dungeons or solo activities where performance is not visible to others.	"Run old or lower level raids on your own."	6 items α=.743	
	12	**Social**	Chatting, guild socializing, or joining voice chats with other players.	"Chat privately with players you know very well."	10 items α=.862	
	13	**Narrative**	Immersing into the story of the game by obsessing over the lore or engaging in role-playing with others.	"Obsess over factions, the lore, and the story of the game."	3 items α=.514	

Table 2.2: Descriptions and example items for each of 13 reasons and activity categories. Item count, Cronbach's α, means, and ± standard error bars.
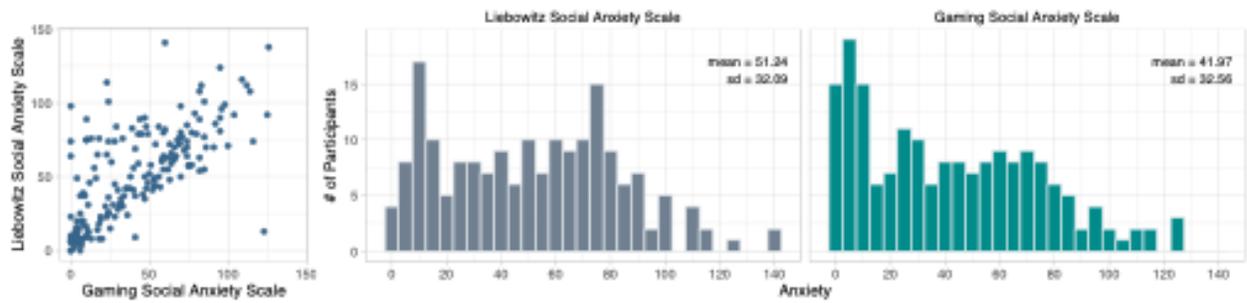
Figure 2.1: Social Anxiety Score (LSAS) and In-Game Social Anxiety Score (GSAS) and the relationship between booth scores (left).

RQ1: In MMORPG players, is there an expression of in-game social anxiety?

Our research is partly motivated by not knowing whether social anxiety is experienced by players during interactions in the game world. Our in-game measure of social anxiety (GSAS, see Methods) suggests that people do experience in-game social anxiety. The distribution of GSAS scores (see Figure 2.1) is similar to that of LSAS, with some differences. Descriptively, we can see that the maximum scores are lower for in-game anxiety and that there are more participants who experience low levels of in-game anxiety (GSAS) in MMORPGs than in the physical world (LSAS).

RQ2: In a sample of MMORPG players, how does social anxiety within games and outside of games relate?

Although both social anxiety and in-game social anxiety were observed in our sample of players, a Pearson correlation between LSAS and GSAS is significant (r=.677, p¡.001), suggesting that the experience of social

	Better World			Easy Exit			Content Volition			Feelings of Safety			Self-Worth			Social Access			Transition			Advancement			Collection			High Challenge			Low Challenge			Social			Narrative		
	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p
LSAS	13.4	4.3	<.001	4.7	1.8	.075	4.6	1.6	.102	11.5	4.2	<.001	15.7	4.7	<.001	6.2	2.3	.022	2.6	0.9	.371	0.9	0.4	.719	2.3	0.9	.333	1.5	0.6	.576	2.4	1.0	.319	-2.1	1.0	.328	-0.2	0.1	.932
GSAS	3.5	1.1	.262	-0.4	1.5	.141	-3.1	1.1	.278	-0.3	0.1	.901	1.1	0.3	.747	-6.4	2.4	.019	-9.6	3.2	.001	-2.9	1.2	.243	0.0	0.0	.969	-11.6	4.4	<.001	-4.3	1.8	.073	-8.4	3.9	<.001	-0.7	0.2	.810
LSASxGSAS	-0.2	2.8	.006	0.0	0.2	.848	0.0	0.4	.675	-0.1	1.9	.059	-0.2	2.3	.023	0.0	0.4	.684	0.0	0.6	.535	0.0	2.2	.030	0.0	1.5	.130	0.0	1.5	.131	0.0	1.2	.219	0.0	0.1	.898	0.0	0.1	.910
R²	.252			.021			.016			.173			.233			.043			.076			.032			.024			.152			.023			.198			.001		
model p	<.001			.305			.438			<.001			<.001			.059			.004			.141			.247			<.001			.265			<.001			.981		

Table 2.3: The moderated regression models for the reasons and activity scales. Significant results are highlighted in bold and coloured. Explained variance for regression models (R^2) displayed are LSAS and GSAS, including the interaction.

anxiety in-game is significantly and positively associated with social anxiety out-of-game. However, the scatter plot and distributions shown in Figure 2.1 suggest that there are also people for whom social anxiety is high, but in-game social anxiety is low. Although there is a strong linear association between social anxiety expressed within and outside of games, Figure 2.1 shows a trend for players to rate their social anxiety out of game as higher than their in-game social anxiety. A paired-samples t-test confirms this difference ($t173=4.736$, p¡.001). We tested for heteroscedasticity by using the Breusch-Pagan test ($\chi^2 =.397$, df = 1, p=.528).

RQ3: For what reasons are players with social anxiety and in-game social anxiety playing MMORPGs?

To determine whether reasons for playing MMORPGs differ based on social anxiety, either within or outside of the game, we conducted moderated regressions predicting each of the Reasons subscales in the Methods Section by LSAS, and moderated by GSAS (i.e., y=Reason subscale, x=LSAS and m=GSAS); see Table 2.3 for results.

RQ3a: For what reasons are people with social anxiety playing MMORPGs? As seen in Table 2.3, LSAS significantly predicts agreement with the subscales of better world, feelings of safety, social access, and self-worth. In all cases, the beta value is positive—that is, higher ratings of social anxiety predict greater agreement with the reasons. This suggests that people with higher levels of social anxiety are more likely to report that the in-game world feels less broken or makes more sense to them than the physical world, that it makes them feel more secure to engage in social interactions, that they find it easier to connect with other players there, and that engaging with others in games elicits stronger feelings of competence. LSAS is not significantly associated with content volition or easy exit. This means that players with higher levels of social anxiety are no more or less likely to report that they play MMORPGs because they can decide what content they want to engage in and ignore the parts of the game they dislike. The same is true for reporting that it is easy for them to be done with a game if things go wrong. Socially anxious and non-socially anxious players are equally likely to report this as a reason for choosing this genre. It should be noted that the sample rated these two reasons highly, indicating that both are descriptively the strongest reasons to play MMORPGs for all players, regardless of social anxiety (see Table 2.3). Finally, LSAS was not significantly associated with transition, suggesting that players with higher levels of social anxiety are no more or less likely to report that they may transition in-game friendships into other contexts.
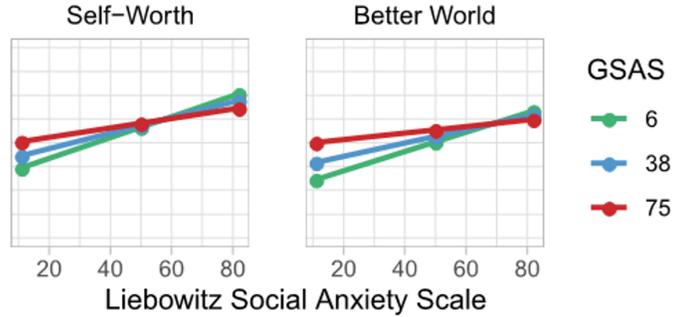
Figure 2.2: The moderation effects of LSAS on self-worth, and better world.

RQ3b: For what reasons are people with in-game social anxiety playing MMORPGs? As seen in Table 2.3, GSAS significantly predicts agreement with the subscales of social access and transition. In both cases, the beta value is negative—that is, higher ratings of in-game social anxiety predict lower agreement with the reasons. These results suggest that players with higher levels of in-game anxiety are less likely to report that they find it easier to connect with other people in the game world and they are also less likely to transition in-game friendships to an out-of-game context. There was no significant association with better world, easy exit, content volition, feelings of safety, or self-worth, suggesting that players with higher levels of in-game social anxiety are no more or less likely to report these reasons for choosing to play MMORPGs.

RQ3c: Does GSAS moderate the prediction of LSAS on reasons to play MMORPGs? As shown in Table 2.3, GSAS significantly moderated the prediction of LSAS on better world and self-worth. The other moderations were non-significant. These moderations follow the same pattern; that is, as reported in-game anxiety (GSAS) increases, it reduces and then nullifies the predictions of LSAS on the scales of better world and self-worth (see Figure 2.2). These results suggest that the demonstrated relationship between socially anxious participants feeling like the game is a better world and that they feel more competent is only true for people lower on in-game social anxiety. Using the Johnson-Neyman algorithm [260, 270], we can determine the inflection point of GSAS value at which the prediction of LSAS is no longer significant, which is 78 for self-worth and 69 for better world.

RQ4: In what kinds of MMORPG activities are players with in-game and out-of-game social anxiety engaging?

To determine whether activity preferences in MMORPGs differ based on social anxiety, either within or outside of the game, we conducted moderated regressions predicting each of the Activity subscales in the Methods Section by LSAS, and moderated by GSAS (i.e., y=Activity subscale, x=LSAS and m=GSAS); see Table 2.3 for results and Table 2.2 for overall means and standard deviations.

RQ4a: In what kinds of MMORPG activities are people with social anxiety engaging? As seen in Table 2.3, LSAS does not significantly predict agreement with any activities (advancement, collection, high-challenge, low-challenge, social, or narrative). We do not see any indication that the likelihood of

	Insulted for Performance			Insulted You			Making a Mistake			Interaction Gone Wrong			Choices Criticized			Judged for Performance			Performance Observed			Being Observed		
	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p	B	t	p
LSAS	-0.09	2.7	.008	-0.07	2.3	.023	-0.08	2.2	.028	-0.08	2.3	.020	-0.10	2.7	.008	-0.11	3.1	.003	-0.13	3.7	<.001	-0.10	2.7	.007
GSAS	0.06	1.7	.087	0.03	0.8	.426	0.04	1.3	.204	0.03	1.0	.314	0.07	2.0	.047	0.10	2.7	.008	0.11	3.2	.002	0.08	2.2	.029
LSASxGSAS	0.0	0.7	.511	0.0	1.0	.322	0.0	0.4	.723	0.0	0.08	.938	0.0	0.0	.989	0.0	0.7	.463	0.0	0.9	.355	0.0	0.4	.670
R²	.048			.044			.029			.035			.043			.056			.079			.049		
model p	.038			.053			.174			.104			.059			.021			.003			.037		

Table 2.4: Moderated regression models for the threat comparison between the physical and the game world. Lower values indicate higher threat experienced in the physical world. Significant results are displayed in bold and blue. Explained variance for regression models (R^2) displayed are LSAS and GSAS, including the interaction.

engaging in MMORPG activities is associated with social anxiety.

RQ4b: In what kinds of MMORPG activities are people with in-game social anxiety engaging? As seen in Table 2.3, GSAS significantly and negatively predicts social and high challenge activities. Although there was no prediction of out-of-game social anxiety on activities, when social anxiety also translates to in-game anxiety, these players become less likely to engage in challenging in-game activities, such as difficult dungeons or PvP content. The same is true for socializing in the game, which becomes less likely with increasing in-game anxiety. There were no significant predictions on advancement, collection, low challenge, or narrative activities, suggesting that players are not more or less likely to engage in these activities based on in-game social anxiety.

RQ4c. Does GSAS moderate the prediction of LSAS on MMORPG activities? As shown in Table 2.3, the only significant moderation was on advancement; however, the total model was not significant and neither GSAS not LSAS predicted advancing directly. Overall we can see that players do not differ in how they play MMORPGs (i.e., what activities they engage in), depending on their level of social anxiety and in-game anxiety when it comes to trying to improve their character (advancement); completing collections such as mounts, outfits for their character to wear, or achievements; engaging in the in-game narrative or role-playing; or engaging in less challenging in-game content (low challenge) such as lower-level dungeons. Descriptively, players are likely to engage in these activities (see Table 2.3), regardless of experienced anxiety. Improving their character and collecting seem to be the most popular in-game activities out of those that we asked about.

RQ5: Does social anxiety or in-game anxiety predict how threatening events in the game world are as compared to the physical world?

We asked players how threatening certain events are to them in the physical world relative to the game world. To determine how threatening MMORPGs are based on social anxiety, either within or outside of the game, we conducted moderated regressions predicting relative threat assessment by LSAS, and moderated by GSAS (i.e., y=Threat slider, x=LSAS and m=GSAS); see Table 2.4 for results. See Table 2.3 for overall means and standard deviations.

RQ5a: How do players with social anxiety perceive the threat of the game world as compared to the physical world? As seen in Table 2.4, LSAS significantly predicts greater agreement that all the events we asked about are less threatening in the game world than in the physical world. This includes being insulted or judged for their performance, being observed by others, making mistakes, performing in front of others, having a social interaction go wrong, as well as being insulted for who they are, and for choices they make.

RQ5b: How do players with in-game anxiety perceive the threat of the game world as compared to the physical world? As seen in Table 2.4, GSAS significantly predicts greater agreement that some of the events that we asked about are less threatening in the physical world than in the game world, including being judged for their performance, being observed by others, performing in front of others, and being insulted for the choices they make. This does not mean that they rate the game world as more threatening than the physical world but it means they are leaning less strongly into this direction than players without in-game anxiety.

RQ5c. Does GSAS moderate the prediction of LSAS on the threat of the game world as compared to the physical world? As seen in Table 2.4, there were no significant moderations, between GSAS and LSAS on the perception of how threatening situations are in the physical or game world.

RQ6: Does social anxiety or in-game anxiety predict MMORPG enjoyment?

To determine how enjoyable MMORPGs are based on social anxiety, either within or outside of the game, we conducted moderated regressions predicting enjoyment by LSAS, and moderated by GSAS (i.e., y=Enjoyment, x=LSAS and m=GSAS); the overall model was not significant ($r2=0.003$, $p=.906$). **RQ6a: Does LSAS predict MMORPG enjoyment?** Social anxiety does not predict how likely players are to enjoy MMORPGs ($B¡.001$, $t=0.4$, $p=.708$). **RQ6b: Does GSAS predict MMORPG enjoyment?** In-game anxiety does not predict the enjoyment of MMORPGs ($B¡-.001$, $t=0.4$, $p=.689$). **RQ6c: Does GSAS moderate the prediction of LSAS on MMORPG enjoyment?** There was no moderation ($B¡.001$, $t=0.7$, $p=.490$).

Overall, there were no differences in MMORPG enjoyment ratings depending on social anxiety, either in-game or in the physical world; however, we also found enjoyment to be subject to a ceiling effect. On a 5-pt scale, the mean rating was 4.78 (SD=0.68). Over 80% of our participants rated their enjoyment as a '5' with an additional 15% rating it as a '4'. This is not surprising as we specifically recruited MMORPG players, but it does confirm that they enjoy playing, and their rating does not depend on experienced social anxiety, either experienced in game or outside of games.

2.3.6 Discussion

Summary of results

We investigated how social anxiety translates to the in-game world of an MMORPG, as well as why socially anxious players choose to play these games and which activities they engage in. We found the following results:

- **RQ0:** We confirmed that our sample of MMORPG players experiences various levels of social anxiety.

- **RQ1:** We see that many players express social anxiety in the game world (GSAS) as well as in the physical world (LSAS), although the scores for in-game social anxiety are lower than for physical-world social anxiety.

- **RQ2:** We find that in-game social anxiety is positively associated with physical-world social anxiety and highly correlated. Additionally, we identified that there are some people who experience physical-world social anxiety, but experience low levels of game-world social anxiety.

- **RQ3:** We find that players with physical-world social anxiety tend to think that the game-world makes more sense and feels safer, view in-game social interaction as more accessible, and perceive a greater sense of self-worth. Players with in-game social anxiety tend to agree less that the game is socially accessible, and are less interested in taking their game relationships to other contexts. In-game social anxiety moderates the effect of social anxiety on self-worth and better world.

- **RQ4:** We find that physical-world social anxiety does not predict any in-game activity preferences, but that players who experience game-world social anxiety are less likely to participate in high-challenge and social activities.

- **RQ5:** We find that physical-world social anxiety predicts greater agreement that events in the physical world are more anxiety-inducing than the same events in the digital world. However, game-world social anxiety predicted less strong agreement that some physical-world events are less anxiety-inducing in the physical world than the digital world (i.e., being judged for their performance, being observed by others, performing in front of others, and being insulted for the choices they make).

- **RQ6:** We saw no differences in the enjoyment of MMORPGs for either type of social anxiety, but overall enjoyment of MMORPGs was very high.

Overall, we find that anxiety in the physical world is different from anxiety in games. It is possible to have players with different anxiety levels in different contexts. Players who experience physical-world social anxiety seem to view MMORPGs as a positive experience, for example, when it comes to socializing, and their in-game activities are not significantly different than their non-anxious peers. However, if the player also experiences anxiety in the game world, then their experience suffers. They do not find social interactions

in the game-world to be as accessible as other players report them to be and they are more likely to avoid high-challenge activities. Despite this, they still very much enjoy the game.

Explanation of findings

As seen in the results, the effects of social anxiety can carry from the physical world to the in-game world: Socially anxious players show similar patterns in-game as in the physical world, such as being more likely to avoid challenging activities and situations with the potential of being evaluated by others than non-anxious players. This behaviour is not surprising, as MMORPG environments can be very social and stable [56] and therefore reputation can matter. Not being perceived as a skilled player by others can lead to expulsion from elite raid groups or guilds. Despite these pressures, there are players with social anxiety who do not experience social fears in the game world to the same extent that they do in the physical world. This discrepancy may be due to the unique features of the MMORPG. Unlike other game genres, MMORPGs expand beyond challenging activities and give players options (e.g., mini-games or small group activities) that are not associated with performance pressure. Additionally, we found that all players, regardless of social anxiety, found the game world less threatening than the physical world. Furthermore, while previous work [123] argues that socially anxious players regard the in-game world to be a safe place, this is only true in part: Players with low in-game social anxiety do use the game to socialize and to express themselves, but on the other hand, players with high in-game social anxiety are less likely to socialize and engage in challenging activities. However, even though they may avoid these activities, they still enjoy the game. This may be due to alternative activities for players to engage in that require less social interaction or do not demand a high level of performance from the player. It might also be because even though they experience anxiety to some extent within the context of a game, it is still less threatening to them than how they experience the physical world.

Implications for design

We structure our discussion through three lenses: Game design, problematic game usage, and mental health.

The Lens of game design Games are designed to evoke various emotions [74], depending on genre and design intent. Likewise, games can be designed to avoid certain emotions, such as frustration or boredom, or to carefully balance between frustration and boredom to achieve a game that is "pleasantly frustrating" [194]. For social games, at a minimum, designers are concerned with ensuring that social interactions are not toxic. While negative interactions may be part of the challenge (e.g., being killed by another player in PvP), those negative experiences should not be accompanied by feelings of social exclusion, harassment, or bullying. Differences in experienced in-game social anxiety make this goal even more significant, as socially anxious players are at high risk of becoming victims of cyberbullying or being socially excluded in the game [120]. Because social anxiety can significantly change how people respond to social interactions [275], players with in-game social anxiety seem to play the game differently than non-anxious players. Game designers can

increase the accessibility of their game by addressing the needs of this user group; for example, by giving players more tools to manage in-game social interactions, preventing toxic behaviours, and creating a more welcoming experience in the game, with a less strong focus on performance that is visible to other players. In games we often find a meritocracy, where players face toxicity for making a mistake while performing in front of others [262]. Game designers must find a balance between allowing players to freely socialize and associate with others and test their skill, while also protecting vulnerable players.

Communication is also an important component of in-game performance. For example, it is crucial for coordination between teammates (e.g., for dungeons or raids). Players of MMORPGs may want to participate in these activities but find it more difficult due to their social anxiety. One possible approach is to leverage in-game actions to automatically communicate important information to teammates [345, 513], instead of relying on chat commands. For example, a player's character could indicate via a special animation that they require support, without the player needing to explicitly chat with their teammates. This is common in some game genres like Multiplayer Online Battle Arena Games but not prevalent in MMORPGs.

Furthermore, game designers should think about the presentation of performance. As shown, socially anxious players avoid highly challenging tasks that could put them under the scrutiny of other gamers. As we expected when we created the activity items, difficult solo activities correlated highly with the scale of low challenge, while difficult duo activities correlated with the scale of high challenge. This indicates that players with social anxiety do not avoid difficult activities or challenges, but they seem to when their performance is visible to other players in those activities. Therefore, to decrease performance-based threat, game designs could decrease the visibility of player performance statistics or to allow players to opt out of being publicly displayed in those statistics or leaderboards in certain contexts. Previous work also suggests that the adjustment of such performance presentations may have a positive effect on player experience [79].

The Lens of Problematic Games Usage Previous research links problematic game usage to social anxiety, suggesting that players use in-game environments to replace social relationships [289, 496]. It was suggested, that the social interactions facilitated by MMORPGs are why players with social anxiety prefer this genre [123, 192, 395]. We found that these results need to be broken down further: While players with social anxiety in the physical world do socialize in-game, players with in-game social anxiety are more likely to avoid in-game social interaction and challenges. Despite this finding, these players still enjoy MMORPGs. These results show that for some players who are at risk of problematic game usage, there may be something other than in-game socializing that contributes to the appeal of MMORPGs. Continuing to understand the relationship between social anxiety and gameplay will help inform when games can be used to increase well-being of players suffering from social anxiety, and when play may be harmful.

The Lens of Mental Health There are various ways to treat social anxiety, including medication and therapy [341], such as cognitive-behavioral therapy (CBT). CBT uses cognitive strategies (e.g., restructuring thoughts, training attention) and behavioral strategies (e.g., exposure) to reduce the feelings and effects of social anxiety [234]. CBT is most effective when led by a therapist; however, many people with social

anxiety avoid seeking help, perhaps due to the inherently social tasks involved with this treatment type [31]. Researchers and clinicians have begun to explore the benefits of new technologies, such as immersive media [528] and also special game mechanics to supplement treatments for social anxiety [265]. In fact, Thorens et al. [510] identify MMORPGs as specifically appealing for health interventions, due to their various structural characteristics, such as the built-in social interactions, reward features, and never-ending nature. These game mechanics could become a helpful tool to improve exposure therapies for social anxiety [38].

2.3.7 Limitations and future research

Future research should investigate culturally diverse samples, such as Asian cultures, which are associated with different expressions of social anxiety [278]. A closer look at the differential effects for adolescents and research about the development and maintenance of social anxiety inside game-worlds is also warranted. Further, future research should compare the results of this study with other genres, such as First-Person Shooter (FPS) games or Multiplayer Online Battle Arena (MOBA) games, to help understand the effects of social anxiety inside of different game contexts.

2.3.8 Conclusion

Socializing is an important aspect of why people play games online [172]. Yet for some, socialization is difficult due to fear and anxiety around social interactions and performing in front of others [491]. We investigated this by creating a new measurement tool, the Gaming Social Anxiety Scale (GSAS) based on the gold standard for self-assessment of social anxiety [322], the Liebowitz Social Anxiety Scale (LSAS). We used these two tools alongside questionnaires that explored possible reasons for play, in-game activities players could engage in, and the relative threat of situations in the game world versus the physical world. Our work provides valuable insight into why and how players who experience social anxiety are choosing to play MMORPGs:

- We observed that players with physical-world social anxiety were likely to experience game-world social anxiety; however, there are players for whom social anxiety is high, but in-game social anxiety is low.

- We find that players with social anxiety find that it is easier to connect with others in game, perceive the game world as less broken, and are likely to feel more socially competent in MMORPGs than in the physical world.

- We further find that social anxiety does not predict player preferences for different activities, but that those with gaming social anxiety are more likely to avoid challenging content and social activities.

- We find that overall, players find events in the physical world to be more threatening than the same events in the digital world.

We establish the construct of in-game social anxiety, and develop a measurement tool. ¬¬¬By enabling game developers to identify and design for players with in-game social anxiety, we promote the development of

games that foster social inclusion through play.

2.4 The influence of customized avatars on the experiences of social anxiety in a gaming task

2.4.1 Research Questions

To better understand whether the usage of customized avatars on expected and experienced social anxiety, Manuscript 2 provides answers to the following research questions:

- **RQ 1:** Does customization affect the *expected* fear in a gaming task?

- **RQ 2:** Does customization affect the *experienced* fear in a gaming task?

- **RQ 3:** Does customization help prevent immediate habituation within repeated exposure?

2.4.2 Design Rationale

In order to answer these research questions, the employed task had to include a customization component and an activity in which participants may potentially experience social anxiety. Following prior work [145], we decided to adapt characteristics from the Trier social stress test (TSST) [10] and deploy it in a web-based application. In the original TSST, participants have to engage in a math task and present in front an audience of judges [10]. In order to create a relatable experience that has commonly been reported as anxiety-inducing, including for people with social anxiety, we decided to use the scenario of a grocery store, at which participants had to buy articles and had to solve a math riddle while being observed, which has been used in order to induce anxiety and stress to participants [184]. As the characteristics of social anxiety show, performing in front of others and the potential experience of being evaluated by others can cause anxiety [235]. To create a similar experience, we asked all participants to solve percentage riddles in a very narrow time window. Furthermore, to evoke the experience of social anxiety, also the social evaluation by others is an essential component. Therefore we added three characters in the scenario: The store clerk and two observing people standing next to the check out. Similar to the original, the clerk stayed neutral over the whole task while confronting the player with math riddles and asking the player to solve them while being observed by *"others"*. Finally, we also added the perception of negative evaluation by others: Whenever the player answered the riddle or was not able to answer it on time, the two observing NPCs showed angry facial expressions and rejecting gestures towards the player.

2.4.3 Steps towards the solution

Similar to Manuscript 1, Manuscript 2 used an online study conducted over Amazon's Mechanical Turk. Participants were instructed to perform our task four times. Before each round, we asked participants to rate

their expected fear. After each trial participants had to rate their experienced fear. In order to measure the effects of customized avatars we had two conditions: Participants had to either design a customized avatar or had to select a predefined avatar based on their prefered gender. We again assessed their trait social anxiety using the LSAS.

2.5 Manuscript 2: The Effects of Avatar Customization on the experience of Social Anxiety

2.5.1 Abstract

The treatment of social anxiety through digital exposure therapy is challenging due to the cognitive properties of social anxiety-individuals need to be fully engaged in the task and feel themselves represented in the social situation; however, avatar customization has been shown to increase both engagement and social presence. In this paper, we harness techniques used in commercial games, and investigate how customizing self-representation in a novel digital exposure task for social anxiety influences the experience of social threat. In an online experiment with 200 participants, participants either customized their avatar or were assigned a predefined avatar. Participants then controlled the avatar through a virtual shop, where they had to solve a math problem, while a simulated audience within the virtual world observed them and negatively judged their performance. Our findings show that we can stimulate the fear of evaluation by others in our task, that fear is driven primarily by trait social anxiety, and that this relationship is strengthened for people higher in trait social anxiety. We provide new insights into the effects of customization in a novel therapeutic context, and embed the discussion of avatar customization into related work in social anxiety and human-computer interaction.

2.5.2 Introduction

Social anxiety is characterized by the fear of being evaluated by others [376], which pushes affected individuals to avoid or withdraw from social interactions, and leads to elevated stress when social interactions are not avoided [13, 491]. However, the fear of evaluation within social situations stands in opposition to the universal human need to form and maintain meaningful relationships [457, 507]. Social anxiety is one of the most common mental illnesses and is highly prevalent world-wide [188, 493], especially affecting children and adolescents [256, 415]. Given the social inhibition and withdrawal of affected individuals, social anxiety symptoms are often mistaken for shyness by others or perceived as a character flaw by the individual [419]. Furthermore, due to the characteristic fear of negative or positive evaluation by others, individuals with social anxiety may avoid consulting mental health workers about their concerns [311]. Prior work shows that only 35% of individuals who are affected by social anxiety receive treatment [454]. Besides the challenges of the mental illness, other barriers [301], such as sociocultural (e.g., discrimination of mental health problems) [18], economic (e.g., lack of financial coverage for mental health interventions) [136], or geographical barriers (e.g., limited access in remote communities) [93] may lower the accessibility of treatment and interventions.

A large body of literature supports cognitive behavioral therapy (CBT) as an effective nonpharmacological treatment for social anxiety [19, 234, 341]. CBT includes different components in sessions guided by a therapist (e.g., psychoeducation, cognitive restructuring) as well as self-guided assignments (e.g., worksheets and homework exercises) for the patient. One central treatment component of CBT for social anxiety is controlled exposure [181], in which the patient faces feared stimuli in a safe environment to challenge their thoughts about the stimulus and to train less maladaptive behaviour [446]. Through different exposure techniques, such as "in vivo" exposure (e.g., roleplaying with the therapist) or "in virtuo" approaches, such as using immersive virtual reality [87, 104], the patient interacts with the feared object (e.g., a spider) or in a simulated context (e.g., a social encounter). Exposure therapy is thought to help the patient in several ways, including through habituation (decrease the reaction to feared stimuli), extinction (weakening of previously learned assumptions about the stimuli), self-efficacy (training how to behave in an encounter with the feared stimuli), and improved emotional processing (gaining new beliefs about feared stimuli) [519]. Digital exposure therapies are a particularly promising technology to tackle the rising need for the treatment of anxieties and phobias, as they offer equitable access, regardless of geography or income, can be tailored for individual patients, and scale better in terms of needs than in vivo exposure therapies [528].

Although virtual exposure therapies have been shown effective at treating a variety of anxiety disorders and phobias (e.g., arachnophobia, fear of heights, agoraphobia, claustrophobia [76, 77, 156, 479]), social anxiety may be more challenging to treat with in virtuo exposure using digital technologies. Cognitive models of social anxiety suggest that an effective exposure needs to simulate an audience, the perception of negative evaluation by an audience, and the perception that it is the patient themselves who is being evaluated. However, the feeling of being evaluated by others can be difficult to achieve in a digital simulation, because participants may not be completely immersed or believe in the simulated content. Prior work shows that the behaviour

of the simulated audience is more essential than the visual representation [409, 484]. However, the accurate simulation of these behaviours may become a challenge within the development of digital interventions due to the more complex nature of the simulation (e.g., a convincing implementation of a rejection gesture or facial expression). To be effective, an exposure therapy for social anxiety must completely engage the patient, capturing their focus [183] and engaging them enough to invoke increased arousal and anxiety [235]. Because exposure is an uncomfortable experience, patients sometimes cope by cognitively disengaging, diverting their attention, or distracting themselves [235]. As such, an exposure task must maintain the patient's attention and focus over the duration of the exposure [544], perhaps by being sufficiently engaging, attentionally demanding, or through mechanisms that increase their investment in the experience. Further, the exposure needs to remain salient for long enough to support cognitive reframing (via habituation, extinction, self-efficacy, or emotional processing). Finally, the user needs to repeatedly feel as if they are being actively judged, which can be difficult to achieve in a system where they are represented by an avatar and other participants are simply virtual representations.

Video games are digital contexts in which players are often represented in the world by an avatar, and in which their interactions with the environment and with other players and non-player characters in the environment often generate emotional responses (e.g. [124]), physiological responses (e.g., [331]), and social interactions (e.g., [250, 294]) that are as intense and real as those that take place in the physical world. Games are known to capture attention [458] through cognitive, emotional, physical, and social demands [82]. Further, previous work has shown that harnessing the game-based technique of avatar customization is one way to increase engagement with a system: avatar customization has been shown to increase identification with the avatar (and resulting engagement with the system) not only in digital games [325], but also in serious games [51], and in therapeutic scenarios [61]. In the context of social anxiety, customization may elevate the experience of fear in a social simulation that involves performance and potential judgement from others. The inner conflict between the mental self-representation and perceived social norms may be intensified through an elaborated self-representation, which would justify how an audience evaluates not only the person's performance, but also the appearance or characteristics of the avatar. Early evidence within the context of virtual reality simulations, in which the face of participants was mapped onto an avatar, showed that individuals experienced higher levels of social anxiety if they saw a character with a mapped photo of their face as the facial texture [25]. However, systems for large-scale exposure therapy may not be able to represent the participant at a high fidelity, so the question remains: *Does customization of self-representation increase expected and experienced fear within an in virtuo digital exposure task for social anxiety?*

In this paper, we conducted an online experiment with 200 participants in which participants had to complete a task inducing social stress. In four trials, participants controlled an avatar through a virtual shop. In this shop, they had to solve a math problem at the checkout counter, while a simulated audience within the virtual world observed them and negatively judged their performance. Before the exposure, we randomly assigned participants into two groups: one with predefined avatars and one in which they were

asked to design their own avatar representation using a customization tool. We estimated the participant's level of social anxiety using the Liebowitz Social Anxiety Scale (LSAS), a commonly used tool for subjectively assessing social anxiety in the clinical context, and we measured both the subjective expected and experienced fear score for each of the four repeated exposures. Further, we used the Player-Identification Scale (PIS) to measure the participants' identification with their avatars and explored whether the customization amplifies the relationship between social anxiety and fear (both expected and experienced). We further explored whether customization helps prevent instant habituation within an immediately repeated exposure.

We show that we can stimulate the fear of evaluation by others in a digital task that is inspired by game interactions. Our results suggest that participants who customized their avatar experienced higher identification, and that the elevated levels of expected and experienced fear stemming from customization were driven by those participants highest in trait social anxiety. Additionally, we show that the level of stimulated fear corresponds with trait social anxiety, and that this relationship between trait social anxiety and fear is amplified for those who used customized avatars as opposed to predefined avatars. We further inspected the changes in experienced fear over repeated iterations and found that customized avatars may help maintain fear over multiple exposures, although longer-term studies are needed. We discuss potential explanations of why avatar customization increases the manifestation of social anxiety in a web-based exposure, and how this may benefit digital exposure therapies for social anxiety. Additionally, we contribute suggestions on how customization may be applied in a gradual exposure to increase the efficacy of an exposure therapy while lowering entrance barricades (e.g. fear of being overwhelmed by the procedure [445]) to the exposure therapy,

Through this paper, we contribute evidence that customizing avatars can amplify the experience of fear in a digital game-like exposure—a necessary condition for efficacy in the development of a virtual therapy to treat social anxiety.

2.5.3 Related work

This research analyses whether the player's representation affects the experience of social anxiety within digital applications, which may be an essential component in the development of digital interventions.

Characteristics of social anxiety

One of the defining characteristics of social anxiety is the fear of social interactions due to the exposure to potential scrutiny from others [470, 284, 235]. As a consequence, socially-anxious individuals withdraw from these fear-inducing social interactions, sometimes accompanied by physical symptoms such as blushing, heavily trembling, or sweating [3]. With a prevalence of 2.0 % [175, 176] in the general population, social anxiety is one of the most prevalent anxiety disorders. The severity of social anxiety is best expressed on a severity continuum where one can experience a high degree of social anxiety but not reach the threshold for a clinical diagnosis [491]. Individual factors (e.g., genetics, temperament and cultural background) and contextual factors (e.g., the social context and the physical environment) affect an individual's likelihood of

developing social anxiety. Due to the high variability of individual and contextual factors, the experience of social anxiety varies. A person might, for example, experience high levels of social anxiety only when presenting in an unfamiliar context (e.g., a talk at a conference), whereas the same person experiences less distress when presenting in a familiar environment (e.g., in front of family members).

Socially-anxious individuals face greater difficulties maintaining relationships with others [434]. Therefore, affected individuals tend to have fewer close friends [480, 529], and are at higher risk of being rejected by their peers. Furthermore, they may be at higher risk of being victimized by others due to the potential deficiencies in social competence [354]. Previous research emphasizes adolescence as a critical phase for the development of social anxiety [120]. If untreated, social anxiety follows a chronic and unremitting course through the lifespan. As a result, social anxious individuals may adapt coping strategies with known negative effects, such as substance abuse [531] and social withdrawal [542], or may develop clinical levels of social anxiety or comorbid mental disorders, such as depression [381, 494]. The harmful consequences of social anxiety also extend beyond the individual, due to a higher risk of unemployment [135] and absenteeism from work [164, 514] among the socially anxious, which may increase the financial dependency on public support systems [514]. However, due in part to the fear of evaluation by medical professionals, many socially-anxious individuals never seek treatment [136, 253, 311].

As previous work introduced, social anxiety is thought to be more cognitive in nature [235, 434, 436, 470] compared to other specific anxiety disorders, which are based in the interaction with either certain animals [75, 479] or physical aspects of the world, such as height or space [156, 422, 427]: Cognitive models of social anxiety [115, 235, 237, 470] depict this anxiety as a reaction to a mismatch between the individual's cognitive self-image, and the perceived expectations of the surrounding social context [235]. Socially-anxious individuals tend to overestimate the expectations of social observers and fear that they will not satisfy these high standards [241, 242]; biased by previous 'failures', they are quick to judge that a social interaction or performance in front of others will go poorly [90]. The effects of social anxiety are explained by emotional processing theory [183, 348], which describes dysfunctional fear as a memory network comprising information about the feared stimulus, the fear response, and propositions of meaning. This network can be (partly) activated by matching inputs, which results in an experience of fear. There are at least two activation paths explored: the perceptual (e.g., visual-fear-related cues) and the conceptual (i.e., fear-related information) path. Previous research [155] shows that patients with specific phobias (e.g., spider phobia) seem to be particularly sensitive to perceptual activations (e.g., seeing a spider), while socially-anxious individuals were not. Furthermore, cognitive models [115, 235] of social anxiety highlight several aspects for a successful exposure, which require information cues and perceptual cues. In these models, social anxiety is depicted as a reaction to a mismatch between the patient's own cognitive self-image, and the perceived social expectations of a given context. Socially-anxious individuals tend to be concerned with how they may fit into the existing context, rather than their own actual performance [69]. Therefore, the models suggest that an effective exposure needs to stimulate not only the perception of an audience but also the perception of negative or positive evaluation by others, depending on

the characteristics of social anxiety for a specific individual.

Digital interventions for social anxiety

Besides medication that reduces the symptoms of anxiety [341, 405, 553], cognitive behavioural therapy (CBT) has shown consistently positive effects on reducing symptoms of anxiety [341, 451, 489] and providing long-term relief for affected individuals [314]. In comparison to medication, psycho-social intervention strategies have fewer side-effects [341] and the likelihood of relapses because they teach patients flexible cognitive strategies. Exposure therapy in particular has shown consistent positive treatment effects and is considered one of the most efficient treatment strategies for anxiety [390]. Trained experts expose patients to either "in vivo" (e.g., roleplay) [536] or "in virtuo" (e.g., imagination) [111] anxiety-inducing situations, and guide patients to restructure their cognitive responses [206] and gain control over their physiological responses [225].

Although effective, CBT approaches face several limitations stemming from geographical restrictions and available resources but also the requirement for individualized content due to the characteristics of social anxiety (e.g., presenting in front of a large audience) [37]. Further, being with a mental health professional itself can become a stressful experience for socially-anxious individuals due to the fear of being negatively judged by the professional [253, 311]. Digital solutions have shown promise in lowering access barriers: immersive media, for example, allows patients to experience anxiety-inducing situations which the therapist can control and manipulate in virtuo, i.e., in virtual reality. Through immersive media, the experience reduces the cost [97] but also increases the patient's feeling of safety [104]. A similar option to deliver treatments are Internet-Mobile-based Interventions (IMI) [166, 263]. IMIs promise to lower barriers of access to interventions by offering anonymous, flexible, and effective treatment options. IMIs guide patients through experience either guided with a mental health professional or they offer unguided help to help patients with their anxiety symptoms [41]. However, research shows that while digital solutions are promising in research studies, the effects are diminished in the wild, because participants are not using technology as required, e.g., participants stop using the technology after a period of time [4, 174]. High levels of attrition undermine even the best designed approach, because participants simply do not use the intervention. However, intervention adherence, either digital or traditional, has been shown to be instrumental for the effectiveness of almost every intervention protocol, e.g., taking medication, following a diet, and/or executing lifestyle changes [461]. To combat attrition and to increase training adherence, designers rely on a variety of methods such as peer-support, and oral or written contracts [453]. Considering the interactive nature of IMIs, their potential to respond to individual differences [360], and their flexibility in protocol and presentation, IMIs show promising characteristics to help intervention designers combat attrition through design [62].

Several approaches for sustaining interest and engagement have shown promising results: notifications have increased the return of clients in the short-term [246] and interface design strategies based on game-based techniques have increased user engagement [324]. Prior research shows that the lack of personalization, interactivity, and support, increases the risk for attrition for mental health apps [11]. Due to their engaging

nature and the high potential to define interactive scenarios, video games and the use of game-design approaches within the intervention context have received attention by intervention designers [332].

To keep players engaged in the long-term and focused in the short-term, avatar customization has been shown to be a promising interface manipulation that reduces attrition in IMIs [62]. While positive results have been shown for increasing engagement in a variety of interventions (see next section), the use of customized avatars for improving exposure therapy for social anxiety has not yet been explored.

The positive effects of avatar customization

As previously introduced, the perception of being with other individuals is a key component for the experience of social anxiety. During exposure therapy patients are exposed, either in vivo or in virtuo, to a fear inducing situation with the goal to train less harmful responses as well as to help patients to restructure personal thoughts about the situation. Avatar customization promises three advantages over design strategies that assign an avatar to a patient. First, avatar customization increases identification with the avatar [62, 61], which may increase the perception that it is the patient themselves who is being evaluated [235]. The degree we are identifying with an avatar—commonly measured using the Player Identification Scale (PIS) [523] —is predictive of play experience [193, 319, 325], time spent in a game [61], and enjoyment [233]. The PIS measures similarity identification, wishful identification, and embodied identification—who we are and how we feel represented in a game influences our experience [53, 397].

Second, avatars can increase the experience of social presence, which is particularly relevant when designing IMIs focused on training resilience to situations known to trigger social anxiety [178]. Previous work on avatars and social presence suggests that dissimilar avatars reduce anxiety [25] compared to similar avatars. The implications of avatars on behaviours and attitudes in and outside of virtual worlds has been shown in several studies [283, 561], and a meta-study confirms small-to-medium effect sizes [437]. Avatars have been used to reduce anxiety, e.g., by destroying a carefully created "anxiety" avatar as an intervention [414] or to reduce speech anxiety [24]. On an individual level, avatars can model behaviour and represent different user-states well. In online environments, they fulfil an important role to foster a sense of presence for the "owner" of an avatar, but also provides affordances for other players to interact with the avatar "owner". In social contexts, avatars have been shown to increase presence and foster trust [47], and are valued by players for several social characteristics, including sociability and social communication [325]. Non-player characters, such as bystanders in games, affect our player experience and the believability of game worlds and contribute to the experience of presence in a game [307, 96, 28].

And third, avatar customization has the potential to increase momentary engagement [62], potentially improving the patient's attention and focus during the intervention [115, 183]. Avatar customization has been shown to increase task engagement, and the efficacy of digital tasks that benefit from momentary focus [62]. Previous work suggests that avatar customization increases the experience of acting under our own volition [472] and alters how we experience play [556], but that the experience of autonomy is mediated by

individual differences such as self-esteem [538]. Across studies, avatar customization has been shown to have positive effects on engagement with a task, which is relevant in studies that rely on participant engagement to investigate differential effects of design elements.

As shown, avatar customization may offer great potential in various directions for games but also for digital mental health interventions. However, prior work strongly emphasizes several aspects that designers need to be aware of in the process of creating avatar customization interfaces [342], such as the selection of gender, skin colour, the amount of customization, as well as to increase ways to create non-binary and diverse avatars [342, 343]. Furthermore, prior research highlights the overwhelming desire for more diversity within the self-representation in-game [191].

In the context of our study, avatar customization is the primary manipulation of the experience. By enabling participants to customize their avatar, we aim to intensify the experience of social anxiety within the exposure task. Furthermore, the representation of observers through non-player characters (NPCs) is also relevant, as bystanders increase social pressure and induce judgement from an audience.

2.5.4 Methods

Exposure task and experimental conditions

Avatar customization

Prior to the task, participants were randomly assigned (between-subjects) to either a Predefined Character or a Customized Character (see Figure 2.3):

Customized character: In this condition, participants could adjust the appearance of their avatar. Participants first selected the gender of their avatar (woman or man), then adjusted the height, weight, muscles, head offset, and breast size as well as the skin colour, eye colour, hairstyle (11 different styles per gender), and hair colour of their avatar. Due to technical limitation of the framework used for the character design process, a non-binary representation could not be created. Participants could then shape the head of their avatar via 34 sliders to define the shape of the face, eye, brows, nose, mouth, chin, jaw, ear, neck. Next, participants could choose the outfit of their avatar by choosing the style and colour of clothing on the upper body, lower body, and shoes, as well as through head accessories, such as glasses, headphones, or hats (13 different options per element). To further increase the player's identification with their avatar [523], we asked participants to set the personality of their avatar, by adjusting five 7-point Likert scales, which each described one personality trait, based on the 10-item short version of the Big Five Inventory (BFI-10) [428]. The 10 items were paired into 5 categories and participants had to choose between the elements (e.g., anxious versus calm).

Predefined character: In this condition, participants could choose the gender representation of their avatar. However, all other characteristics were pre-selected by the system to be as generic as possible (e.g., mid-tone hair colour, mid-tone skin colour, generic clothing, no accessories, mid-range slider values) and could not be customized. Average options were chosen to most broadly represent a range of people using a single predefined
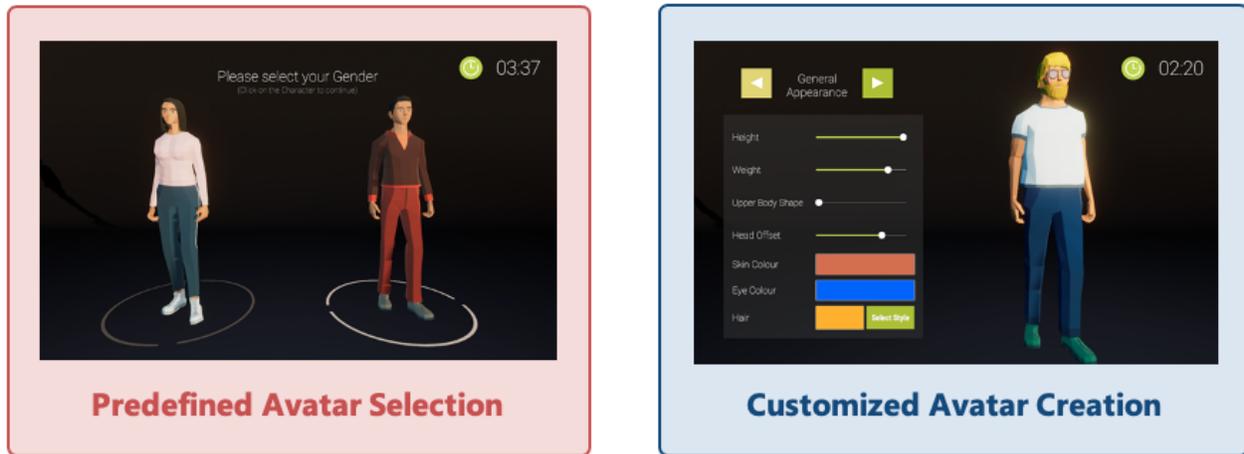
Figure 2.3: Avatar Creator User Interface for the Selection of Predefined (left) and Customization of Player's Avatar

character. Participants were asked to focus on the selected predefined character, once they were finished with the selection.

To make sure that exposure to the avatar did not bias results, both groups had to spend at least four minutes inside of the character creator. After four minutes, participants could move on to the next step of the experiment by clicking a button on the screen. In both avatar conditions, participants were asked to answer the Player Identification Scale (PIS) [523] to determine how much participants associated their avatar with themselves on three dimensions: Similarity, embodied, and wishful identification. Because there are limitations of the character creator to fully represent all people, such as the lack of a non-binary gender option and limited selection of headgear or hair styles, we gathered avatar identification to help explain variance when participants may have felt they were limited in their self-expression.

The shopping task (exposure) To create a relatable experience that has commonly been reported as anxiety inducing by people with social anxiety, we created a virtual grocery store and designed an interactive purchase scenario (Figure 2.4). This scenario is based on the Trier-Social-Stress-Test (TSST) in which participants have to present in front of an audience of judges [10]. Participants were instructed to go to the check-out of the store. Participants controlled their avatar using the keyboard (WASD or arrows), and the mouse to control the camera. The scenario featured three non-player characters (NPCs): the cashier, and two observing characters marked with "Observer" tagged with a random number to indicate different observers per round, as well as an icon indicating their emotional state (see Figure 2.4). The two observers were included to add an element of social evaluation to the exposure task, as potential social evaluation by others plays an essential role for the experience of fear. These observers were introduced as representations for other human observers, observing the participant through a text notification in the beginning as well as a separate screen, which indicates that external observers are joining the session. Prior work suggests that the social stress effect of being observed is also present with two instead of the three observers of the original TSST [161].

We decided to have participants virtually purchase a product associated with potential embarrassment
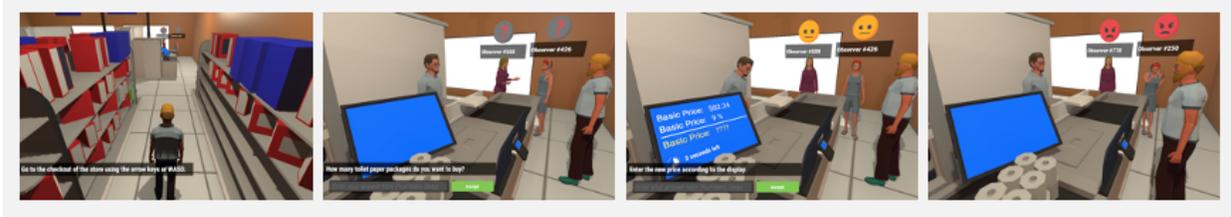
Figure 2.4: The four steps of the task (from left to right: Approach the situation; Introduction to problem; Math riddle; Exposure)

(toilet paper) [318] to foster a situation that would be likely to induce an experience of social anxiety. The players only interacted with the cashier. Once they approached the cashier (the toilet paper was visible at the checkout), a dialog would start:

Cashier: *"How many roles of toilet paper do you want to buy?"*

After answering the question with a number, the cashier names a price and offers a percentage discount that the player needs to calculate and respond to within 8 seconds.

Cashier: *"Thank you very much. That costs $ 86.45. But today we offer you a discount of 8%. Could you help me and name the price for your purchase?"*

During this interaction, the observers are visible, responsive, and are watching the participant complete the task. Similar to previous work, we selected a task to simulate the experience that participants have to perform a hard task in front of other individuals (the observers) [145, 421]. We chose a math task because math has shown to be relevant for our self-perception [113] and is a known source of performance-based anxiety [184]. We chose an 8-second window, as it was too short to use an external calculation tool, but long enough to be answerable.

While the calculation was chosen to be difficult, independent of the answer being correct or not, the player receives a negative response by the cashier and the NPCs after entering a number. The cashier shows no reaction to the player's performance and looks towards the player's avatar. The NPCs are facing each other while the player approaches, but both turn towards the player while they answer the math question and show a 5-second animation of disappointment once an answer has been given. The price and discount were randomly selected per trial.

In total, participants played through the shopping task four times. As previous work suggested [145], the four trials were included to evaluate how repeated exposure affects the experience of social anxiety in an online task, and to determine whether or not participants habituated to the exposure.

The task was implemented using Unity Engine [518] combined with the Asset-Bundle "Advanced People Pack 2" [315] and deployed using the Bride of Frankenstein framework [257]. The Advanced People Pack 2 offers prepared 3D-objects with blend-shapes, which allow to adjust the body shape (weight and muscularity) and the skin colour. These 3D objects are mapped either to the basic shape of either a female or male character. The characters implement blend-shapes as well to manipulate different features of the face. Based

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on these 3D assets, we created our character editors that allow for customization based on the previously introduced conditions.

Participants and procedure

We deployed our experiment to participants recruited using Amazon's Mechanical Turk (MTurk). MTurk is an online platform where Human Intelligence Tasks can be posted by requesters and workers can opt-in to complete them. Data collected from MTurk has been successfully used for different research projects in the human-computer interaction (HCI) community [147, 258, 400]. But this approach requires some special care to ensure that bots or negligent workers are removed from the final analysis [226]. Participants who were not able to perform a 3D interaction task on their computers, as well as those who abandoned the experiment were excluded from analysis. For this experiment, we used the cover story that the experiment aims to explore the effects of gamified elements in an immersive shopping experience. The cover story was used to reduce the risk that participants behaved differently (e.g. white coat hypertension [476]) as a result of knowing the goal of the study. This experiment as well as the usage of the cover story was approved by Ethics board of the University of Saskatchewan. The real intention of the study was revealed in the debrief of the study. Requesters can invite participants based on given filters on the MTurk platform, such as demographics, prior work experience as well as the used technology and custom filters (e.g., if participants participated in prior work). For this study we recruited participants, who indicate that they live either in Canada or the United States of America as well as have a high approval rate (95%) and successfully participated in at least 100 other tasks before.

We collected data from 213 participants. After removing suspected bots (n = 13), we conducted our analysis with the remaining 200 participants (72 woman, 126 men, 2 non-binary) aged 21-70 (M = 36.6, SD = 9.6). Participants were randomly assigned to either the "Predefined Character" condition, n = 102; or the "Customized Character" condition, n = 98 (See Table1 for further details). All participants received $6 compensation; the study took approximately 20 minutes to be completed.

After providing consent, participants were introduced to the cover story and had to answer several questionnaires to assess trait social anxiety as well as several questionnaires about the shopping preferences to distract users from the main goal of this study. After finishing the avatar creation/selection participants had to answer the Player Identification Scale (PIS) [523]. Following this, we introduced the controls and that external observers would evaluate the participants performance via a text tutorial. As prior introduced, we further emphasised the illusion of being watched by showing a loading screen that indicated a waiting period while observers were being connected to the current session with the participant. This screen lasted for 5 seconds before the tasks started. Four repeated trials of the shopping exposure task were conducted using randomized values for the percentage discount and the asked price. Expected fear was assessed prior to each trial and experienced fear was assessed directly following each trial. After the trials, demographic data were recorded and participants were debriefed about the false cover story and the real goal of this study. Then, we

provided additional support resources such as contact information to a crisis hot-line, and a link to pictures of baby animals to reduce the potential negative effect on participants.

Measures

Trait social anxiety: Participants answered the self-report version of the Liebowitz Social Anxiety Scale (LSAS) [29, 322]: The LSAS consists of 24 items divided into two subscales: social interactions (11 items) and public performance (13 items). The same items are then rated a 4-point scale for fear (0 = "none" to 3 = "severe") and avoidance (0 = "never/0 %" to 3 = "usually/68-100 %"). The sum of all scores is computed and the level of social anxiety defined between 0 and 144, where higher values indicate greater social anxiety. A threshold score of 30 distinguishes between non-anxious and anxious people while a score of 60 provides the best balance to classify between generalized and non-generalized social anxiety [459]. In our sample, LSAS scores ranged from 0 to 141 (M = 58.95, SD = 31.403) with an excellent internal consistency (Cronbach's-α = 0.97). LSAS was higher on average in our sample than in a study of 31,243 cross-cultural participants (M=44.07) [99] or in a study of 1007 UK college students (M=34.7) [455], but is in line with previous work examining a US MTurk sample (M=51.24) [147].

Avatar identification: We used the avatar-related subscales of similarity identification, embodied identification, and wishful identification from the Player Identification Scale (PIS) [523]. Participants rated their agreement to different statements such as "My Character is like me in many ways" on a 5-pt Likert Scale from 0 ("strongly disagree") to 4 ("strongly agree"). As previously introduced, avatar identification is an important aspect for the various effects of avatar customization [62, 325]. Internal consistency was excellent for all scales: similarity (Cronbach's-α = 0.93), embodied (Cronbach's-α = 0.94), and wishful (Cronbach's-α = 0.90) identification.

Expected and experienced fear ratings: We asked participants to rate their expected fear prior to being exposed to the shopping task using a single text field and the following prompt: "In the following scene you have to buy some groceries in a virtual shop. Other people will join you in this task and evaluate your performance. Please indicate on a scale from 0 (not at all) to 100 (very high level of fear) how much fear you feel in expectation of completing the described task.". Experienced fear was assessed after exposure to the Shopping Task, using the following prompt: "Please indicate on a scale from 0 (not at all) to 100 (very high level of fear) how much fear you actually felt in completing the task.".

Demographics: We gathered a variety of demographic factors, including: age, gender, income, marital status and ethnicity.

Data analyses

Data were gathered and stored using an on-premises server and then exported once data collection was complete. All data were analyzed using SPSS 26; moderated regressions used the Process 3.4 integration. Statistical tests are described prior to reporting the results.

Variable	Categories	Predefined Avatar						Customized Avatar					
		N	%	M	Sd	Min	Max	N	%	M	SD	Min	Max
Age		102		35.99	9.61	22	70	98		37.28	9.59	21	66
Gender	Woman	32	31.4					40	40.8				
	Men	69	67.6					57	58.2				
	Non-Binary	1	1.0					1	1.0				
LSAS Score		102		60.16	32.33	0	141	98		57.68	30.51	0	123
Similarity Identification		102		1.94	1	0	4	98		2.91	0.6	0.6	4
Embodied Identification		102		2.01	1.12	0	4	98		2.5	0.87	0	4
Wishful Identification		102		1.68	1.03	0	3.8	98		2.2	0.8	0.6	4

Table 2.5: Overview per condition of demographic information, LSAS, and PIS measurements.

2.5.5 Results

RQ0: Characterizing the Sample

We first looked to see whether random assignment to condition yielded differences between the groups. Independent-samples t-tests showed that there was no difference in terms of age (t198=.954, p=.341) or LSAS (t198=.558, p=.577). Both were slightly skewed in terms number of men (see 2.5) We control for age and gender in all subsequent analyses.

RQ1: Can We Confirm that Customization Increases Avatar Identification?

Based previous work (e.g., [53, 58, 397]) , we expected to see higher avatar identification among the group who were able to customize their avatar, as opposed to being assigned a predefined generic avatar. To confirm whether these effects appear in our sample we used a MANCOVA on similarity, wishful, and embodied Identification with avatar customization as a between-subjects factor and co-variates of age, gender, and LSAS, which was significant ($F_{3,193}$=26.0; p<.001, $_p\eta^2$=.29). Results showed that identification was higher for customized than predefined avatars in term of Similarity ($F_{1,195}$=68.3; p<.001, $_p\eta^2$.26), Wishful ($F_{1,195}$=22.9; p=.001, $p_p\eta^2$=.05), and Embodied ($F_{1,195}$=11.2; p<.001, $_p\eta^2$=.11) identification. This suggests that even though avatars were low-poly graphics, our avatar customization manipulation was successful at fostering identification among participants.

RQ2: Does Customization Amplify the Relationship between LSAS and Expected Fear?

We expected that participants who used a customized avatar would have a stronger relationship between LSAS and the fear that was expected prior to an exposure. A moderated regression with X=LSAS, Y=mean expected fear, W=dummy-coded condition (Customized=1, Predefined=-1), with continuous variables mean-centered, and controlling for age, gender, and the three forms of avatar identification shows a significant model (R2=.318, F8,191=11.1, p<.001). The significant effect of LSAS (β=.350,p<.001, LLCI=.232, ULCI=.468) shows that LSAS predicts expected fear. The effect of customization on prediction of expected fear is not significant
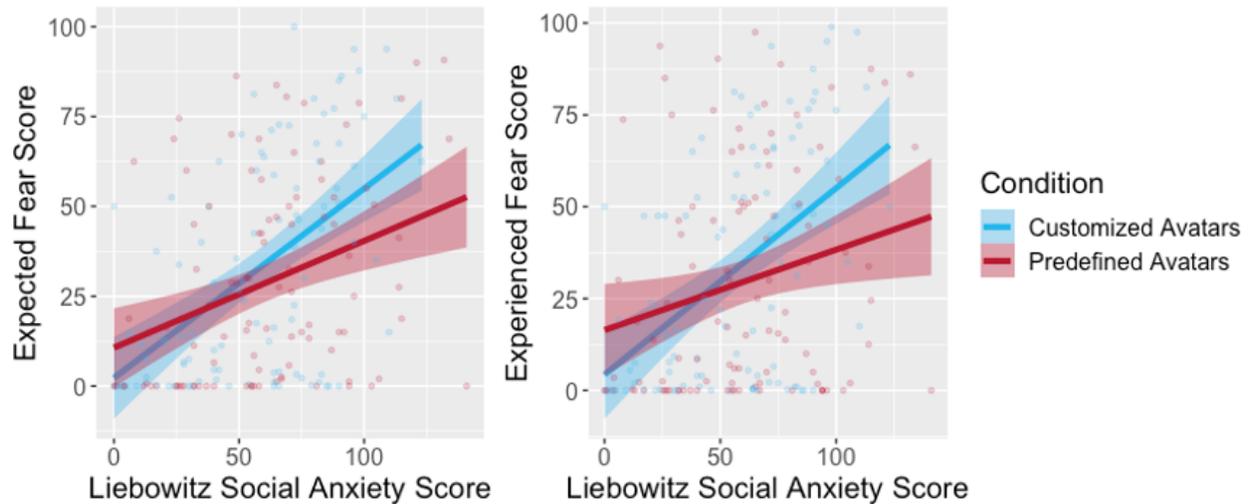
Figure 2.5: The comparison between predefined (red) and customized (blue) avatars for expected and experienced fear.

(β=-7.5, p=.059, LLCI=-15.3, ULCI=-0.3), suggesting that at mean LSAS, the increased fear from customizing fails to reach significance. However, the significant interaction of LSAS and customization on expected fear (β=.128, p=.026, LLCI=.016, ULCI=.241) suggests that the prediction of expected fear by LSAS depends on customization. The conditional effects show that the linear relationship between social anxiety and expected fear is larger for customized avatars (β=.479, p<.001, LLCI=.310, ULCI=.647) than for predefined avatars (β=.222, p=.006, LLCI=.065, ULCI=.379). Figure 2.5 shows these relationships.

RQ3: Does Customization Amplify the Relationship between LSAS and Experienced Fear?

We expected that participants who used a customized avatar would have a stronger relationship between LSAS and the fear that was experienced during an exposure. A moderated regression with X=LSAS, Y=mean experienced fear, W=dummy-coded condition (Customized=1, Predefined=-1), with continuous variables mean-centered, and controlling forage, gender, and the three forms of player-avatar identification shows a significant model(R2=.272, F8,191=8.92, p<.001). The significant effect of LSAS (β=.279, p<.001, LLCI=.150, ULCI=.409) shows that LSAS predicts experienced fear. The significant effect of customization on experienced fear (β=-10.1, p=.022, LLCI=-18.6, ULCI=-1.5) identifies that at mean LSAS, experienced fear is higher in the customized avatar condition than in the predefined avatar condition (because LSAS was mean-centered). The significant interaction of LSAS and customization on experienced fear (β=.153, p=.016, LLCI=.029, ULCI=.276) shows that the prediction of experienced fear by LSAS depends on customization. The conditional effects show that the linear relationship between social anxiety and experienced fear is larger for customized avatars (β=.432, p<.001, LLCI=.247, ULCI=.617) than for predefined avatars (β=.127, p=.150, LLCI=-.046, ULCI=.299), which does not reach significance. Figure 2.5 (right) shows these relationships.
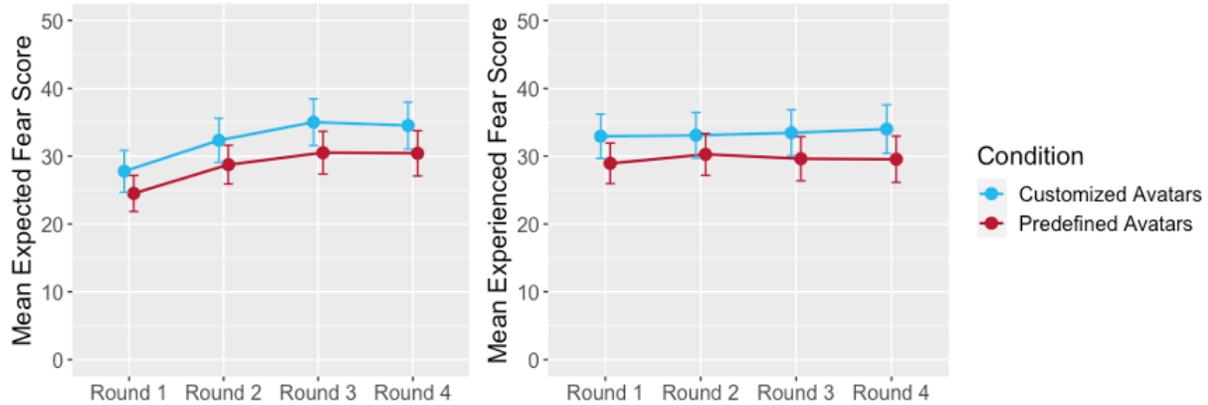
Figure 2.6: The mean score of expected and experienced fear over the four exposure rounds, for participants with LSAS >60 (threshold for elevated social anxiety [459]).

RQ4: Does customization help prevent immediate habituation within repeated exposure?

For digital exposure therapy to be a successful treatment, the virtual exposure needs to maintain its capacity to produce a fear response in people with that anxiety. That is, there cannot be instant and rapid habituation to the virtual stimuli; habituation happens over time through repeated exposure and cognitive restructuring (see Related Work). If habituation is instant, it implies that stimuli is failing to evoke a fear response, not that the treatment has been instantly successful. Figure 2.6 shows the mean expected fear response over each of the 4 iterations for participants with LSAS over 60 (the threshold used to indicate social anxiety [459]), whereas Figure 2.6 (right) shows the mean experienced fear over the four iterations for this same group. In all cases, there is not a rapid drop after the initial exposure. In terms of expected fear, both customized and predefined avatars follow the same trend with decreasing differences in fear from one iteration to the next. This suggests that participants are getting more comfortable with their expectation of fear from the exposure. In terms of experienced fear, the mean ratings for the group using customized avatars is monotonically increasing; however the mean ratings for the group using predefined avatars is decreasing over several iterations. Although preliminary, and based only on visual inspection, these results suggest that there is no instant habituation in either condition, or that customizing avatars may help maintain fear within the exposure over multiple iterations; however, more research is needed to systematically investigate fear responses over time.

2.5.6 Discussion

Summary of the results

In this study we evaluated the effects of avatar customization on the experience of social anxiety in a task that induces social stress. We found the following results:

- **RQ1:** Customization of the avatar results in increased feelings of similarity, wishful, and embodied identification in comparison to using a predefined avatar.

- **RQ2:** LSAS predicts expected fear scores; however, the strength of this prediction is larger when participants customized their avatar.

- **RQ3:** LSAS predicts experienced fear scores; however, the strength of this prediction only reaches significance when participants customized their avatar.

- **RQ4:** Preliminary evidence suggests that customized avatars may help maintain fear within the exposure over multiple sessions more effectively than with predefined avatars.

Overall, participants expected, and experienced, fear in this web-based exposure task for social anxiety. Furthermore, customizing the self-representation heightened the experience of fear, in particular for those higher in trait social anxiety. Also, visual inspection shows that the experience of social anxiety does not drop over time, suggesting that the sensation of fear may be maintained over multiple exposure trials.

In the following we provide potential explanations of why avatar customization increases the manifestation of social anxiety in a web-based exposure, and how this may benefit digital exposure therapies for social anxiety. We will give suggestions how customization may be applied in a gradual exposure to increase the efficacy of an exposure therapy while lowering the level of difficulty for the patient.

Explanation of the results

To explain our results, we need to consider the primary manipulation of our study, i.e., avatar customization, the designed context of our study, i.e., the Shopping Task, and the larger study context, i.e., MTurk, and finally, the interaction of all three contexts.

Avatar customization has been shown to increase the effects of online inductions before [61, 58], but not in the context of inducing social anxiety. Engagement with the task, explained through an increase in motivation due to social-contextual choice (customization) of the individual is one potential explanation [61]. However, another potential explanation of the increased experience of social anxiety is the heightened relevance of the task itself by feeling increased ownership over the task through having actively contributed to the design of a task element [264]. The increased motivation to engage with the task and the heightened task ownership, would suggest increased task focus, which is particularly relevant in the MTurk study context, in which participants are susceptible to distraction and attention-loss.

Our system featured the following elements that aimed to heighten participant responses to the task which likely played a role in the success of the task at eliciting fear and anxiety: Task Design. We included a number of general design considerations. First, the focus on performing in front of others, one of the commonly feared situations [169] while interacting with others. Through the repetition we ensured to distinct the experience of social anxiety from the experience of embarrassment [359]. Second, the usage of a third-person camera to display the player's avatar as a way to heighten self-awareness within the task, similar to the effects of a mirror in the physical world [195]. Audience Observers. As suggested by similar experiments [444, 145], the design of the simulated audience focused on providing a negative evaluation to further highlight the socially threatening

nature of the task. Prior research suggests, that the experience of social presence [178], the feeling that other individuals are within a digital interaction, plays an essential role for the experience of social anxiety in a virtual exposure. We intensified the experience of social presence through the illusion that actual observers are observing the participant through the description as well as the connection screen in the beginning of the exposure. Avatar Customization. Customization in itself is particularly effective in the context of social anxiety because customization reveals personal preferences, can be interpreted by others, and potentially results in the dreaded social rejection by others. Especially in online environments, customization is powerful because it is uncertain who really sees and evaluates our choices—e.g., is a negative response simulated or is it indeed the result of social observation and judgment, potentially even by many others [370].

Considering the distracting context of online crowd work, we show that a well-considered digital task, combined with a socially relevant manipulation of our digital representation has implications for our experience, and the potential to be foundational in designing future induction paradigms using avatar customizations.

The Explicit Influence of Customization: As our results show, character customization affects the subjective measurements of expected and experienced fear in a web-based exposure. Consistent with prior work [25], we saw that customized avatars increased the subjective ratings of expected and experienced fear. One explanation may be the identification with their own avatar: with a customized character, it is not only their own performance, but also their own design choices for their avatar that may be evaluated by others. Prior work in digital games shows that customizing an avatar increases overall player engagement and enjoyment of the game [523]. Furthermore, customization allows players to express themselves through their avatar while hiding personal flaws [556]. But as our results show, customization may also increase the personal concern that the audience may not only judge the user's performance, the main source for experiencing social anxiety, but also the user's appearance or self-expression through the avatar.

Current models about the experience of social anxiety [491, 235] offer a potential explanation. The dominant factor for the experience of social anxiety is the perception of an audience. We intensified this experience through our intervention design by representing a simulated audience (the judging characters at the other side of the counter) into the gaming context. These representations also always gave negative feedback to a highly challenging task. Through the contextualization of the game, where we mentioned that actual persons are watching the performance, the illusion of a potential audience was created. Our results show that participants with higher trait social anxiety gave higher fear ratings, which may suggest that this simulation of an evaluating audience was playing a role. As models of social anxiety suggest (see Related Work), once an audience is perceived, two major behaviours are triggered [116, 235, 501]. First, the individual scans the context for more social clues and potential social threats. These clues are used to model an image of oneself in the current context as well as the social expectations. In our experiment, the emotional indicators and the emotional response of the avatars satisfied this aspect, resulting in an elevated score of experienced as well as expected fear. Second, memories of past events are used to evaluate the current social context. Social anxiety arises from the mismatch of the expectation and the self-image of the individual [235, 526]. Through

the actual self-expression through an avatar, the individual reveals personal information about oneself. But previous work suggests that socially anxious individuals tend to avoid talking about oneself [195] and prefer anonymity in online communication [9, 134, 423]. However, the customized avatar may have reduced the anonymity in the context and led to an increased experience of social anxiety in comparison to predefined avatars, where no personal preferences are expressed through the avatar.

Our results suggest that an immersive web application has the potential to expose individuals to social anxiety threats, but that further studies are required to confirm and understand these effects. In our study, we show (in both conditions) that participants were responsive to the social threat, in degrees that were associated with their own trait social anxiety (see Figure 2.5), but that customized avatars heightened the exposure.

Implications for Design of Exposure Therapies

Our results provide insights into how to further enhance existing techniques for digital exposure, namely the platform, the scenario, and the self-representation:

As our results show, we were able to create an exposure through a game-related web-based interface. In comparison to existing virtual reality applications, the web application can be used without the need for expensive hardware. Our results suggest that interventions can be delivered on a computer platform and therefore allows therapists to choose a suitable solution for the needs of the patient. While one patient may require more immersive virtual reality solutions and an on-site training, others may not have the resources to set up immersive hardware but can access an intervention delivered online. However, in either case, exposure therapy should happen under the guidance of a mental health professional [405]. The digital accessibility of a system like ours should not automatically imply that self-guided treatment is effective. As an accessible "training exercise", exposure may be more harmful due to the lack of guidance helping patients to restructure their thoughts [206] and may in fact increase the salience of social threats.

But designers of interventions need to carefully craft the scenario and need to be aware of the representation of the participant. As our results show, the representation of the player affects the experience of social anxiety. Allowing the participant to customize the own representation may bias the experience of social anxiety. On one side, if participants customize their self-representation, they may experience elevated levels of social anxiety due to additional potential threats. But our results suggest that the inverted effect could be used as well—by giving a non-customizable avatar, the experience of social anxiety may be reduced. This can be helpful in the beginning of an exposure; guidelines for exposure therapy note that a slow increase of the level of potential social threats is a helpful strategy to balance the efficacy of the exposure with the potential risks of withdraw from the patient [111]. Using non-customized characters may allow participants to explore different, predefined roles, as prior research shows that individuals maintain self-perception and skills obtained through a digital persona even beyond the game [561, 55]. This effect is referred as the "Proteus Effect" [561]. After gaining resilience through exploring another perspective of a scene, individuals may enable a

customized avatar to map the gained insights from being another person into the "own" body. Through the customization of the avatar, the individual may not only experience a more intense experience, but also feel more committed to the intervention. As prior work shows, customized avatars increased the user's motivation and persistence, but also performance and overall satisfaction [216, 438]. Furthermore, the customization increased the invested effort in the short-term [62]. These aspects may further help to tackle attrition in digital interventions.

Ethical considerations

While internet and mobile based interventions may increase the accessibility of treatment, this increased access also raises several issues. As prior work suggests, cognitive behavioural therapies aim to restructure the patient's own thoughts and behaviours to increase resilience towards a feared stimulus [19, 390]. While exposure is a powerful tool it can become overwhelming for users to successfully complete the intervention [445]. As earlier work shows, both patients and mental health professionals tend to avoid exposure therapies due to the elevated stress for the patient and the clinician. By lowering the barriers to access, one must ensure that the exposure to social threat does not become harmful for patients or clinicians. Further, earlier work suggests that the combination of exposure with cognitive restructuring techniques is a more effective approach [35]. Instead of only exposing and training patients how to behave in the feared situation, the individual reflects on the experienced situation, provoked thoughts, and their behaviours, and may practice behaviour strategies, such as avoiding using safety behaviours. Finally, previous research suggests that CBT approaches may be an effective tool, but not for every patient. Other techniques may still be helpful, such as the usage of medication may be helpful for patients which cannot bear the challenges of CBT techniques.

When implementing a digital intervention that leverages digital data, designers must always be aware of ethical considerations such as inferring identity of the user, the secure handling personal data, and the communication of very personal information with the users and how the intervention may affect not only the patient but also their social connections. The protection of the privacy of the patient, ensuring a safe space in which to play, and the legality of gathering data unobtrusively are also important aspects to be considered [335]. The use of data derived from digital sources is part of a growing discussion [182, 274, 353, 361]. Prior work emphasizes the importance of the therapeutic relationship between the therapist and the patient for the success of the intervention. Therefore, designers need to make sure that the proposed solution can be only accessed within a safe space for the therapist and the patient [146, 558].

Overall, the use of internet-based interventions should be seen as an additional tool, which can address some shortcomings of existing solutions by lowering barriers, such as cost, distribution, and availability. But like other interventions, this approach needs to be used with the support of a therapist, who can help the individual to restructure their own thoughts and behaviour to grow resilient against social anxiety.

Limitations and future research

There are several limitations to the interpretation of our results that can be addressed by future work. First, our evaluation analyzed only the effects of one session with four trials. However, exposure techniques require repetition over multiple sessions with different stimuli [478, 555], and potentially personalization to individual factors that trigger social anxiety through more adaptable scenarios [405], such as giving a talk at a conference. Second, we only exposed individuals to the stimuli but did not try to restructure their own thoughts about the experienced situation. Future work may include this approach in a clinical trial, combined with restructuring exercises in a long-term study. Third, we only measured the subjective score of expected as well as experienced social anxiety. Future work may leverage the measurement of physiological data, such as heart rate or galvanic skin response (e.g., [253, 350, 304, 299]) to gain more insights about the experience of social anxiety in the exposure as well as additional measurement tools for trait social anxiety. Fourth, the avatar customizing tool did not provide sufficient options to equally represent different people. Due to the underlying software architecture, participants chose a binary gender as a starting point; however, there were two non-binary participants in our sample. Although options could be adjusted (e.g., facial hair, breast size), the pre-defined avatars were limited in this regard. Further, the technical aspects of the system could not represent what may be felt as defining characteristics for a participant, such as curly hair or freckled skin. These technical limitations as well as the selected graphical low poly style may also explain the overall low-to-neutral scoring on the Player Identification Scale in the Predefined Avatar condition and the neutral-to-above-neutral scores in the Customized Avatar condition (See Table1 for results). Fifth, we only used one standardized questionnaire (LSAS) to assess the trait social anxiety. Although standard in clinical assessment, the LSAS is generally combined with interviews, observation, and interaction with the patient's social circle to effectively assess the presence and degree of social anxiety. Sixth, the sample: while our contribution shows that avatar customization may be more influential for individuals higher in social anxiety, future work may focus only on socially anxious individuals and explore additional aspects of customizing the avatar (e.g., the effects of experiencing anonymity with customized avatars). Seventh, the engagement with their own character: While participants in the customized avatar condition were allowed to craft their character for four minutes, participants with predefined avatars were asked to focus for 4 minutes on their selection. This may form a gap between the conditions, as participants engaged more with their character while creating a customized version in comparison to the predefined avatar selection, where players were asked to look at the selected figure instead of interacting with it. As previously explained, the missing interaction with the avatar may affect how players connect to their avatar, which may in turn cause the reduced experience of social anxiety within the game. Future work may use a more equally engaging approach for both conditions, to investigate the effects of engagement with their own avatar on the experience of social anxiety within games.

Through our research, future researchers may further enhance existing exposure techniques to support existing interventions. By altering and expanding on an existing technique, future researcher may tweak the representation of the surrounding environment, for example the representation of the audience, the clerk, or

the environment.

2.5.7 Conclusion

Cognitive behavioral therapies (CBT) in general, and exposure therapy in particular, are effective nonpharmacological treatments for social anxiety [341]. However, digital implementations of existing exposures must stimulate the experience of an audience and the judgement of this audience, but also need to ensure that the individual with social anxiety experiences social threat. One way to foster this threat is the use of a customized avatar. In this study we explored whether the customization of avatars affects the experience of fear in a social stress task among participants with varying levels of social anxiety. Our results show that the experience of fear is mainly driven by trait social anxiety. However, we found that the effects of trait social anxiety on expected and experienced fear are stronger when using customized avatars. Further, we explored whether the customization affects how quickly participants are desensitized to the exposure over repeated iterations, suggesting that customized avatars demonstrate potential to maintain fear over multiple exposures. We provide new insights about how avatar customization affects the experience of social anxiety, which helps designers of interventions to increase the efficacy of their digital implementations of exposure therapies.

2.6 Summary

The results of Manuscript 1 show that social anxiety manifests within the digital game context and although is dependent on personal levels, social anxiety may cause a biased perception but also alter the preferences and activities that players engage with in-game. Typical preferences, like the preference for easy and non performance-based activities and the avoidance of social interactions in-game were found. Further, we see that socially-anxious players are still aware about the difference between the physical and the digital realm as they perceive the digital world as less broken and less dangerous for them.

Manuscript 2, on the other hand, shows that game mechanics like the customization of the player's avatar affects how players experience social anxiety in-game. As shown, both expected and experienced fear were intensified by using a customized avatar. Within the context of assessment, these results suggest that digital games may be suitable for detecting characteristic behaviour, due to the translation of typical cognitive patterns of social anxiety into the gaming context. However, designers need to be aware of which game mechanics they choose in order to increase or decrease the strength of the manifestation of social anxiety in-game.

2.7 Contextualisation

Previously introduced cognitive models [235, 115] of social anxiety show that this mental burden may cause various biases, expressed in altered perception of the environment. One defining aspect of social anxiety is the

withdrawal from social interaction in order to avoid the confrontation with any judgement by others. However, prior work shows that players experience less social anxiety when playing online video games together with others [337] and socially-anxious players even prefer social online games, like MMORPGs [312, 395]. While these prior results suggest that social anxiety may not transfer into the realm of the digital game, Manuscript 1 provides new insights and shows that social anxiety still manifests in-game, but perhaps not as strongly. Players with elevated social anxiety tend to withdraw from activities that involve performing with and in front of others, similar to the physical world [347]. Further, we confirm that players with in-game social anxiety also feel that the in-game world is less threatening and more accessible. Therefore Manuscript 1 lays the foundation for further explorations into whether in-game behaviour can be harnessed for assessing social anxiety.

In a second step, we raised the question of whether in-game self representation may alter the experience of social fear. On one hand, prior work suggests that personality traits, motives, and even the level of self-esteem transfer into game behaviours. Yet there is also evidence that suggests that social anxiety may not be expressed in-game because players may sometimes behave unlike their physical-world selves. Games allow players to explore different roles and identities [387] or express their ideal-self [426, 53] within the magic circle afforded by games [248]. Manuscript 2 provides a better understanding about this relationship between expressing social anxiety in-game and the self-representation. As shown, the perception of social stress in-game may be biased by the player's self-representation, resulting in an increased expected and experienced fear. In the context of this thesis, Manuscript 2 shows that core aspects of the game, like the self-representation, may affect how intensely social anxiety may be expressed through the in-game behaviours. Both manuscripts form the foundation for further investigations and define the design space for the development of game-based digital behaviour markers for assessing social anxiety.

3 Development and Implementation

Based on the findings of the foundation, part two focuses on the exploration of which aspects of in-game behaviour can be leveraged for the assessment of social anxiety. Therefore, part two of this thesis focuses on the development and the implementation of potential digital biomarkers for the assessment of social anxiety, and provides answers to the question *which aspects of in-game behaviour may be useful for the assessment of social anxiety?*

3.1   Problem and Motivation

In the context of evidence-based assessment, Manuscript 1 showed the personal perspective of players and provided evidence that even in digital games, the cognitive bias of social anxiety manifests in a manner characteristic of social anxiety. However, the question remains of whether social anxiety manifests in measurable behavioural changes, which could be harnessed for the assessment of social anxiety.

Prior assessment work in the context of social anxiety suggests the usage of biomarkers—which are measurable responses that could be used to predict the incidence of an illness [424]. *Digital* biomarkers, which are objective and quantifiable data collected via *digital* devices [198], may even further strengthen the reliability of existing assessment techniques by increasing the temporal and spatial resolution of captured behavioural data during the assessment process. Further, prior work shows that digital biomarkers are less prone to human bias and may also be less stressful for the patient and the clinician, and allow mental health experts to collect more insightful data through new information sources, which are gathered with minimal effort from the mental health expert as well as the patient.

The growing popularity of digital games elicited the interest of researchers to employ digital games as a tool to deploy mental health assessment. When players engage in games, they produce a large volume of data which can be harnessed as digital biomarkers to assess mental health concerns. Mandryk et al. [335] define two complementary approaches for the development of game based biomarkers: Either harnessing the traces left behind through natural interaction with digital games; Or developing custom games which place the player in a certain situation and monitor their response or in-game performance using known behavioural correlates of mental health issues, such as social anxiety.

As previously outlined [115, 235], there are several known behaviours of social anxiety with the potential to manifest in a digital environment. As such, while digital biomarkers are likely to be useful for assessing social anxiety, and games show great potential as a context for integrating digital biomarkers, the question

remains: do behaviours known to relate to social anxiety in the physical world also manifest in gaming contexts? Manuscript 3 tries to answer this question, by conducting an online experiment. The goal of this project is to investigate whether and how social anxiety manifests in a simple gaming task and how important design aspects of digital games—the camera perspective as well as the player's representation—affect this manifestation. Manuscript 4 expands on the results of Manuscript 3 by adding not only certain aspects of the movement behaviour in-game but also introduces interpersonal distance as an additional tool. Further, Manuscript 4 refines the task setup and tries to replicate the results of Manuscript 3, but by predicting the level of trait social anxiety for an individual, based on the proposed digital biomarkers.

3.2 Potential biomarkers and their relationship to core game mechanics

Games offer an endless palette of game mechanics and ways to entertain players. Following the suggestions of prior work [335], we decided to build a custom gaming task to better understand which aspects of the game are useful for the assessment of social anxiety in-game. Further, prior work suggests, that movement behaviour in the physical world, as well as in virtual reality simulations, is influenced by cognitive biases, resulting in an increased preference for social space towards strangers. Therefore, we hypothesized, based on the results of Manuscript 1, that this cognitive bias may manifest in similar behaviours in-game as observed in the physical world, as we saw with the biased in-game preferences.

3.2.1 Research Questions

As a first step towards potential biomarkers, we sought answers for the following research questions:

- **RQ2.1 :** Which aspects of in-game behaviour are affected by social anxiety?

- **RQ2.2 :** Do the character customization as well as camera perspective, affect the manifestation of these behavioural characteristics?

- **RQ2.3 :** Does the NPC's Emotion affect the expression of social anxiety in-game?

3.2.2 Design Rationale

Following the framework proposed by Mandryk [335], we had to decide whether to use a custom or of-the-shelf game. We decided to use a custom-built gaming task as a first step towards finding potential biomarkers. The custom game gives offers full control over the game's mechanics and access to all potential in-game data. Further, in the first step, we decided to use a minimalistic interaction in-game to reduce potential biases of in-game movement behaviour caused by the game mechanics, which require players to behave in certain ways.

At the core of social anxiety is social interaction and behaviour around others. Based on prior work about biased distance estimation [201], as well as movement patterns in virtual reality [305], we decided to build a simple task in which the player has to bypass a stranger non-player character (NPC) and move towards a given target position. The target positions were at certain distances towards the stranger. Further, we implemented two emotions of the NPC to test whether the emotion of the NPC affects the movement of the player around it. The literature suggests that social anxiety may cause individuals to misinterpret angry and neutral facial expressions [363]. As Manuscript 2 shows, a customized avatar resulted in an increased rating of expected and experienced social fear in the exposure task. However, while these results are promising, the camera perspective, a second core game mechanic, may also intensify these results. As prior work shows, seeing a virtual self-representation with a mapped face texture of the participant increases the experience of social anxiety in a VR task. To better understand the effects of the camera perspective, we include two commonly used camera perspectives: First person and third person. The first person camera perspective shows that what a character is looking at. The third person camera follows the self-representation and shows the in-game experience *"over the shoulder"* of the player's avatar.

3.2.3   Solution and Steps towards the Solution

The experiment had to implement the following aspects: First, the task itself, in which the player has to bypass a stranger in-game and find a target position next to this stranger. As previously described, we had to ensure that both camera perspectives allow the player to see their self-representation. Therefore, large mirrors were placed in the beginning of the task to show the avatar to the player. Further, we ensured that the self-representation was always present even in first person view. This allowed player to see their own body whenever they looked to the ground. Second, the influence of the emotion: To ensure that players actually focus on the presented emotion, we asked participants to indicate the hair colour of the avatar to force them to look at the face area of the NPC, as previous work has shown that socially-anxious people avoid looking at faces, even in virtual environments. To increase the experience of social presence, we used a label above the head of the NPC indicating that this NPC is representing another player. Additionally, we also used a screen indicating time needed to set up a connection to external reviewers to further enhance the experience of social presence. Third, the avatar customization: The character editor either offered two predefined avatars (female, or male) or we asked participants to shape a fully customized avatar. The customized avatar editor offered features such as face shape, body, clothing and hair style. For the camera perspective we offered either a first person camera perspective or a third person camera perspective. Additionally, we included a large mirror in the beginning of the task to ensure that players see their avatar representation in-game. Our participants were recruited on Amazon Mechanical Turk and split into four user groups (in-between 2x2 design).

3.3 Manuscript 3: Assessing Social Anxiety Through Digital Biomarkers Embedded in a Gaming Task

3.3.1 Introduction

Forming and maintaining relationships is a fundamental human need [507] that is important for our wellbeing [457]. Neglecting this fundamental need may lead to serious problems, including depression [171, 217] overall low life satisfaction [285], and a higher risk of developing more severe physical and mental health problems [107, 227, 236]. Although essential, some people have trouble satisfying this need due to elevated social anxiety [131], characterized by a fear of social situations, in which a person gets exposed to potential negative evaluation by others [13, 491]. People with social anxiety (and its extreme form—social anxiety disorder [269, 349]) try to withdraw from social situations due to their elevated fear of negative consequences. However, this reaction stands in strong contrast to the basic need for socializing. Although affected individuals want to socialize with others, they become too anxious of any potential negative consequences from others and therefore avoid it. This inner conflict between the fear of socializing and the need for it may lead to serious consequences [433]. But when people who are socially anxious are unable to withdraw from social situations, the stress of forced interaction with others can be damaging to their mental and physical health [255]. The harmful effects of social anxiety also extend beyond the individual, due to a higher risk of unemployment [164, 316] and absenteeism from work [164] among the socially anxious, which leads into an increased financial dependency on public support systems [176, 286]. If left untreated, social anxiety increases the risk of related health problems, such as depression [296] and substance dependence [531].

These burdens of social anxiety could be reduced through early and easily accessible assessment. Prior

research shows that assessment—especially performed on adolescents [102]—increases the efficacy of treatment and would allow people to seek treatment prior to experiencing the most harmful effects [135]. The best practices for an evidence-based assessment of social anxiety involve gathering information from multiple perspectives to characterize the patient's concerns, developing treatment strategies, and monitoring the patient's response to treatment [481, 516]. Assessment considers the personal perspective of the patient and the analysis of the patient's behaviour within social situations. A commonly used and effective approach is through standardized questionnaires and interviews, in which experts first identify concerns and a potential level of social anxiety. Although effective in most cases, this subjective assessment alone can be affected by problems related to self-report (e.g., social desirability bias [143] and practice effects [128]), especially for children and adolescents. Therefore an additional second step of collecting information about the patients' behaviours is used in clinical assessment—relying on reports of people close to the patient who can describe behaviours or exposing patients to a threatening stimulus and observing their response [16]. Both of these behavioural approaches are time and resource intensive, and the former involves multiple people beyond the patient and the mental health professional and allows biases and false assumptions that lead to wrong conclusions. Further, accurate assessment is impeded when socially anxious individuals avoid seeking help because they are ashamed of their illness or fear of negative evaluation [311]. This fear also may influence how patients answer personal questions if they feel intimidated [189]. Finally, assessment through mental health services in general involves access barriers that may be sociocultural (e.g., discrimination in mental health, lack of family supports), economic (e.g., costs of access exceed health care coverage), or geographical (e.g., limited access to services in oversubscribed or remote communities) [301]. Because both early [239] and ongoing [229] assessment are so important for patient health, mental health professionals require a less expensive, more robust, and easier approach to gain insights about a patient's behaviour in social situations.

One promising approach to support existing methods for assessing behaviour in social situations is the use of biomarkers, which are measurable responses that can be used to predict the incidence of disease [424]. Digital biomarkers—objective and quantifiable data collected via digital devices [198]—may strengthen assessment by increasing the temporal and spatial resolution of captured behaviour during an assessment [162]. Moreover, digital biomarkers are less prone to human bias, and may induce less stress for patients [476]. Further, they represent a rich source of previously unobtainable information, gathered with minimal effort from both health experts and patients alike [512]. Although there are multiple sources of data for digital biomarkers (e.g., smartphones [253], social media [420], interaction traces [78]), the huge popularity of digital games has prompted researchers to consider game-based digital biomarkers for mental health assessment [335].

In 2019, two-thirds of the online population play digital games [550], including players of all ages, genders, and races/ethnicities [172]. When people play digital games, they produce a large volume of data that can be used as digital biomarkers to assess mental health concerns. Mandryk and Birk [334] outline two complementary approaches for developing game-based biomarkers: harnessing the traces left behind through natural interactions with digital games; and developing custom games that place a player in a situation and

monitor their response or performance using known behavioural correlates of mental health. In the context of social anxiety, there are a variety of known behaviours with potential to be translated into digital environments (see Related Work). There are several reasons to assume that behaviours related to social anxiety translate into gaming contexts: first, physical world biases of interpersonal interaction have previously been observed in interaction between avatars in gaming contexts [561]; second, the cognitive biases of social anxiety were shown to manifest in-game in a sample of massively multiplayer online role player game (MMORPG) players [147]; third, avatar-based interactions related to social anxiety have been shown in non-game virtual reality contexts [305]; and finally, as proposed by media equation theory, people react to computers with social responses [374, 440], including how socially anxious people react to virtual characters [267]. However, there are also reasons to assume that social anxiety fueled behaviours will not translate into gaming contexts. The 'magic circle' of entering a gaming context may offer players the opportunity to behave differently than they would in the physical world [248]. Players sometimes represent idealized versions of themselves in games [53], allowing them to shed physical-world identities, such as that of a socially-anxious person. Additionally, games commonly use input devices and interaction approaches (i.e., controller, mouse, keyboard) that are not embodied and can influence the sense of 'self' in a game [57]. As such, while digital biomarkers are likely to be useful for the assessment of social anxiety, and games show great potential as a context for integrating digital biomarkers, the question remains: do behaviours known to relate to social anxiety in the physical also manifest in gaming contexts?

To inform the development of game-based digital biomarkers for the assessment of social anxiety, we conducted an online experiment with 116 participants, adapting a social interaction task from previous work in a virtual reality context [305]. Players were asked to walk through a room and stand as close as possible to a highlighted spot, which necessitated walking past a non-player character (NPC). We estimated the participants' level of social anxiety using the Liebowitz Social Anxiety Scale (LSAS) [322, 352], used for subjective assessment of social anxiety in the clinical context, and we evaluated which aspects of in-game behaviour predict social anxiety level. We further evaluated the influence of two important game interface factors: the type of the camera perspective (i.e., first-person versus third-person perspective [152]) and the in-game representation of the player (i.e., customized versus predefined avatars [58]). We investigated how these game interface factors affected the expression of social anxiety in the gaming task to inform the development of digital biomarkers.

Our results suggest that several aspects of in-game behaviour are candidates for digital biomarkers to assess social anxiety levels. In general, players scoring higher on social anxiety tended to stay farther away from NPCs, which is reflected in several movement-based features we developed and analyzed, such as the minimal distance between the player and the NPC. Further, players higher in social anxiety also showed greater error in their estimates of a target location. However, the interface factors played a significant role in the strength of these biomarkers—only the third-person, customized avatar condition yielded consistent and expected predictions, suggesting that the use of predefined avatars and first-person views decrease the

expression of social anxiety in gaming contexts.

We discuss how these potential in-game biomarkers can help to create novel strategies that could reduce the barriers to assessment of social anxiety, which is a major mental health issue globally [176, 439, 514]. Further, the relationships between in-game behaviour and social anxiety that we uncover could be used as a starting point for the development of custom games that place a player in a specific situation to measure their response and behaviour [491, 436], similar to other games that have been helpful in assessment, diagnosis, monitoring, and intervention of other mental health issues (e.g., depression [447], dementia [197], alcohol misuse [449]). Game-based biomarkers are a potential complement to existing techniques of assessment. By supporting early assessment, ongoing assessment, and even remote assessment of social anxiety, game-based digital biomarkers may evolve into a helpful tool that helps patients access support for their mental health burdens while also supporting mental health professional to conduct early and ongoing assessments.

3.3.2   Related work

This research adds to a body of work in digital games in the context of mental health. In this section, we introduce the characteristics of social anxiety, review existing techniques for the assessment of social anxiety, and discuss how digital games may be beneficial as an assessment tool for social anxiety.

The characteristics of social anxiety

Social anxiety is characterized by an intense fear of social situations in which there is potential exposure to negative evaluation from others [13]. This fear results in changes of the individual's behaviour such as social withdrawal, as well as in physical symptoms such as blushing, heavily trembling, or sweating. With a population prevalence of 2.0% [175, 176], social anxiety is one of the most common anxiety disorders. It is most accurately expressed along a severity continuum, i.e., one can experience a high degree of social anxiety but not reach the threshold for a clinical diagnosis [491]. Several individual factors as well as the social context and the physical environment affect how people experience social anxiety. For example, people may experience high social anxiety only within a specific context, such as giving a presentation in front of an unfamiliar audience, whereas the same task is less distressing within a familiar environment. In the development of social anxiety, adolescence is a critical phase [378, 485, 537]. If untreated, social anxiety follows a chronic and generally unremitting course through the lifespan [281, 105].

People with social anxiety face greater challenges forming and maintaining relationships with others [354]. Therefore, affected individuals tend to have fewer close friends, and are at higher risk of being rejected or ignored by their peers. Also, they may be at higher risk of being victimized by others [120] due to the potential deficiencies in social competence [354]. As a result, people with social anxiety may develop dangerous coping strategies, such as substance abuse [95], or more severe mental illnesses, such as depression [494].

Due to the social inhibition and private anguish inherent to social anxiety, the symptoms are often mistaken for shyness by others or perceived as a character flaw in the individual [495]. Therefore, the nuanced effects of

social anxiety are frequently unreported and under-recognized. In addition, patients with social anxiety often avoid consulting physicians about their psychological problems [311]. Based on previous estimates, only 35% of individuals with social anxiety disorder symptoms receive treatment for their anxiety [454]. Therefore, to increase the efficacy and success rate of treatment, early and reliable assessment of social anxiety plays an essential role in preventing more severe harm [239].

The assessment of social anxiety via (digital) biomarkers

For a reliable assessment of social anxiety, mental health experts use standardized procedures, which include interview approaches, combined with questionnaires. Most of these scales, such as the Liebowitz Social Anxiety Scale [322], present scenarios of different social situations and ask respondents to rate their fear and/or avoidance within the presented situations. Other questionnaires focus either on the special needs of a specific demographic group, such as adolescents or children [151]. However, ongoing discussion about the benefits of evidence-based assessment [249], which require not only the self-reported perspective of the patient but also objective evidence of the mental illness, has led to an increased interest in finding behavioural correlates that are predictive of mental health. These behavioural correlates are often referred to as biomarkers, which are defined by the World Health Organization as "any substance, structure, or process that can be measured in the body or its products, and that influences or predicts the incidence of outcome or disease" [502]. For example, the measurement of blood pressure in a social situation to assess the experience of social anxiety [177]. But research on biomarkers for the assessment of social anxiety has produced mixed results [308]. Digital biomarkers focus on objective, quantifiable physiological and behavioural data, which are collected and measured by means of digital devices such as portables, wearables, implants, or digestibles [335, 198].

To further the research agenda of generating reliable biomarkers of social anxiety, researchers have identified potential biomarkers based on both cognitive and behavioural characteristics—we can turn to this work to inform the development of digital biomarkers for the purposes of assessment: cognitive factors of social anxiety include aspects like biases in attention [94, 351], interpretation [237], and memory [448]. An example would be an estimation bias in social situations: individuals with social anxiety tend to estimate ambiguously oriented figures as facing towards them more often than facing away [88, 201]. Researchers show that socially anxious individuals prefer to maintain greater distance from strangers [282, 407]. Depending on the individual's personality [71], the cognitive bias caused by social anxiety may lead to behavioural characteristics, such as avoidance and safety behaviours. But social anxiety also may affect preferences and behaviour in digital worlds, such as in online chats [413] and in immersive applications, such as digital games [312, 395]. These safety behaviours involve strategies that individuals with social anxiety use to avoid the risk of being negatively evaluated by others [279]. For example, people with social anxiety rehearse sentences in their mind to prevent feared situations such as stuttering in front of an audience. However, an excessive use of safety behaviours has several problematic consequences, as it increases experienced anxiety and self-focused attention, maintains negative beliefs, and may even contaminate social situations by making these individuals come across as

distant or uninterested [532]. Researchers have successfully applied sensors, such as gaze tracking [145], skin conductance sensors [350], and global positioning system (GPS) devices (which measure movement patterns) [247] to find digital biomarkers for social anxiety. Especially in the context of virtual reality, researchers have successfully demonstrated the presence of behaviours and cognitive markers characteristic of social anxiety, mostly by recreating physical situations in the simulated environment of a virtual simulation [266, 421]. Specifically, Lange et al. [305] confirmed a distance bias towards virtual characters, in which highly socially anxious participants stand farther away from the character than healthy participants.

In the context of games, little research has explored cognitive and behavioural biomarkers of social anxiety. One study demonstrated that behavioural and cognitive biases in the physical world did manifest in games: For example, the level of social anxiety affected how much players engaged in social interactions as well as which level of challenge they sought when they engaged in Massive Multiplayer Online Roleplaying Games (MMORPGs) [147]. When we consider the expression of social anxiety in games, an important aspect is the experience of social presence [178], because social anxiety focusses on social interaction and the fear of negative outcomes of these interactions. In digital games, social presence is affected by the design and implementation choices around player avatars [441].

Social presence in virtual environments

Measuring social anxiety using in-game behaviour requires that the player's in-game persona behaves similarly to their self. As shown, the potential presence of other individuals is a key component for the experience of social anxiety. This experience, that others are sharing the digital space with the player, is referred as "social presence" [396]. In this section, we discuss the role of avatar customization and its effects on social presence play and the relationship between players' real and digital selves. In many digital games, the player's avatar plays an essential role [330], as it represents the player in the digital world of the game [92]. They allow players to explore their own [524] or different [250, 346] identities and are a way to form social relationships in multiplayer games [556]. Furthermore, the identification with one's avatar has positive effects on the player's enjoyment of the game [58] and can shape their behaviour, even outside of the game [61].

Beyond enjoyment, the integration of personalized avatars increases the feeling of social presence for users. Prior research highlights the important role of social presence for the therapeutic effectiveness of digital interventions for social anxiety in that the experience of social presence may be more predicative of a social anxiety response than the self-reported experience of physical presence in the virtual environment [178]. An elevated experience of social presence also affects the experience of social anxiety: early research showed that experienced social anxiety in a virtual reality task was increased if avatars were more similar to the participants [25]. The virtual representation of the player can even change the user's behaviour inside and outside of virtual environment [54, 55, 561]. Furthermore, the similarity of the person's avatar to the player's appearance increases their self-awareness [525] of their own body. This increased self-awareness plays an essential role in the maintenance of social anxiety, because socially anxious individuals are highly

aware of their self-presentation to avoid any negative consequences [72]. However, to our knowledge, previous research has not investigated whether personalization of an avatar is enough to facilitate the perception of similarity that has been shown to coincide with higher experienced social anxiety [25]. If this were the case, avatar personalization might be a useful tool to enable social presence to a degree that players would exhibit behavioural patterns indicative of their social anxiety levels, making these behaviours useful as digital biomarkers. Besides the player's representation, the fidelity of the non-player characters also affects the person's emotions [559], due to the experience of co-presence of other individuals.

Overall, previous research has shown the value of biomarkers of social anxiety in the physical world, mostly expressed through physical avoidance or safety behaviours. These same behaviours have been demonstrated within virtual reality simulations of social situations, in which researchers highlighted the influence of social presence on the experience of anxiety. However, we do not know: whether these biomarkers express in a non-immersive digital environment (e.g., desktop platform); whether they express in a gaming context in which players can shed their identity within the context of the game; or how their expression is affected by the representation of the player through their avatar (e.g., personalized or not).

3.3.3   Methods

We conducted an online experiment to understand whether characteristic behaviours of people with social anxiety manifest in digital games. In the experiment, participants performed several trials of a typical gaming task (i.e., walking past a non-player character to a predefined position). Because the avatar should trigger social presence and elicit avoidance behaviours indicative of social anxiety, we also varied the presentation of the player's representation in the game. We collected different metrics related to movement and accuracy to assess their value as digital biomarkers for social anxiety that are embedded into a digital game.

Apparatus

The main part of the experiment was a movement task in a 3D room.

The task

To evaluate how social anxiety affects a player's movement patterns, we asked participants to complete the following movement tasks inside of a 3D game like environment several times: In the game environment, participants were placed in a small room in front of a mirror (the mirror was present both to facilitate the experience of social presence and to provide a view of the player avatar when playing in a first-person perspective). Players had to exit this exposition room by passing by the mirror and entering a connected larger room, referred to as the assessment room.

In the assessment room, participants were asked to move towards a target position (See Figure 3.1), past an NPC, and until they reached the target position. We had three setups for this room: A non-player character (NPC) with an angry facial expression and a suit, an NPC with a neutral facial expression and a casual outfit, or no NPC was visible at all. The clothing was used to elevate the perception of the NPCs as a
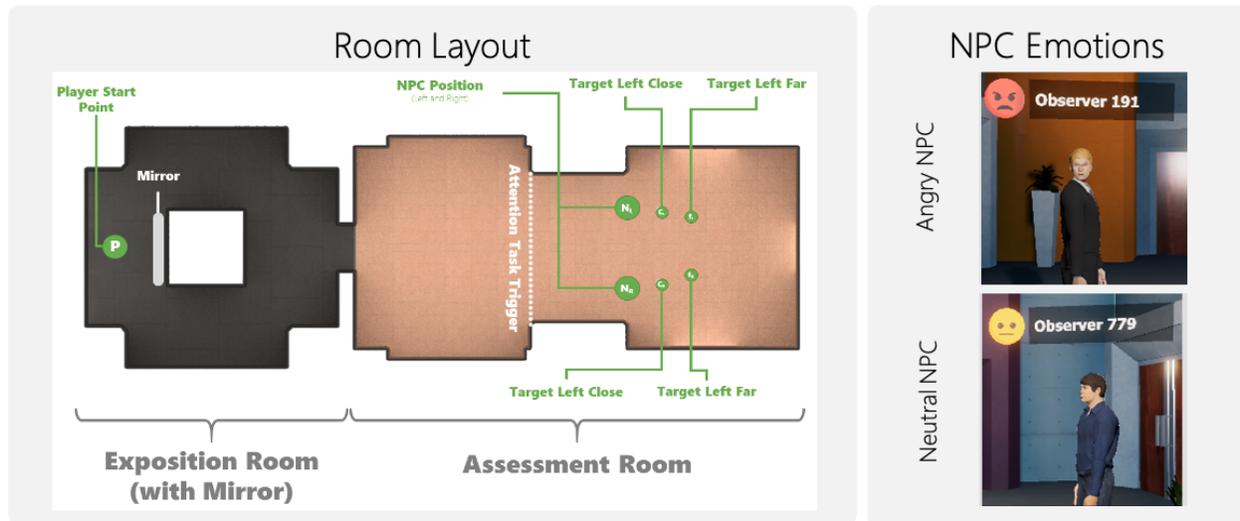
Figure 3.1: Scheme of the task environment (left) and the NPC emotion (right)

potential threat. The NPC stared at the player's position by rotating their head towards the players, whereas the neutral NPC did not move their head in the direction of the player. We included NPCs with different emotions to see if a greater social threat (angry-looking NPC) induced a greater behavioural avoidance and safety response in the player, as the emotional state of the observer is known to affect how strongly social anxiety is expressed in physical contexts [84, 344, 362]. We placed a textbox over the NPC's head, indicating that this NPC is an observer and a random number to show that these NPCs are different observers (see Figure 3.1). Further, the emotional state of the NPC was indicated by an icon next to this text. NPCs were standing either on the left or right side of the room and had randomly assigned hair colours. Trials without an NPC were used to distract participants from the core measurements (their behaviour around an NPC) as well as to provide variety within the task.

Whenever an NPC was in the room, participants had to answer an attention test, naming the hair colour of the NPC, to ensure they were looking at the head of the NPC (see Figure 3.2). After that, a green marker was shown for 100 milliseconds indicating the goal position for the participants (in trials with no NPC, the green marker was triggered at the same location where the attention test would happen). Next, participants moved until they felt they were standing at the previously indicated position and pressed the spacebar to finish the trial. The green dot appeared at one of two positions in each trial: 33 cm or 66 cm away from the NPC. In total, the 2 NPC positions (left/right), 2 target distances (33cm/66cm), and 3 types of NPC presence (no NPC /neutral NPC /angry NPC) resulted in 12 trial configurations. Each configuration was completed 4 times, resulting in an overall number of 48 trials per participant, which were completed in a pseudorandom order. Every participant was introduced to the task by a tutorial trial, which explained the task's goal but was not recorded or evaluated.

Experiment Conditions

Prior to the movement task, participants were randomly assigned (between-subjects) to one of four

Figure 3.2: The four steps of the movement task (exposition to the in-game self, approaching the NPC, answering attention test, movement to the final position)

Figure 3.3: The camera perspectives (left) and the character design conditions (right)

conditions. We deployed a 2x2 experiment design: The camera perspective (First-Person Perspective and Third-Person Perspective) and the player's avatar type (Predefined and Customized avatar). These conditions represent major design aspects of digital games (see Related Work).

We used two camera perspectives (see Figure 3.3):

First-Person Perspective (FPP): In this condition, the participant's point of view was from the perspective of their own avatar. Therefore, their own body was only visible as reflected in the mirror in the virtual environment.

Third-Person Perspective (TPP): In this condition, a camera was following the avatar through the experiment. Therefore, participants could see their avatar over the whole experiment as well as through the mirrors in the environment.

For the player's avatar type, we implemented a custom avatar creator that was used to generate two commonly used versions of character design in games, customized avatars, and predefined avatars:

Customized Avatar: In this condition (see Figure 3.3), participants had to select the gender of their avatar (woman or man) first. Afterward, they could adjust the general appearance of their avatar, by adjusting the height, weight, fitness, head offset, and breast size, as well as the skin colour, eye colour, and the hairstyle (10 different styles per gender) and hair colour. After that, participants could shape the head of their avatar via 34 sliders to define the shape of the face, eye, brows, nose, mouth, chin, jaw, ear, neck. Furthermore, participants could choose the outfit of their avatar by choosing the style and colour of clothing on the upper body, lower body, shoes, and head accessories. Afterwards, we asked participants to set the personality of their avatar, by adjusting five 7-point Likert scales, which each described one personality trait based on the 10-item short version of the Big Five Inventory (BFI-10) [428]. Personality did not affect the appearance or

behaviour of the avatar but was integrated to increase the player's identification with their own avatar, as described in previous work on avatar customization [58].

Predefined Avatar: In this condition (see Figure 3.3), participants could only choose the gender representation of their avatar, and every other characteristic was chosen to be as generic as possible (e.g., mid-tone hair colour, skin colour), as has been previously done [305].

To make sure that exposure to the avatar did not affect results, both groups had to spend at least four minutes inside of the avatar creator. After four minutes, participants could move on to the next step of the experiment by clicking a button on the screen.

In both avatar conditions, participants were asked to answer the Player Identification Scale (PIS) [523] to determine how much participants associated their avatar with themselves on three dimensions: Similarity, Embodied, and Wishful Identification. As there were known limitations of the character creator, such as the lack of a non-binary gender option, facial hair options, and curly hair styles, we gathered identification to help account for when participants felt they were limited in their self-expression.

Participants and Procedure

We deployed our experiment to participants recruited using Amazon's Mechanical Turk (MTurk). MTurk is an online platform where Human Intelligence Tasks can be posted by requesters and workers can opt-in to complete them. Data collected from MTurk has been successfully used for different research projects in the human-computer interaction (HCI) community [147, 229, 277, 477]. However, some special care must be given to ensure that bots or negligent workers are removed from the final analysis [473, 394, 393, 339]. Ethical approval for this study was provided by the ethics board of the University of Saskatchewan.

We recruited 191 participants, but we removed participants who did not finish the experiment due to technical difficulties or incomplete data recordings, as well as suspected bots (N = 75), leaving 116 participants (36 women, 78 men, 2 non-binary) aged 18-73 (M = 36.08, SD = 8.78) across the four conditions (N: FPP-Predefined = 23; FPP-Customized = 30; TPP-Predefined = 28; TPP-Customized = 35). All participants were paid $6 for participating in this study, which took approximately 30 minutes to complete. After providing informed consent, participants were told a cover story that we were investigating effects of input lag in games both to justify why they were asked to repeat a movement task 48 times, and to reduce the risk that they behaved differently as a result of knowing the intent of the study. Participants answered the Liebowitz Social Anxiety Scale (LSAS) [322, 459] and questionnaires about their experience of lag in games to reinforce the cover story. The LSAS consists of 24 items covering social interactions (11 items) and public performance (13 items). On 4-point Likert scales, participants rated the fear (0="none" to 3="severe") and the avoidance (0="never/0%" to 3= "usually/68-100%") of a variety of social situations. All scores are summed together to estimate a level of social anxiety that ranges between 0 and 144 (higher value indicates greater social anxiety), with a threshold score of 30 generally used for distinguishing between non-anxious and anxious people [459]. LSAS scores in our sample ranged from 0 to 113 (M = 47.0, SD = 28.9). The scale had excellent internal

consistency ($\alpha = .973$). To reduce the potential risk of any bias induced by playing the task, we assessed social anxiety before exposing participants to the task. Doing so may have primed participants to manifest their anxiety within the task; however, this is more generalizable to our use case (online assessment) than biasing the assessment of social anxiety.

Participants were told via on-screen prompt before the first trial started that external observers would watch their performance in the task. Participants then completed the experiment as described. After finishing all trials, demographic information was recorded, and participants were debriefed about the real goal of this study. Then, we provided additional support resources, such as contact information to a crisis hot-line, and a link to pictures of baby animals to reduce the potential negative effect on participants.

In-game Digital Biomarkers for Social Anxiety

We calculated several in-game measures. To assess movement in the assessment room, we recorded the location of the participant's avatar in the game world with a timestamp, sampled every 500 milliseconds. Although low, the sampling rate was selected to allow for potential technical limitations such as the server's performance as well as variable internet speed quality among participants. Using this raw data, we developed the following features to assess their utility as a digital biomarker.

Speed and Accuracy Features: We measured the time in seconds starting from entering the assessment room until participants completed a trial (Time in Room). This time measurement also included the time participants spent in answering the hair colour question about the NPC. We assessed how close players stood to the expected target when they finished the task (Target Error). Closeness was calculated as the Euclidean distance between the target position and the position of the player's avatar when they hit the spacebar to finish the trial.

Movement Features: We measured the absolute travelled distance per trial from the entrance of the assessment room to the target position (Path Length). According to previous work, socially anxious individuals prefer to stay farther away from strangers [22, 121], and we explored whether these preferences express in the digital realm by measuring the player behaviour around the NPC. We measured the following three aspects: Final Distance to NPC represents the Euclidian distance between the NPC's position and the player's position at the end of the task. Previous research showed that this marker was a reliable indicator of social anxiety within a virtual reality application [305]. The Minimum Distance is the smallest Euclidian Distance to the NPC over a whole trial. The Mean Distance represents the average distance to the NPC, based on the samples after the target was made visible, calculated within samples that are within three meters of the NPC's position. This allowed us to focus on the movement behaviour around the potential threat (the NPC). Additionally, we took all samples after the attention test trigger (minimum distance to NPC was 9m) and pooled all sampled distance from the NPC across the four trials with the same NPC emotion, distance, and side. We calculated two statistics of the distribution of these pooled distances: skew and kurtosis; players giving the NPC a 'wider berth' should have a higher (right-leaning) skew and players with more consistent
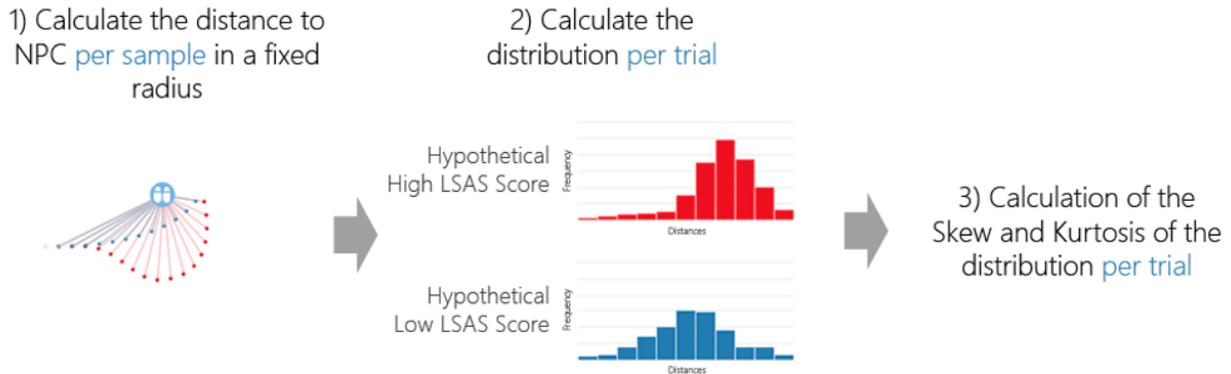
Figure 3.4: The calculation of skew and kurtosis of the distribution of distances per trial

movement patterns should have a lower kurtosis (see Figure 3.4).

Expectations Based on Literature: Literature suggests [372] that players with higher social anxiety will aim to complete a task involving potential threatening stimuli as quickly as possible, likely sacrificing accuracy in the process. As such, we expected that: 1) players with higher social anxiety will have greater Target Error, and 2) players with higher social anxiety will spend less Time in the Room. Further, based on this same literature, we expected less 'exploration' of the assessment room and deviation from the task requirements (in order to finish quickly and remove themselves from the situation), which would be reflected in: 3) a higher kurtosis (i.e., fewer outliers of being farther from or very close to the NPC, and a more consistent path) for players higher in social anxiety.

For player movement characteristics, we expected that players would stay farther away from the NPC throughout the task, because literature suggests that the avoidance behaviours of socially anxious people that manifest in physical contexts may transfer into virtual worlds [223]. Thus, we expected higher: 4) Final Distance to NPC, 5) Minimum Distance, 6) Mean Distance, and 7) Skew for players higher in social anxiety.

Because we expected players higher in social anxiety to both try to get to the target location as quickly as possible (suggesting a shorter path) and to give the NPC a wide berth (suggesting a longer path), we 8) did not expect to see consistent differences in total path length, depending on social anxiety.

Data analysis

We used regression analysis to investigate the relationship between features for movement and social anxiety scores, represented as a continuous variable to account for the full range of experienced social anxiety. We used hierarchical regressions with three levels. After discarding all trials with no NPC, we controlled for player factors (gender and similarity identification) at the first level in case participants were not able to effectively self-represent using the character customizer and to account for the predefined avatar being randomly more similar to some participants than others. Trial level factors (side, distance, and type of NPC presence) were included at the second level to account for significant main effects of the trial factors and interactions with social anxiety on several features, which were suggested by a repeated-measures MANOVA with side, distance,

| | Third-Person Perspective (TPP) | | First-Person Perspective (FPP) | |
	Customized	Predefined	Customized	Predefined
Target Error	B=4.794, β=.138, p=.026*	B=-11.432, β=-.273, p<.001***	B=4.895, β=.135, p=.021*	B=-15.186, β=-.415, p<.001***
Time in Room	B=0.344, β=028, p=.641	B=-0.151, β=-.023, p=.763	B=-1.131, β=-.152, p=.027*	B=-0.528, β=-.060, p=.395
Kurtosis	B=4.444, β=.128, p=.036*	B=-4.854, β=-.118, p=.088	B=4.007, β=.134, p=.019*	B=-1.343, β=-.037, p=.599
Final Distance to NPC	B=19.789, β=.191, p=.010*	B=25.666, β=.304, p=.001**	B=-5.888, β=-.086, p=.209	B=0.546, β=.008, p=.919
Minimum Distance to NPC	B=27.863, β=.276, p<.001***	B=-3.813, β=-.028, p=.714	B=15.873, β=.193, p=.001**	B=-2.809, β=-.034, p=.652
Mean Distance to NPC	B=30.572, β=.239, p<.001***	B=4.919, β=.037, p=.624	B=17.423, β=.158, p=.008**	B=0.339, β=.003, p=.964
Skew	B=24.057, β=.258, p<.001***	B=6.752, β=.087, p=.210	B=-9.613, β=-.111, p=.062	B=6.665, β=.074, p=.293
Path Length	B=-1.898, β=-.102, p=.097	B=3.109, β=.184, p=.007**	B=-1.942, β=-.151, p=.010*	B=4.106, β=.268, p<.001***

Table 3.1: The regression results for third-person (TPP) and first-person perspectives (FPP) and customized and predefined avatars. B denotes unstandardized regression coefficients, β standardized coefficients. *p < .05, **p < .01, ***p < .001

type of NPC presence as repeated factors and median split of LSAS as a between-subjects factor on the eight features. The third level included our measured features, effectively testing their value for the prediction of social anxiety within a model that accounted for gender, similarity, side, distance, and type of NPC presence. To compare how the avatar factors affected the prediction of social anxiety, we conducted separate regression analyses for camera perspective condition (FPP and TPP) and avatar condition (predefined and customized).

We report unstandardized regression coefficients (denoted as B) and standardized regression coefficients (denoted as β). In all models for which the feature was significantly predicting social anxiety, the model fit was significant.

3.3.4 Results

We present the results of our analysis grouped by the previously discussed measurement groups. Table 3.1 shows results from the regression models.

Speed and accuracy features

Target error predicted social anxiety in all conditions. When customized avatars were used, target error was a positive predictor for social anxiety for both camera perspective conditions. In contrast, when predefined avatars were used, social anxiety was negatively associated with target error for both camera perspective conditions. Time in room was not a significant predictor in third-person perspective, and for predefined first-person avatars, but was negatively associated with social anxiety for customized avatars in first-person perspective.

Path length was a significant, positive predictor for social anxiety for predefined avatars in both camera

	Third Person Perspective (TPP)		First Person Perspective (FPP)	
	Customized	Predefined	Customized	Predefined
N (Total: 116 Participants)	35	28	30	23
Age	m = 35.94; SD = 1.31	m = 34.21; SD = 2.27	m = 38.1; SD = 1.46	m = 35.95; SD = 1.27
Gender	m = 0.2; SD = 0.09	m = 0.37; SD = 0.09	m = 0.16; SD = 0.08	m = 0.10; SD = 0.104
LSAS	m = 45.94; SD = 5.30	m = 42.67; SD = 4.98	m = 46.16; SD = 5.53	m = 52.95; SD = 5.63
Target Error	m = 0.8851; SD = 0.14	m = 0.69; SD = 0.10	m = 1.15; SD = 0.14	m = 1.00; SD = 0.14
Time in Room	m = 9.5082; SD = 0.36	m = 10.61; SD = 0.68	m = 11.26; SD = 0.64	m = 10.1957; SD = 0.50
Kurtosis	m = -0.4326; SD = 0.12	m = -0.69; SD = 0.09	m = -0.41; SD = 0.14	m = -0.5157; SD = 0.10
Final Distance to NPC	m = 1.5104; SD = 0.02	m = 1.50; SD = 0.02	m = 1.71; SD = 0.05	m = 1.5804; SD = 0.04
Minimum Distance to NPC	m = 1.3592; SD = 0.04	m = 1.30; SD = 0.01	m = 1.41; SD = 0.05	m = 1.4159; SD = 0.05
Mean Distance to NPC	m = 1.7398; SD = 0.03	m = 1.70; SD = 0.02	m = 1.85; SD = 0.03	m = 1.8303; SD = 0.04
Skew	m = -0.1477; SD = 0.03	m = -0.11; SD = 0.04	m = -0.05; SD = 0.04	m = -0.1673; SD = 0.03
Path Length	m = 16.4129; SD = 0.22	m = 16.95; SD = 0.22	m = 17.01; SD = 0.34	m = 16.88; SD = 0.29

Table 3.2: Mean and standard deviation per condition

perspective conditions. For customized avatars, effects were less consistent. Path length did not significantly predict social anxiety in third-person perspective and was negatively associated with social anxiety in first-person perspective. In third-person perspective, social anxiety was positively associated with final distance to NPC with predefined and customized avatars. On the other hand, social anxiety was not significantly predicted by this feature for first-person perspective in either avatar condition.

For customized avatars, social anxiety had a positive association with the minimum distance to the NPC in both first-person and third-person perspectives. The minimum distance to NPC was not significantly associated with social anxiety when predefined avatars were used, regardless of camera perspective condition. Mean distance to NPC was positively associated with social anxiety for customized avatars, but was not a significant predictor for predefined avatars across camera perspective conditions. Skew had a positive association with social anxiety for customized avatars in third-person perspective; however, this feature did not significantly predict social anxiety if predefined avatars were used, and in first-person perspective with customized avatars. When customized avatars were used, the kurtosis was a significant, positive predictor for social anxiety; however, social anxiety was not significantly predicted by kurtosis when using predefined avatars. A one-way ANOVA showed that there were no significant differences between the groups in terms of age $(F_{3,112})=.952$, $p=.418$, or LSAS $(F(3,112)=.543, p=.654)$, whereas a Kruskal-Wallis test showed no significant differences between the groups in terms of gender $(H(3)=3.639, p=.303)$. Table 3.2 summarizes shows descriptive statistics for these measures.

Expected Relationships of Features with Social Anxiety

To assess how the perspective and avatar conditions affect the predictive power of in-game behaviour, we summarized our results in terms of which predicted associations were confirmed in each condition (see Section 3.3.3). We expected that players with higher social anxiety would exhibit greater target error, less time in the room, greater final distance to the NPC, minimum distance from the NPC, mean distance to the NPC, skew, and kurtosis, with no predicted difference in path length. As Table 3.3 shows, with the exception of

Expected Relationship of Feature with Increasing Social Anxiety	Third-Person Perspective (TPP)		First-Person Perspective (FPP)	
	Customized	Predefined	Customized	Predefined
1) Higher Target Error	✓		✓	
2) Lower Time in Room			✓	
3) Higher Kurtosis	✓		✓	
4) Higher Final Distance to NPC	✓	✓		
5) Higher Minimum Distance to NPC	✓		✓	
6) Higher Mean Distance to NPC	✓		✓	
7) Higher Skew	✓			
8) No relationship with Path Length	✓			

Table 3.3: The anticipated relationships of social anxiety with the features.

time in the room, these relationships were all significant in the predicted direction when using customized avatars in the third-person perspective. However, many of these results do not hold when participants used a first-person perspective with a customized avatar, and only one of the behaviours was expressed as expected when using predefined avatars.

In summary, a variety of features showed promise for the prediction of social anxiety; however, the effects depended on the combination of perspective and avatar type. For instance, final distance to the NPC was a predictor only in third-person perspective, but not in first-person perspective and the higher mean distance to the NPC was only predictive with customized avatars. The combination of TPP and customized avatars led to the largest number of significant predictions, and predictions that were consistent with our expectations of how social anxiety influences movement behaviours of players as represented by avatars. For the other combinations of interface factors, the predicted relationships were either inconsistent or absent. Our results show that features were useful for the prediction of social anxiety but that their value and consistency depend greatly on contextual factors like avatar type and camera perspective. This highlights the importance of considering game design aspects in the use of digital biomarkers for social anxiety. Figure 3.5 summarizes the anticipated relationships of LSAS with the previously introduced features, by condition.

3.3.5   Discussion

Summary of the results

We investigated whether digital biomarkers embedded in a gaming task can be used to predict social anxiety. In general, we found that social anxiety was associated with increased target error, a more consistent path (i.e., kurtosis), and movement features that reflect physical safety behaviours around an NPC (i.e., increased skew, and the minimum distance to the NPC, mean, and final distance to NPC), but only consistently in the third-person customized avatar condition. Some of these features still held predictive value for first-person customized avatars, but with predefined avatars, behaviours did not conform to expectations.
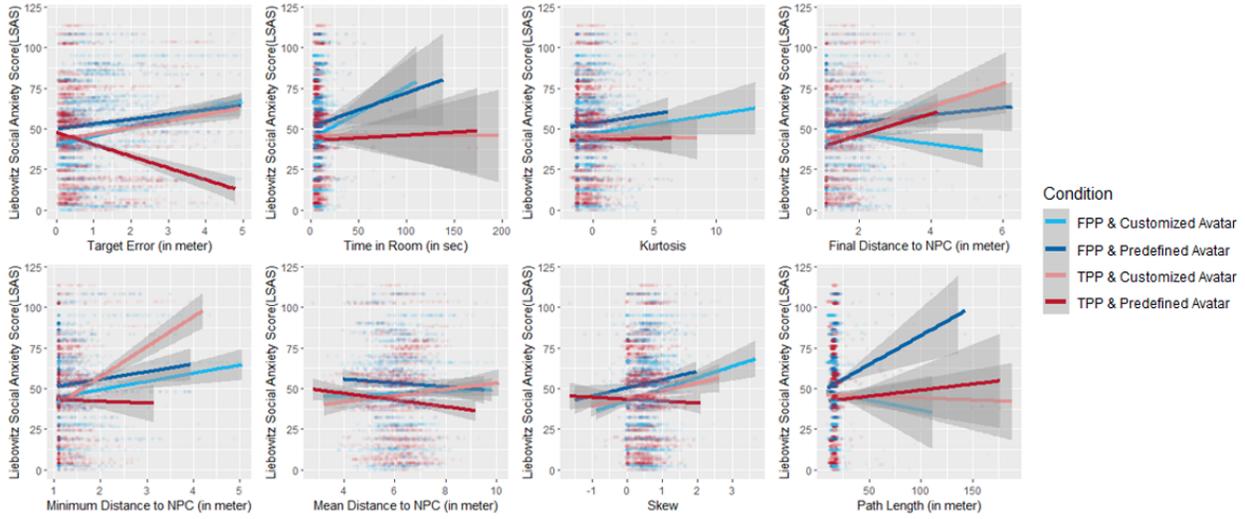
Figure 3.5: Scatter plots of the regression results for third-person (TPP) and first-person perspectives (FPP) and customized and predefined avatar.

Explanation of the findings

As seen in the results, behaviours indicative of social anxiety in the physical world can also manifest in-game: socially anxious individuals kept a higher distance from NPCs and tried to avoid moving and interacting in their close vicinity. This behaviour is consistent with evidence that individuals with elevated social anxiety prefer to stay farther away from strangers [201]. Further, this increased distance is thought to be mediated by an underlying cognitive bias in estimating distances towards strangers in the physical world [201]. Our work shows that the safety behaviour manifests in a similar way in the digital world as well: socially anxious players tended to stay farther away from virtual characters, such as NPCs, likely because they could experience potential negative consequences if they came to close to another individual. However, we cannot confirm whether it is due to an estimation bias or an explicit safety behaviour.

However, results also indicate a significant influence of camera perspective and player representation on how these behaviours express in game contexts. Our features significantly predicted social anxiety consistently only in the third-person perspective with a customized avatar, less reliably with a first-person perspective, and not at all with a predefined avatar. Social presence [178] can help explain the effects of avatar type. Avatar customization is associated with higher identification with the avatar [58], which in the social presence context can help to create the illusion that the avatar is more socially present in the environment, and reinforce the notion that other characters in the game world represent other human beings. With enhanced social presence, the participants' experience of the social aspects of the situation feel more realistic, facilitating a more stressful experience. The increased awareness of potential social stress would lead to a stronger expression of social anxiety in their behaviours in the game, because participants would try to avoid the potential negative evaluation by others. Social presence and avatar identification can explain why social anxiety behaviours are expressed with a customized avatar, but not with a predefined avatar.

Additionally, our results are in line with earlier work showing that the experience of social anxiety was associated with elevated self-awareness, induced by the presence of a mirror [72, 195, 392]. Similar to seeing oneself in a mirror in the physical word, seeing one's digital avatar strengthens the participant's perception of themselves. In the third-person perspective, participants were able to see the self-representation throughout the entire task, whereas participants in the first-person perspective saw their representation only in the beginning of the task in a mirror. Further, the third-person perspective allowed users to see their own avatar during the interaction around the NPC, strengthening the participants' perception that they perform in front of an observing person. A potential explanation for this is that this thought increases their experience of social anxiety, which may result in stronger expression of movement-based safety behaviours. However, further evidence is required to confirm this suggestion. When we consider customized avatars only, self-awareness can help explain why the social anxiety behaviours expressed in the third-person perspective, but less consistently with first-person perspective. Together, our findings support that customizing an avatar and seeing it throughout the task enhances identification with the avatar, facilitates the experience of social presence, and activates self-awareness, which prompts the expression of safety behaviours.

Implications for design

Digital biomarkers embedded in a digital game can help to create new approaches for the assessment of social anxiety. Affected individuals, as well as professionals, may benefit from their use as an additional tool to assess and manage mental health. The early onset of social anxiety (around 14 years old) [208] makes timely and accurate assessments quite challenging. Early assessment, i.e., while individuals are still young and forming their identities, habits, and behaviours, may prevent the harshest outcomes [354]. However, patients, especially younger ones, may either not continue with the assessment task because it is not engaging enough [198], or because they are intimidated by the assessment process itself [189]. However, digital biomarkers embedded in games can be useful for aiding assessment if individuals consider play an appealing activity [2, 334].

Once initially assessed and in active treatment, patients often have to monitor social anxiety through ongoing assessment to ensure that treatment is working, but this ongoing assessment can be tedious for both the patient and the clinical expert [127]. Prior research on interventions for other anxiety-related mental illnesses show, that exploring the expression of anxiety within different environments can be beneficial for its reduction [478]. If patients are passionate gamers, continued assessment can happen where players spend their time anyways, i.e., integrated into games that patients play for fun and at times they find convenient. This way, they do not have to engage in further burdensome tasks that are used for tracking social anxiety levels during treatment but can provide similar insights through engaging in leisure activities, such as playing games. As such, games can be a useful addition to the mental health professionals' toolbox to address preferences of the patients.

Additionally, embedding digital biomarkers into a game creates digital biomarkers that are broadly

accessible. While with other approaches, patients might have to wear or use special sensors (e.g., an eye tracker to measure the patient's eye gaze), game-based biomarkers can be more subtle. This can further reduce stress because patients are not always confronted with the assessment itself.

With our results, we were able to show that social anxiety was measurable in a simple desktop environment without any additional immersive presentation techniques, such as virtual reality. Our results confirm and further expand prior work within virtual reality [305] by providing insights how other aspects of the user's movement within a virtual room can be used to assess social anxiety. This could potentially help patients to access services and remote assessment through the usage of digital games.

Developing Customized Games versus Harnessing the Traces within Commercial Games

When proposing game-based biomarkers for the assessment of mental health, Mandryk & Birk [335] highlighted two complementary approaches: developing custom games that place a player in a situation and monitor their response or performance using known behavioural correlates of mental health, and harnessing the traces available within natural gameplay. Our results show that embedded digital markers can be useful for the assessment of social anxiety, but we also must highlight considerations for their implementation.

Offering participants the chance to create a personalized representation of themselves was essential as the customized avatar facilitated the experience of social presence in the scene so that social anxiety behaviours would manifest. Game designers need to consider how to implement this in an assessment game. The efficacy of the customized character could be attributed to the increased identification with the avatar [58], the increased autonomy experienced as a result of being supplied customization options [58], or the increased effort in the task that results from character customization [62]. Regardless of the mechanism, our results suggest that designers should employ a third-person customized character, limiting the potential of commercial off-the-shelf games that take am alternative approach. Embedding the behaviour into custom games would allow designers to make the interface decisions themselves; however, further work needs to be conducted to determine how social anxiety manifests in differing gaming contexts.

Also, we showed the importance of camera perspective. The interplay of third-person perspective and a customized avatar increased the manifestation of social anxiety in the game; but game designers could still freely choose which camera perspective to use. It might be that increased exposure to the avatar over time and through use might compensate for the potentially reduced self-awareness of first-person perspectives, enabling more design opportunities. However, more work needs to determine how social anxiety behaviours express in commercial games. By implementing a custom game environment, designers could more readily create a helpful tool for assessment, which can be combined with other digital intervention strategies.

Finally, game designers need to carefully balance the rules, goals, and environment of the game task with the requirements of the assessment task. Otherwise, movement behaviours within the game could be triggered by a ruleset or goal of the game task and not by the player's social anxiety. Embedding biomarkers into controlled customized games more readily supports these types of design considerations, but also increases development time and sacrifices the high engagement offered by existing commercial off-the-shelf games.

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However, commercial games also come with higher risk in the potential misuse of player data, mismatch between the player's intentions (enjoyment) and the game's monitoring (assessment), and other ethical issues.

Ethical concerns about the use of in-game data

Despite the potential benefits, game-based digital biomarkers also raise several ethical concerns. The use of data derived from digital sources is part of a growing discussion [182, 274, 353, 361]. As with all digital data, game-based biomarkers require consideration of topics such as inferring identity of the patient, how results of embedded assessment are communicated to the patient, the protection of the privacy of the patient, ensuring a safe space in which to play, and the legality of gathering data unobtrusively [335]. Communicating detected mental health issues might have negative consequences for players and designers need to be aware of potential harm of reporting mental health predictions to the player. When used by qualified mental health experts, assessment data is interpreted in a context that reduces the risk of bias. Further, to apply these approaches in a healthy way, designers need to ensure that patients as well as therapists can use them in a safe environment. Applying these features to a commercial game might put players at higher risk of experiencing harm.

In addition to ethical considerations of data-driven interference, designers need to be aware of another important characteristic of in-game data: depending on the complexity of the game environment and mechanics, players may behave differently in digital games than in the physical world. Games allow players to enact fantasies [73] and try out different personalities [325]. Players may adapt their regular behaviours based on the ruleset of the game, which could bias the results of the assessment. Extensive play for the purpose of assessment should be avoided, especially in the context of social anxiety, due to the link between problematic game usage and social anxiety [395, 192, 123]. This again highlights the importance of using game-based biomarkers in collaboration with medical experts. In fact, these ethical considerations suggest that game-based biomarkers should only be used within the context of a protected patient-therapist relationship.

Limitations and future research

There are several limitations to the interpretation of the results of this study that can be addressed by future work. First, for our evaluation we used a contrived gaming task that does not compare to the rich variety of more elaborated interactions within modern games. Future work should focus on the development of more realistic tasks in custom games built for the assessment of social anxiety. Second, our evaluation modeled interaction over many repeated and controlled trials, which potentially overestimates the movement effects; classification of individual participants and in less controlled contexts both need to be demonstrated to argue for the robustness of this technique. Third, we only used one standardized questionnaire (LSAS) to operationalize social anxiety. Future comparison with other measurement tools is needed. Finally, we modeled a range of features indicative of social anxiety, using the level of social anxiety as a continuous predictor, but as noted previously, social anxiety must be assessed both through validated scales and with the inclusion of clinical expertise. However, our research identifies several in-game movement features that will further help to

unlock the potential of embedded digital biomarkers for the assessment of social anxiety.

3.3.6 Conclusion

Social anxiety is a severe mental burden but underdiagnosed due to several barriers of existing assessment approaches. Digital biomarkers within digital games may offer solutions because they allow a timely identification for early interventions, ongoing assessment during a treatment as well as lowering the barriers to access systems of care. In this study, we explored game-based digital biomarkers' effectiveness for social anxiety assessment, based on a player's interaction with and around a non-player character. The results of our study show that social anxiety manifests in several behaviours in-game, similar to avoidance behaviours from the physical world. These behaviours might be useful as digital biomarkers. In particular, social anxiety was reflected in player accuracy and the movement paths. Furthermore, this study presents the influence of customized avatars as well as camera perspective on how much social anxiety is expressed in a gaming task. With our findings, we provide new insights about how game-based digital biomarkers can be effectively used for the assessment of social anxiety, offering the benefits of early and ongoing digital assessment.

3.4 Using the found movement behaviour as a way to predict social anxiety

Manuscript 3 offers first evidence for potential biomarkers for assessing social anxiety, which are linked to the movement behaviour around a character. These biomarkers can be seen as being a rather implicit behavioural measurement because the user is not prompted directly that a measurement is happening. However, prior work outlines that preferences, such as the preferred stopping distance to others—known as interpersonal distance, may be biased by social anxiety and therefore be an potential addition to the implicit biomarkers we studied within Manuscript 3. Therefore, Manuscript 4 focuses beyond only implicit behavioural measurements, with the goal to test whether other aspects of in-game behaviour can be used as digital biomarkers for social anxiety.

3.4.1 Research Questions

Manuscript 4 aims to answer the following research questions:

- **RQ1:** Is interpersonal distance (IPD) affected by Social Anxiety in-game?

- **RQ2:** Can we use the proposed digital biomarkers, including IPD, to predict trait social anxiety of participants?

3.4.2 Design Rationale

The results of Manuscript 3 allow us to refine the task for this study to increase the strength of the assessment through in-game biomarkers. As suggested by the results from Manuscript 3, we only combined third-person camera perspective and customized avatars for further work, because in this combination most proposed aspects were significantly biased by the player's trait social anxiety. Next we decreased the complexity of the task and placed the NPC into the center of the room to avoid any influence of the movement direction that would unnecessarily complicate the analysis and prediction at the participant level. Further, we redesigned the task and included a direct interaction with the NPC rather than only bypassing it. In this version of the task, which is more similar to interaction task used in Manuscript 2, participants were instructed to find the correct elevator to deliver files to a team, and had to ask the NPC for guidance. Because prior work suggests that interpersonal distance may be biased by the perceived emotion of an approached individual, we decided to include two emotions again.

3.4.3 Solution and Steps towards the Solution

In order to provide answers to the proposed research questions, the task was split into three phases: Phase 1 focused on the interpersonal distance measurement. We ask participants to approach the NPC, which indicates their preferred distance, similar to prior work in similar contexts. When stopping, the NPC had already revealed their emotion through a facial expression, which was either neutral or angry. Phase 2 exposes the player to the emotion of the NPC within a social interaction—a conversational exchange. This exposure is used to intensify the experience of the emotion. Phase 3 replicates the task of Manuscript 3, but adapts that instead of standing next to the NPC, participants had to approach an elevator door, which was revealed by the NPC.

Through threes three phases, we are able to provide a better understanding of the explicit interpersonal distance as well as the implicit features of the movement behaviour, which may be used in concert to predict the trait social anxiety of the player.

3.5 Manuscript 4: Assessing social anxiety harnessing in-game behaviour

3.5.1 Introduction

Social anxiety, one of the most common mental problems worldwide [493, 275], is characterized by the intense fear of being exposed to the judgement of others. This intense fear may push affected individuals to withdraw from social interaction or can lead to elevated stress when facing an unavoidable social encounter [376, 268]. But this intense fear of evaluation in social contexts stands in strong contrast to the universal human need to be part of a social group and form and maintain social bonds with others [457, 149, 507]. As prior research shows, social anxiety is a highly prevalent mental illness worldwide and especially affects children and adolescents [432, 281]. Unfortunately, the characteristic social inhibition and withdrawal of affected individuals are often mistaken for shyness by others or perceived as a character flaw by the individual [238, 419]. Additionally, social anxiety and the underlying fear of any evaluation may cause individuals to avoid consultation with mental health professionals about their concerns [311]. As a result, only a minority of socially anxious individuals receive treatment [454]. Individuals seeking help have to face not only the challenges of the mental disorder and the inherent social fears themselves, but also have to overcome sociocultural barriers, such as stigmatization and discrimination of mental health problems, economic barriers [530], such as lack of financial coverage for mental health treatments, and geographical barriers (e.g., limited access to mental health care in remote communities) [383, 301].

The heavy burden of social anxiety may be decreased through early and easily accessible assessment; prior work showed that early assessment of social anxiety in adolescenthood—which is a critical time for the development of social anxiety [527, 432]—increases the efficacy of treatment and could prevent the development

of the most harmful effects [135]. Prior research suggests evidence-based assessment of social anxiety as a reliable way to identify affected individuals [481]. This approach combines information gathered from multiple perspectives to characterize the patient's concerns, develop suitable treatment strategies, and monitor the patient's response to the selected treatment approaches [516]. Assessment combines the personal perspective of the patient and the analysis of the patient's behaviour when confronted with social situations [206]. Mental health professionals utilize standardized questionnaires and interviews, in which the expert identifies concerns and the potential severity of social anxiety. While this approach is very effective in most cases, the subjective answers may be biased by several problems related to self-report measurements such as social desirability bias [101]. Within the context of social anxiety, these biases can often occur due to the desire of the patients to "please" the expert or to fit into the surrounding cultural and social context [189]. To compensate for these effects, experts analyze behavioural data either by recording the reaction of the patient while being exposed to social situations within clinical assessment or by interviewing people close to the patient [16]. However, these approaches of behavioural information gathering are time consuming, can become expensive, and further involve additional people beyond the patient and the expert, which can introduce biases and false assumptions leading to biased conclusions [139, 385]. However, any accurate assessment is prevented when socially anxious individuals avoid reaching out for support because they are ashamed of their illness or in fear of negative evaluation [311].

But prior research suggests a promising tool to assist existing techniques in assessing social anxiety: digital biomarkers. Digital biomarkers are measurable responses gathered from digital devices and used to reliably predict the incidence of a dysfunction or disorder [198, 335]. Digital biomarkers can be harnessed to predict the severity of a disease and increase the temporal and spatial resolution of recorded behaviour during an assessment [162]. Furthermore, digital biomarkers are more resistant against human bias and may be less stress-inducing for patients [476]. Through various sensors (e.g., gaze tracking [145]), platforms (e.g., social media platforms [420]), and devices (e.g., smartphones and wearables [247, 253]), researchers can access a rich source of previously unobtainable insights, recorded with minimal effort from the patient and the expert alike [512]. One subcategory of these digital biomarkers are digital behavioural markers which focus on the overall behaviour, such as movement patterns using GPS coordinates [364]. More recently, motivated to harness the popularity of digital games, researcher have started to develop ways to incorporate game-based digital behavioural markers into the context of mental-health assessment [146].

In 2019, two-thirds of the online population enjoy digital games [550], including players of all ages, genders, and ethnicities from around the world. While enjoying digital games, players produce a large volume of data that can be used to create digital behavioural markers for the assessment of mental health concerns. Mandryk and Birk [335] describe two complementary ways for developing game-based biomarkers: by harnessing in-game behaviour data, which was produced naturally through interactions with the digital game or by developing custom games that place a player in a relevant context and record their response or performance using known behavioural correlates of mental health. Within the context of social anxiety, prior research outlined several

reasons why behaviours related to social anxiety may translate into the context of a game: First, interpersonal interaction biases of the physical world have also been observed in similar player-avatar interactions [55]; second, cognition biases and the characteristic avoidance behaviour of social anxiety have been shown to manifest in-game as players of massively multiplayer online role player games (MMORPG) affected by social anxiety tend to avoid social interactions and highly challenging activities [147]. Third, prior research shows typical avoidance behaviour of social anxiety in virtual reality simulations [305]. Finally, the media equation theory suggests that people react to computers with social responses [374, 441], which likely includes how socially anxious individuals react to virtual characters.

In developing digital behavioural markers, a first step is to identify behaviours that are characteristic of the mental health concern; the next step is to determine if these behaviours can be measured reliably by a system.

Characteristic Behaviour of Social Anxiety

At the core of social anxiety is an intense fear of potential exposure to negative or positive evaluation from others [376, 491]. This fear leads to changes in an individual's behaviour, for example social withdrawal, but also in physical symptoms such as blushing, trembling, or sweating. Prior work suggests that social anxiety is one of the most common anxiety disorders with a population prevalence of 2.0% [176, 175]. This mental burden is most accurately expressed along a severity continuum where someone can experience a high level of social anxiety but not reach the threshold for a clinical diagnosis [491]. Several personal as well as environmental risk factors, such as social environment, can cause the development of social anxiety and affect how individuals could be affected by this mental burden. For example, people may experience high social anxiety only in a certain context, such as presenting in front of an unfamiliar audience, whereas the same task is less distressing with a familiar audience. Prior research emphasizes that adolescence is a critical phase for the development of social anxiety, which can grow into a chronic and generally unremitting course through a lifespan if left untreated [410, 439, 531].

Socially anxious individuals face greater difficulties forming and maintaining social relationships with others [354]. As a result of this fear, individuals tend to have fewer close friends, but are also at greater risk of being rejected or ignored by their peers. Additionally, affected individuals are also at higher risk of being victimized by others due to their lack of social competence [377]. As a way to escape this vicious circle for a moment, some socially anxious individuals develop dangerous coping strategies, such as substance abuse [95]. Untreated social anxiety can also lead to other severe mental illnesses, such as depression [521, 410].

As prior research shows, social inhibition and private anguish are inherent to social anxiety. However, these symptoms are often misinterpreted as shyness or as a character flaw of the individual rather than a mental illness [419, 253]. Also patients affected by social anxiety may avoid the consultation about their psychological problems with their physicians due to elevated experience of shame [311]. As a result, the nuanced effects of social anxiety are frequently under-reported and under-recognized. According to previous

estimations, only 35% of individuals with symptoms of social anxiety disorder receive proper treatment for their anxiety [454]. Therefore, to increase the efficacy and success rate of treatment, reliable assessment of social anxiety plays an important role in preventing serious harm [239].

Leveraging (Digital) Biomarkers for the Assessment of Social Anxiety

Mental health experts use standardized procedures that combine interviews, questionnaires, and behavioural information to achieve reliable assessment of mental health concerns. Most of the used scales, such as the Liebowitz Social Anxiety Scale [322, 29], depict different social scenarios and ask respondents to rate their fear and/or avoidance within the described situations. Other tools focus on the special needs of specific groups, such as children [151]. But there is an ongoing discussion about the advantages of evidence-based assessment, which harnesses not only self-reported perspectives but also relies on objective evidence for the mental illness. This search for evidence-based assessment approaches has fueled an interest in finding behavioural correlates that are also predictive of mental health. These behavioural correlates are often referred to as biomarkers, which are defined by the World Health Organization (WHO) as "any substance, structure, or process that can be measured in the body or its products, and that influences or predicts the incidence of outcome or disease" [502]. One example within the context of social anxiety would be the measurement of the individual's blood pressure while being exposed to a social interaction. However, prior research provides only mixed results about the benefits of biomarkers for the assessment of social anxiety. Digital Biomarkers focus on objective, quantifiable physiological and behavioural data, which are collected and measured by means of various digital devices (e.g., wearable devices) [253].

To enhance the research agenda of finding reliable biomarkers for social anxiety, researchers have identified potential cognitive and behavioural characteristics of social anxiety which could be used for the assessment of social anxiety in a gaming task. Cognitive characteristics of social anxiety include aspects such as attentional biases [416] and interpretation [356] or memory biases [202] that are affected by social anxiety. Prior work shows that socially anxious individuals prefer to maintain a greater distance from strangers [201]. Depending on the personality of an individual, these biases may cause the development of behavioural characteristics, such as the reliance and usage of avoidance and safety behaviours in the physical world [532, 347]. These behaviours include individual approaches that aim to reduce the risk of drawing attention to oneself and therefore the risk of subsequent evaluation by others. For example, individuals with social anxiety over-rehearse a speech to prevent stuttering or other feared situations in front of an audience. But excessive reliance on safety behaviours results in consequences, such as the increased experience of anxiety, as well as self-focus attention, maintenance of negative beliefs, and even contamination of social situations, as the affected individual may come across as uninterested and insecure to others [279]. Through various sensors, such as global positioning system (GPS) devices [247], gaze tracking devices [110], and skin conductance sensors [533], researchers successfully identified several promising digital biomarkers for social anxiety. Especially within virtual reality simulations, researchers have demonstrated the robustness of describing cognitive and behavioural markers

for social anxiety, mostly by simulating physical situations in the safe space of virtual reality applications [462, 111]. However, instrumenting people with contact sensors (e.g., gaze or skin conductance) limits the accessibility of the developed biomarkers. To gain the widest reach, digital biomarkers and behavioural markers should be extracted from standard interactions with computers or smartphones. One common source of engagement on computers or smartphones is through digital gaming.

Prior research has shown preliminary evidence that in-game behaviour might be harnessed for the assessment of social anxiety [146]. In this earlier study, participants were asked to bypass a non-playable character (NPC) and move towards a targeted position in the room. Speed, accuracy, and path characteristics were measured per trial. Furthermore, two common game design aspects were altered to investigate design choices that may affect the visibility of typical social anxiety behaviours in the game. The results suggested that a third-person camera perspective combined with a customized self-representation resulted in the strongest effects of social anxiety on in-game behaviour. People with higher levels of social anxiety tended to walk farther around the NPC and were less accurate in finding the final destination. This first investigation lays the essential foundation for further research about how digital behavioural markers in-game can be harnessed within digital games for the assessment of social anxiety. However, this initial work did not fully demonstrate the validity of in-game behaviours as a digital behavioural markers, as effects were shown on a trial level. To substantiate the initial evidence, we require further insights showing relationships per participant—a necessary approach for classifying individuals and suggesting the incidence of the mental health concern.

The Present Research

Given the need for digital behavioural markers to assist with the assessment of social anxiety, the accessibility and prevalence of digital gaming, and preliminary evidence that behaviours characteristic of social anxiety also manifest in digital contexts, we conducted a study with the aim of identifying promising digital behavioural markers of social anxiety, drawn from interactions with a digital game.

Our game environment involves a player using a customized self-representation to interact with a NPC through a dialogue, and to move around the NPC in the digital world. Based on previous work [146], we look for the manifestation of movement behaviours, such as moving farther around an NPC. We also introduce new measures that rely on explicit behaviours (e.g., ask participants to indicate a comfortable distance to a stranger), and not just implicit ones (e.g., the movement behaviour around a stranger), similar to prior work [306, 450]. Explicit measurements are valuable for the prediction of deliberate and controlled behaviour, whereas implicit measurements are assumed to be more indicative of less controlled and more impulsive behaviour. Within the context of in-game digital biomarkers and behavioural markers for assessing social anxiety, prior work leveraged implicit measurements, which means that these behaviours are characteristic of less controlled, more impulsive, and rather autonomic in nature. However, an explicit measurement of behaviour could also hold valuable insights for the development of further digital behavioural markers for the assessment of social anxiety. For example, interpersonal distance (IPD) describes the distance between an

individual and a stranger at which individuals are comfortable to interact [407]. Prior research shows that socially anxious individuals prefer to stand farther away in social interactions [300], resulting in a higher IPD. Therefore, the goal of this work is to answer the question of whether both explicit and implicit measurements of in-game behaviours can be harnessed as digital behavioural markers for the assessment of social anxiety. To be a reliable digital behavioural markers, measurements also must be able to identify affected individuals, a more challenging task than identifying characteristic behaviour in a single trial. As such, we model the relationship between behaviour and social anxiety at the level of participant.

3.5.2 Materials and Methods

We conducted an experiment to investigate whether aspects of an in-game movement path as well as the interpersonal distance between player and an in-game character can be harnessed for the assessment of social anxiety of players. In the task, participants were asked to deliver documents to different teams in a building.

Task Description

The task itself consists of two elements: The character editor and the assessment task; these elements will be described in the following sections.

Character Editor Prior to the in-game task, participants were asked to create an avatar for the game, as prior work shows that customized avatars not only increase the engagement with a game but also affect the expression of social anxiety in-game [146]. First, participants selected the gender of their avatar (woman, man), then adjusted major aspects of the avatar's body (i.e., height, weight, muscles, head offset, and breast size) and selected the hairstyle and skin and eye colour of their avatar. Due to technical limitations of the underlying framework for the character creation, we were not able to offer a non-binary gender option in this experiment. Next, participants shaped the head of their avatar via 34 sliders to define different aspects of the head, such as face, eye, brows, nose, mouth, chin, jaw, ear, neck. After that, participants could choose the outfit of their avatar by selecting the style and colour of clothing on the upper body, lower body, and shoes, as well as through head accessories, such as glasses, headphones, face masks, or hats (13 different options per element). To further enhance the participant's identification with their avatar, we asked participants to describe the personality of their avatar by adjusting five sliders, which each represented one personality trait based on the Big Five Inventory. The 10 items of the BFI-10 [428] were grouped into bipolar semantically anchored categories for the five traits and participants were asked to choose the slider position between the elements (e.g., calm to anxious). Participants had to spend at least four minutes with the design of their avatar. After four minutes, a button appeared on the screen that allowed participants to move to the next step of the experiment.

After customizing their in-game representation, participants filled out the Player Identification Scale (PIS) [523]. Through the PIS, we were able to determine how much participants associated their avatar with themselves on the following three dimensions: similarity, embodied, and wishful identification. These

insights were used to explain potential variance when participants may have felt they were limited in their self-expression due to the limitations of the character editor, such as the missing non-binary options as well as the lack of certain hair styles, such as curly hair styles. Figure 1 shows the character editor.

Figure 3.6: The character editor interface: First participants selected the gender (image 1), then customized their avatar's body (image 2) and outfit (image 3), and then selected their personality traits (Image4)

Assessment Task In the beginning, participants were introduced to the background story and the control scheme of the task: As new interns at a large company, participants were instructed to deliver documents to 20 teams in a large building, named after Greek letters (e.g., Team alpha). Each team was randomly assigned to one floor number. These floors were then assigned to two elevators (1-10: right elevator; 11-20: left elevator). To find out the floor number, participants were instructed to walk towards a Non-Playable Character (NPC), which stood ten meters in front of both elevators and centered in the room (see Figure 3.6), and to ask them on which floor they could find the team they were looking for. This interaction was intended to replicate a social situation with another stranger similar to prior work in the context of social anxiety assessments [146].
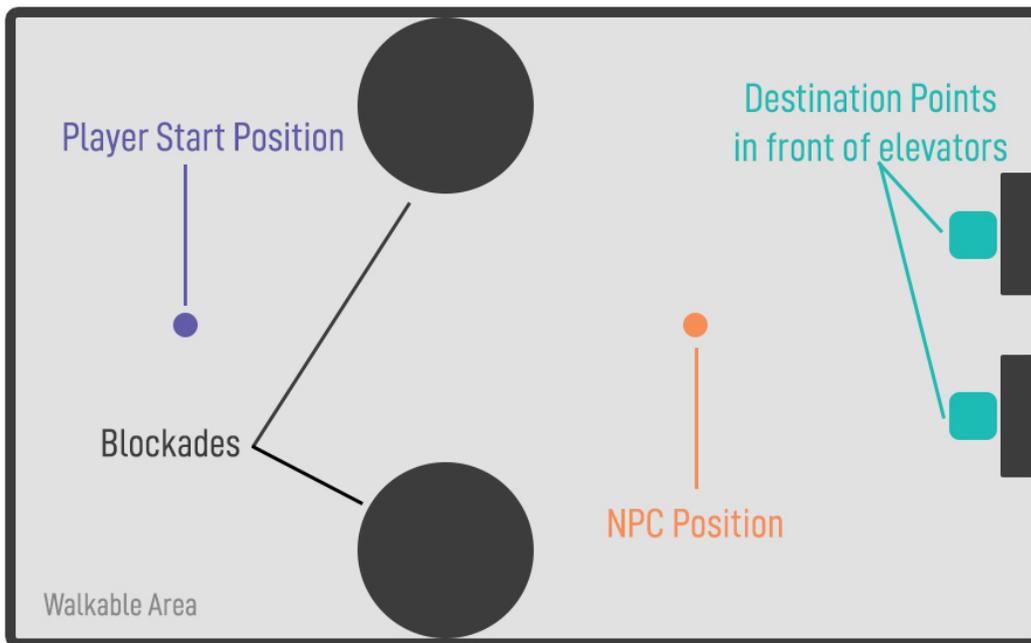

Figure 3.7: The setup of the of the assessment room: The avatar of the player stands at every trial on the purple point, the NPC on the orange point. Blockades (black) were used to guide the users' movement towards the NPC.

Once participants stood at a comfortable distance to the NPC, they had to press spacebar to start a conversation with the NPC. The NPC reacted either in a friendly, greeting participants and offering to help, or angry manner, insulting participants at the beginning of the conversation. In the conversation, the camera focused the face of the NPC and a chat interface appeared (see Figure 3.8). After either a friendly (e.g., "Hi! Nice to meet you. Let me know if I can help you.") or angry (e.g., "What do you want, idiot?") introduction, participants were asked to enter their question for the NPC, including the team name. Next, the NPC stated the floor number of the desired team in a friendly (e.g., "Team alpha is on floor 12.") or insulting manner (e.g., "Team alpha is on floor 12, idiot."). The two emotional reactions were balanced across the elevator sides over the experiment (five time for each side for each emotion). After the conversation, participants were asked to go to the elevator that led to the floor of the team. Once in front of the elevator, participants had to hit the space bar to confirm their selection. After that, we asked participants to rate the friendliness of the NPC on a scale from 0 (= "very angry") to 100 (= "very friendly"). In total, participants had to deliver 20 files (2 elevator sides x 2 emotions x 5 repetitions). For each trial (one delivery of a file), we used a distinct team name. Prior work suggested the usage of a third-person camera setup, so that the participant can see the over the shoulder of their own avatar over the whole trial to maximize in-game expression of social anxiety (because the self-representation is always visible on screen) [72, 195]. Whenever the player interacted with the NPC, the camera focused the NPC. Figure 3.8 summarizes the task implementation.

Figure 3.8: The task: First participants have to approach the NPC and then ask for directions. Afterwards they have to select the correct elevator.

The task was implemented using the Unity Engine [518] combined with the Asset-Bundle "Advanced People Pack 2" [315] and deployed in a web browser using the Bride of Frankenstein framework [257]. The asset package offers prepared 3D objects with blend shapes, which allowed us to adjust the body shape (e.g., weight and muscularity) as well as the face characteristics (e.g., the shape of the eyes). Furthermore, the package includes a suitable variation of clothing and hair styles for both genders that we could use for customization.

Participants & Procedure

The experiment was deployed online, and participants were recruited using Amazon's Mechanical Turk (MTurk). MTurk is an online platform, on which human intelligence tasks (HIT) can be offered by requesters. Workers can opt-in to these HITs. Prior researchers in different areas [258, 154, 358, 400] successfully used this platform to collect data online. However, researchers need to carefully examine the data and ensure that bots or negligent workers are removed from the final analysis [339]. Participants who were not able to play a

3D interaction game on their computers and those who left the experiment prior to completion were excluded from our data file. To avoid any behavioural bias induced by knowing the original goal of the story (e.g., white coat hypertension [476]), we used a cover story to explain why participants were engaging in this task. For this experiment, we used the cover story that the goal of the experiment is to analyze effects of lag (input lag or network lag) on performance in a 3D game. The experiment itself as well as the usage of the cover story was approved by the Ethics board of the University of Saskatchewan. The actual goal of the experiment was revealed in the debrief of the study, at which point participants could ask to have their data excluded from further analysis.

MTurk allows requesters to use predefined or custom filters, such as demographics, prior work experience or how many HITs the worker successfully finished. For this study, we recruited participants who indicated that they live either in Canada or the United States of America, had at least 500 successfully completed HITs, and had a high approval rate of previous HITs ($\vdots$ 95%).

We recorded the data of 117 participants following the work of prior work [146]. First, we identified negligent participants based on their time spent answering the trait social anxiety questionnaire (LSAS; described later) and a short summary of the experiment, which they were required to provide in an open text field after the experiment. Participants who spent less than 1.5 seconds per item in the LSAS questionnaires were removed from the sample as well as participants who provided a non-descriptive or inaccurate summary of the experiment (e.g., "This is a nice experiment") Furthermore, we removed participants who did not complete all 20 trials. After removing suspected bots and negligent participants (n = 11), we conducted our analysis with the remaining 102 participants (39 women, 62 men, 1 non-binary), aged 20-65 (M = 37.5. SD = 9.893). All participants received $8 USD compensation for participating in this study, which took approximately 40 minutes to be completed.

After providing consent, participants were provided with the cover story and had to answer one questionnaire to assess trait social anxiety and multiple aspects of their gaming behaviour, as well as their personal experience with lag in digital games (see Measurements). These gaming questionnaires were used to emphasize the cover story. Following this, the task started with the previously introduced character creation interface, in which participants were instructed to design an avatar that represented them as best as possible. After that, the assessment task started, and participants completed their 20 trials. After the assessment task, demographic information was recorded, and participants were debriefed about the goal of the study. Additionally, we offered support resources such as contact information to a crisis hotline, and a link to picture of baby animals to reduce the potential negative effect on participants in considering their individual level of social anxiety.

Measurements

Trait Social Anxiety

Participants answered the self-report version of the Liebowitz Social Anxiety Scale (LSAS) [29, 322]. The LSAS consists of 24 items, split into two categories, which describe different social situations and interactions:

social interaction (11 items; e.g., "Giving a party") and public performance (13 items e.g., "Eating in a public place"). These items are rated on two 4-point Likert scales, one to measure the fear (0 = "none", 3="severe") and a second on how often these items were avoided in the last 2 weeks (0 ="0% / never", 3 = "usually/68-100%"). The answers are summed together to estimate the level of trait social anxiety, between 0 and 144, where higher values indicate a higher level of social anxiety. Prior work suggests a score of 30 as a threshold to distinguish between non-anxious and anxious individuals, while a threshold of 60 provides the threshold that identifies a high risk of generalized social anxiety. In this sample, LSAS scores ranged from 1 to 126 (M = 58.7; SD = 28.65) with a high internal consistency (Cronbach's $\alpha = 0.97$). On average, our sample scored higher in comparison to a study with 31,243 cross-cultural participants (M=44.07) [99] as well as a study of 1007 college students in the UK (M = 34.7) [455]; However, this study is in line with prior work examining US MTurk samples (M=51.24 [147] and M=58.85 [146]), which contain workers with elevated levels of social anxiety.

Avatar Identification

In this experiment, we leveraged the avatar-related subscales of similarity, embodied identification, and wishful identification from the Player Identification Scale (PIS) [523]. Participants rated their agreement to different statements such as "My avatar is like me in many ways" on 5-point Likert scales from 0 (= "strongly disagree") to 4 (= "strongly agree"). Internal consistency was high for all subscales: similarity (Cronbach's α = 0.93), embodied (Cronbach's $\alpha = 0.94$), and wishful identification (Cronbach's $\alpha = 0.90$).

Perceived Emotion of the NPC

After each trial, participants were asked to rate the perceived emotional state of the NPC on a scale ranging from 0 (= "very angry") to 100 (= "very friendly"). This measurement was used to emphasize the reflection of the social interaction with the NPC.

In-game Digital Behavioal Markers for Social Anxiety

To assess the level of social anxiety within the digital game, we recorded the following aspects of the participant's in-game behaviour: comfortable interpersonal distance, movement features, and temporal features.

Comfortable Interpersonal Distance

As previously described, participants were asked to approach the NPC and had to press the spacebar once they reached a comfortable distance to start a conversation. We calculated the Euclidian distance between the position of the participant's avatar and the NPC when they hit spacebar to start the conversation with the NPC. This measurement is referred to as interpersonal distance (IPD). Prior research shows that individuals with social anxiety show a distance estimation bias. As a result of this bias, socially anxious individuals tend to prefer a larger IPD to other individuals, not only in the physical world, but also in virtual reality simulations [201, 300, 305]. Therefore, we expected that elevated levels of social anxiety would result in a higher IPD.

Speed & Movement Features

We measured the time in seconds from starting the trial until participants completed the whole trial (time spent in room). This time measurement includes the time in the conversation and the rating screen in the end of the trial.

According to prior research, socially anxious individuals tend to walk farther around other individuals in the physical world as well as in simulated realities, such as virtual-reality experiences [305]. Furthermore, prior work suggests several aspects of the movement behaviour in-game which can be used to identify social anxiety [148, 305]. Similar to prior work, we recorded the location of the participant's avatar in the digital world with a timestamp, sampled every 50 milliseconds after the conversation with the NPC was completed, as they approached the elevator.

Based on these samples, we calculated the following movement features, as suggested by prior work: The path length describes the absolute travelled distance per trial from the point where the conversation with the NPC started to one of the selected elevator doors.

Prior work shows that socially anxious individuals prefer to stay farther away from strangers in the physical realm [201] and also in the digital realm [300]. To confirm these findings, we measured the minimum distance between the participant's avatar and the NPC after the conversation, measured as the smallest Euclidean distance to the NPC over the whole trial. We expected that participants with elevated social anxiety will show higher minimum distances as they prefer to stay farther away and walk farther around strangers [305]. The mean distance to the NPC represents the average distance to the NPC of all recorded samples per trial. Like prior work recommends, we additionally took all samples per trial and calculated two statistics related to the distribution of the samples: skew and kurtosis. Participants walking farther around the NPC should result in an elevated (right-leaning) skew. An elevated kurtosis is reflective of a narrower distribution, which results from a more consistent path with fewer points either very close to or very far from the NPC, indicative of less exploration and more controlled movements characteristic of people with elevated social anxiety (see Figure 3.9).
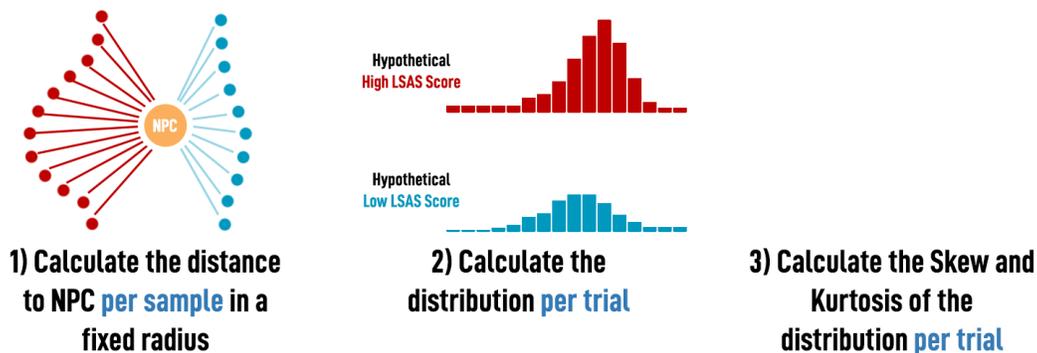

Figure 3.9: The calculation of skew and kurtosis of the distribution per trial.

In summary, we had one explicit measurement, the 1) IPD, and six implicit measurements: 2) minimal and 3) mean distance to NPC, 4) time spent in room 5) kurtosis and 6) skew of the distribution of the distances

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and the 7) path length.

Demographics

We recorded a variety of demographic factors, such as: age, gender, income, marital status, and ethnicity. Table 3.4 summarizes the details about the characteristics of the sample.

Hypotheses based on prior work

Prior work suggests that highly socially anxious participants will aim to complete the task—which includes potential social threats and performance aspects—as quickly as possible, resulting in reduced seconds spent in the task (time spent in room). Further, elevated levels of social anxiety will result in elevated levels of skew and kurtosis, as participants with elevated social anxiety will try to walk farther around the NPC and have a higher minimum and mean distance to the NPC. As a result of this behaviour, also the path length will increase as participants need to travel greater distances. Furthermore, we expect that the distance estimation bias caused by social anxiety [201] will lead to an increased IPD for people with elevated levels of social anxiety.

Analysis

Data were gathered and stored using an on-premises server and then exported once data collection was complete. All data were analyzed using SPSS 26; moderated regressions used the Process 3.4 integration. Statistical tests are described prior to reporting the results.

3.5.3 Results

RQ1: Characteristics of the Sample

We first looked at the characteristics of the recorded sample and whether players feel represented and connected to their self-created in-game representation. Table 3.4 summarizes the characteristics of our sample of 102 participants. The PIS subscales revealed that players felt that the self-representation is similar to their own visual appearance, resulting in a high score of similar identification score compared to prior work [148].

Varable	Categories	N	%	M	Sd	Min	Max
Age		102		37.5	9.89	20	65
Gender	Woman	38	38.2				
	Man	62	60.8				
	Non-Binary	1	1.0				
LSAS Score		102		58.7	28.65	1	126
Similarity Identification		102		3.015	0.7	0	4
Embodied Identification		102		2.65	0.87	0	4
Wishful Identification		102		2.27	0.95	0	4

Table 3.4: Overview of demographic information, LSAS and PIS measurements

RQ2: Is there an influence of the NPC's emotion as well as the elevator side?

First, we investigated whether the emotion of the NPC as well as the side of the destination elevator affected the explicit and implicit measurements. We used a repeated measures MANCOVA with side and emotion of NPC as repeated within-subject factors on the seven previously introduced dependent measures, controlling for age and gender. We found no significant results indicating that neither the side of the elevator (all p>.129) nor the emotion of the NPC (all p>.148) significantly affected any movement behaviours. Therefore, we merged all trials together to calculate the central tendency, using the means of each measurement, and modelled the results on the participant level. Table 3.5 summarizes the results.

Effect			Value	F	Hypothesis df	Error df	p	Partial Eta Squared
	Intercept	Pillai's Trace	0.992	1232.904	9	91	0.00	0.992
		Wilk's Lambda	0.008	1232.904	9	91	0.00	0.992
		Hotelling's Trace	121.936	1232.904	9	91	0.00	0.992
		Roy's Largest Root	121.936	1232.904	9	91	0.00	0.992
Between Subjects	age	Pillai's Trace	0.286	4.1	9	91	0.00	0.289
		Wilk's Lambda	0.711	4.1	9	91	0.00	0.289
		Hotelling's Trace	0.406	4.1	9	91	0.00	0.289
		Roy's Largest Root	0.406	4.1	9	91	0.00	0.289
	sex	Pillai's Trace	0.182	2.252	9	91	0.025	0.182
		Wilk's Lambda	0.818	2.252	9	91	0.025	0.182
		Hotelling's Trace	0.223	2.252	9	91	0.025	0.182
		Roy's Largest Root	0.223	2.252	9	91	0.025	0.182
	emotion	Pillai's Trace	0.067	0.726	9	91	0.684	0.067
		Wilk's Lambda	0.933	0.726	9	91	0.684	0.067
		Hotelling's Trace	0.072	0.726	9	91	0.684	0.067
		Roy's Largest Root	0.072	0.726	9	91	0.684	0.067
Within Subjects	side	Pillai's Trace	0.3	0.316	9	91	0.968	0.030
		Wilk's Lambda	0.970	0.316	9	91	0.968	0.030
		Hotelling's Trace	0.31	0.316	9	91	0.968	0.030
		Roy's Largest Root	0.31	0.316	9	91	0.968	0.030

Table 3.5: The results of the RM-MANCOVA

RQ3: Can we predict the participant's trait social anxiety through in-game behaviour?

To find out whether the proposed measures can be used for assessing the social anxiety of a player, we conducted hierarchical linear regressions for each measure to analyze whether it predicts trait social anxiety, expressed by the LSAS score [186, 322]. We included age and dummy-coded gender (-1=man; 1=woman, removed 1 non-binary participant) in the first block, and the movement feature in the second block, with LSAS as the dependent measure. We report unstandardized regression coefficients (denoted as B) and standardized regression coefficients (denoted as β). In all models for which the feature was significantly predicting social anxiety, the model fit was significant.

The results show that most of the proposed in-game biomarkers were useful for the prediction of trait social anxiety. As expected and suggested by the literature [201, 407], the interpersonal distance shows that players with elevated social anxiety explicitly prefer to stop at a larger distance when approaching an NPC. Furthermore, kurtosis and skew indicate that individuals with elevated social anxiety tend to maintain a consistently farther route around the NPC and avoid any close distance to the NPC, as the minimum distance to the NPC shows. Contrary to prior work, the complete length of the path starting from the recording of

	B	β	p	R	R2	p (Model)
Interpersonal Distance (IPD)	**7.637**	**0.199**	**0.044**	**0.307**	**0.094**	**0.022**
Time Spent in Room	**0.386**	**0.229**	**0.023**	**0.308**	**0.095**	**0.01**
Kurtosis	**10.895**	**0.217**	**0.027**	**0.319**	**0.101**	**0.015**
Skew	**27.482**	**0.0236**	**0.019**	**0.328**	**0.107**	**0.011**
Minimum Distance to NPC	**15.859**	**0.267**	**0.008**	**0.348**	**0.121**	**0.006**
Mean Distance to NPC	4.571	0.068	0.507	0.244	0.59	0.113
Path Length	1.299	0.093	0.379	0.249	0.062	0.1

Table 3.6: The regression results. B denotes unstandardized regression coefficients, β standardized coefficients. Significant results are highlighted.

the IPD to the selected elevator door, shows no significant relationship with LSAS. Also the mean distance between the player's avatar and the NPC indicated no significant relationship with LSAS once modelled on the participant level. Figure 3.10 visualizes these results.
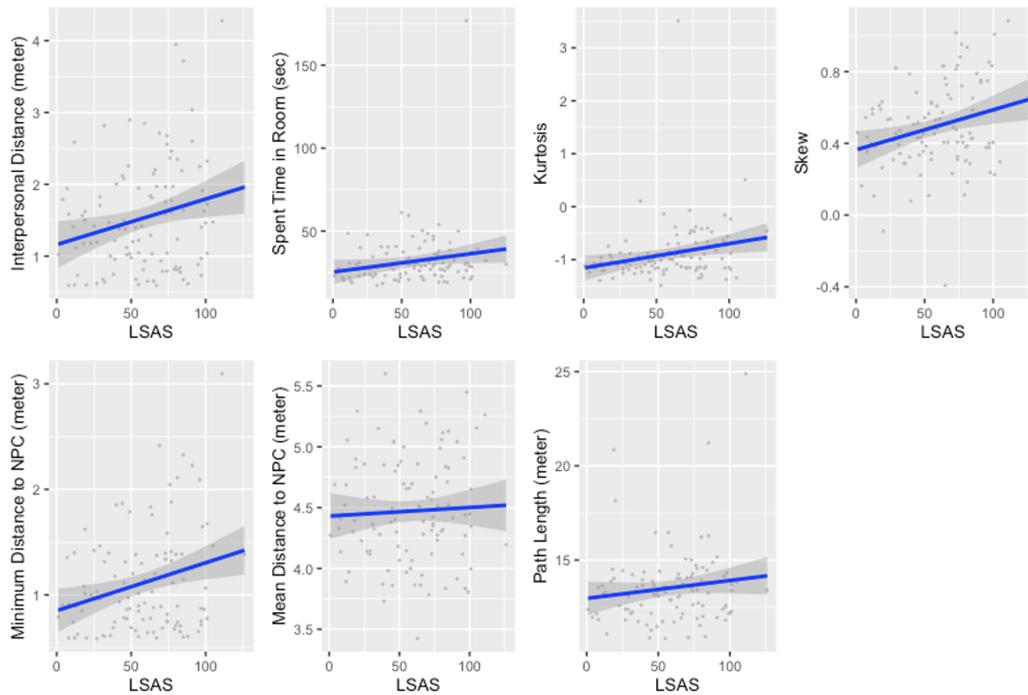
Figure 3.10: Scatter plots of the regression results for all proposed features

3.5.4 Discussion

Summary of the Results

In summary, the results of this study confirm that characteristic behaviours of social anxiety appear within the realm of digital games. We show that higher levels of social anxiety result in a biased movement pattern expressed by an increased kurtosis and skew as well as increase in the minimum distance to the NPC. Additionally, we show that the characteristic preferences of social anxiety are also expressed by players prior

to interacting with the NPC, as displayed in the increasing interpersonal distance. Contrary to prior work, the mean distance to the NPC as well as the path length around the NPC were not significant predictors for social anxiety.

Explanation of Findings

In line with prior work, the results of this study show that explicit and implicit behaviours characteristic to social anxiety that have been observed in the physical world may also manifest in-game.

According to prior work in the physical world, as well as in virtual reality simulations, individuals with elevated social anxiety show that they prefer a larger physical distance between themselves and other individuals. Socially anxious individuals have also been shown to prefer less intimidating communication platforms, such as online chats [358] over voice or in person meetings. Within the context of digital games, players affected by social anxiety have been shown to be drawn towards games with a focus on playing together with others, such as Massively Multiplayer Online Roleplaying Games (MMORPGs); however, even in this context, the characteristic preference for distance towards others appears and biases the players' preferences. Players with an elevated level of social anxiety withdraw from social activities in-game and avoid highly challenging tasks to avoid any potential exposure to the judgement of other players [147]. The results of our study contribute a similar result: socially anxious participants showed that they prefer greater distance between themselves and NPCs in-game, similar to within the physical world. However, this preference bias induced by social anxiety also appears in our study as what may be characterized as some visible strategies, similar to safety behaviour techniques in the physical world. Prior work provides evidence for a distance estimation bias of socially anxious individuals. This bias may cause individuals to walk farther around another individual to not harm the personal space of another person as previously discussed. This study demonstrates similar behaviour in the digital realm, which may stem from a similar strategy, or may be a habitual transfer of behaviours from the physical realm into the digital one.

A potential explanation for why social anxiety may trigger avoidance and preference biases that we observe in movement patterns may come from the elevated experience of self-awareness intensified by social presence; experiments in which socially anxious patients had to interact in front of a mirror show an association between experiencing social anxiety and elevated self-awareness [195]. This increased self-awareness plays an essential role in the maintenance of social anxiety, because socially anxious individuals are highly aware of their self-presentation to avoid any negative consequences [72]. In our study, the third-person camera perspective can be seen as a mirror which shows the player's action within the digital realm of the game. Additionally, this effect is intensified through the use of a customized self-representation in the game. The combination of both resulted in prior work in the strongest expression of social anxiety within the game. Therefore, this study may provide more evidence for the hypothesis that customizing the own avatar and seeing it throughout the whole task enhances identification with the avatar, which triggers self-awareness and prompts the expression of safety behaviours.

Furthermore, the usage of customized avatars may enhance the experience of social presence [47]. Social presence describes the experience that others are sharing the digital space with the player [178]. For the therapeutic effectiveness of digital interventions for social anxiety, the experience of social presence plays an essential role, because the experience of social presence may be more predicative of social anxiety responses than the self-reported experience of physical presence in a virtual world [119]. For example, prior work shows that participants experienced elevated social anxiety when their self-representation looked more similar to themselves [25, 525]. Also, social presence may also intensify the self-awareness of participants which may cause even stronger expression of social anxiety within the digital realm. Customizing avatars has also been recently shown to enhance fear within an exposure task for social anxiety [146]; the authors show that the customization enhances identification with the avatar, and speculate that customization enhances the invested effort and engagement in the task. In our study, all players customized their avatar, which may have helped reinforce the perception that they themselves were interacting with the NPC, aiding in the transference of behaviours and coping strategies common in physical spaces into our game.

Digital behavioural markers embedded in a gaming task may help to develop new approaches for the assessment of social anxiety, which may offer many benefits for health professionals as well as the affected individuals. Early assessment, such as when individuals are still young and developing their identities [208], habits, and behaviours, may prevent the harshest outcomes of social anxiety [354]. However, a common challenge for the assessment is the risk of attrition due to waning of the patient's motivation to continue with the process. Game based assessment may help to increase the engagement of patients who enjoy playing video games [58, 335], which is not only limited to younger generations, as the still growing popularity of digital games in older generations suggests [172]. These customized games may offer an easily accessible screening tool in combination with other existing tools as well as a way for continuous monitoring of the current progress in a treatment. However, researchers as well as developers need to be aware of several ethical implications when harnessing digital biomarkers in a gaming task.

Ethical Implications

Despite the suggested benefits of digital biomarkers in general within a digital game, the growing discussion about the appropriate usage of data derived from digital sources raises several ethical concerns that are part of an ongoing discussion [182, 274, 361]. When harnessing digital biomarkers, we need to ensure the protection of the user's privacy as well as the creation of a safe space for the patient grounded on a legal basis. The communication about measured (mental) health issues might have negative effects for the patient, and experts need to be aware of the potential harm the communication can cause for the player. When deployed by mental health experts, assessment data is interpreted within a safe context that can lower the risk for a biased interpretation of the results of the assessment. Additionally, to leverage these approaches in an appropriate and healthy manner, developers must ensure the safety of the patient as well as the therapist while using such tools.

However, designers of these applications need to balance the enjoyment of the digital game and the requirements of an effective assessment. Depending on the complexity of the game mechanics as well as the context of the game, players may behave differently in the digital realm as compared to the physical. As prior work outlines, games allow players to explore and enact different roles or fantasies, which guides them to behave differently. Furthermore, excessive play of video games should be avoided especially within the context of social anxiety. Prior work emphasizes a relationship between problematic gaming behaviour and social anxiety [312, 123]. However, this relationship highlights the potential of using game-based biomarkers applied by medical experts for assessing social anxiety. Overall, these techniques should only be applied within a health and safe patient-therapist relationship.

Limitations and Future Research

There are several questions future research may address in further follow-up investigations. First the lack of non-binary representation; although only one participant identified themself as non-binary, future research should overcome the technical limitations of the used framework to offer participants a non-binary character option, which will allow them to identify themselves with their character. Second, we must consider the influence of culture on the expression of social anxiety. This work focused on the development of digital behavioral markers for characteristics linked to social anxiety in a western context. However, the literature suggests the differentiation of social anxiety and Taijin kyofusho [278] which, in comparison to social anxiety (disorder), focusses on the fear of embarrassing or offending another person rather than embarrassing oneself in front of others. Furthermore, the preference of the interpersonal distance may also be biased by the cultural background, where the shape of what constitutes personal space varies over different cultures. Therefore, future research may investigate the effect of the cultural background on the expression of social anxiety behaviour within the digital realm. Third, we acknowledge the lack of comparison to other mental illnesses. Prior research suggests a comorbidity between different mental illnesses, such as Autism and Social anxiety. Therefore, future work may investigate if related mental illnesses will be expressed differently through the proposed in-game digital behavioral markerss. However, this paper further confirms that prior suggested in-game movement behaviours and preference features embedded into a game can be used for assessing the personal level of social anxiety.

3.5.5 Conclusion

Social anxiety, one of the most common mental disorders worldwide, is underdiagnosed due to several barriers induced by the disorder as well as by existing assessment approaches. However, prior work suggests digital behavioral markers embedded in a gaming task to complement existing assessment techniques. These behavioral markers allow for a timely identification for early intervention, ongoing assessment during an intervention and lowering barriers to access systems of care, due to their broad accessibility and low cost. This study replicated previous findings that movement behaviours characteristic of people with social anxiety

also manifest in digital spaces, and also provides new evidence that digital biomarkers within a game can be harnessed to assess the personal level of social anxiety. Specifically, the player's preferred distance from an NPC prior to interaction as well as altered movement path around the NPC after interaction were able to predict social anxiety. However certain aspects of the movement path, such as the length of the path, were less useful as they were strongly affected by the surrounding game environment. The presented findings confirm prior research showing how game-based digital behavioral markers can be effectively used to assess social anxiety and offering the benefits of early and ongoing digital assessment for the mental health expert and the patient.

3.6   Summary

Manuscripts 3 and 4, the core of this dissertation, describe the development of potential digital biomarkers, based on the in-game behaviour of players. First, Manuscript 3 explores potential of a variety of in-game movement behaviour, based on existing work about how movement behaviour is altered by social anxiety in VR simulations as well as the known biased distance estimation. As Manuscript 2 showed that the experience of social anxiety in-game may be altered by the self-representation in-game, Manuscript 3 investigates further and explores how the camera perspective (how the player sees the game) and the self-representation (how is the player represented in-game) affects the expression of social anxiety in a gaming task. Manuscript 3 shows that several aspects of the movement around a NPC is biased by social anxiety, leading to an increased distance towards the NPC, more errors when finding a position close to the NPC, as well as a further movement around the NPC.

Building on these findings, Manuscript 4 expands on these findings: On one side, the proposed yet complex setup of the task was reworked and became more streamlined. Furthermore, Manuscript 4 adds interpersonal distance as an additional measurement of the potential biases in the distance preferences of socially-anxious players. Further, Manuscript 4 replicated the findings of Manuscript 3 and shows that IPD, as well as the characteristics of the movement path around the NPC, can be used as predictors for trait social anxiety of the player.

3.7   Contextualisation

The evidence we found for the manifestation of social anxiety in-game within Manuscripts 1 and 2 were confirmed within Manuscripts 3 and 4: As shown, social anxiety not only affects the player's preferences in the physical world but also in the digital world. Further, social anxiety manifests in-game in a similar way as in the physical world, resulting in similar patters of avoiding close distances towards a stranger and stopping at an increased distance to them. Further, we confirm that not only the self-representation, but also how the player sees the game, affects how much they experience social anxiety in-game, resulting in an increased expression of social anxiety. Manuscripts 3 and 4 form the core of this dissertation: They propose potential

behavioural biomarkers in-game and provide first evidence for the reliability and robustness. However as a final step towards the development of behavioural biomarkers in-game, Manuscript 5 uses these same biomarkers to investigate whether socially-fearless individuals—the opposite of socially-anxious individuals—show the opposite behaviour resulting in opposing biomarker indications of mental health concerns.

4 Extension: The assessment of psychopathic traits by harnessing in-game behavioural data

As shown in prior work, several aspects of in-game movement behaviours can be harnessed as a way to help assess social anxiety. However, the question remains how other mental health concerns or related contexts may use digital behavioural makers within the context of assessment. As previously described, social anxiety shows many overlaps and relationships to other mental disorders, such as depression and substance abuse. Further, some personality traits, such as psychopathic traits, have been described as the "opposite to social anxiety" [245]. To better understand how the proposed digital behavioural biomarkers can be applied in mental health assessment overall, we decided to apply our found digital biomarkers within the realm of psychopathic character traits in Manuscript 5. The goal was to see whether the conceptualized opposite to social anxiety may manifest as well in the opposite in-game behaviours, compared to the findings of Manuscripts 3 and 4. These insights may also help future researchers to apply the proposed concepts of the prior work into their realm to develop their own game-based assessment techniques.

4.1   Problem and Motivation

Like social anxiety, psychopathy has also been associated with problematic in-game behaviour, as well as problematic gaming usage. Psychopathy is often characterized by the "triarchic" model that contains three core qualities: Impulsivity or disinhibtion, boldness, and meanness [403]. Similar to other personality traits, psychopathy is also expressed on a spectrum where the extreme end has been associated with personality disorders or even criminal activities. Further, social anxiety and psychopathy have been suggested to exist on one shared spectrum: Hofmann et al. [245] propose that social anxiety and psychopathy can be mapped on a single spectrum, ranging from socially fearful (social anxiety) to socially fearless (psychopathy).

In the context of digital games, elevated levels of psychopathy may be expressed through behaviour which can be seen as toxic by other players, like toxic language or violation of the personal space. However, it is not clear whether psychopathic traits also manifest in-game. On one hand, prior work as well as the previously introduced manuscripts show that personal beliefs, motives, and even the level of self-esteem may transfer from the physical space into the digital realm. However, other research challenges these results and suggests that players may engage with games in order to explore other roles and identities or even express their ideal-self through their in-game behaviour. Therefore, Manuscript 5 investigates the relationship between in-game

behaviour and psychopathic character traits, based on the "triarchic" model of Patrick et al. [403]. In prior work, we focused on avoidance reactions of socially-anxious individuals. However, there is some evidence that other more aggressive reactions towards social stress may be a way in which social anxiety manifests [221, 327]. Insights into how socially-fearless individuals may help future researchers to better understand this sub-genre of social anxiety.

4.2   Research Questions

To better understand how useful the suggested digital behavioural markers are in the context of psychopathy, the suggested opposite to social anxiety, Manuscript 5 investigates the following research questions:

- **RQ3.1:** Do psychopathic character traits affect the perception of emotion in-game?

- **RQ3.2:** Do elevated levels of psychopathic traits lead to a more rude communication in-game?

- **RQ3.3:** How do psychopathic character traits affect the interpersonal distance in-game as well as the movement behaviour around a stranger?

4.3   Design Rationale & Solution Description

Within the context of social anxiety and psychopathy, there is an ongoing discussion about whether both phenomena can be seen on one continuum [245, 137]. Based on these insights, we hypothesize for this manuscript that psychopathic traits may lead to the opposite behaviour of socially-anxious players: Players with elevated psychopathic traits may stand closer to the NPC and walk closer around the NPC. Based on the results of Manuscripts 2 and 3, we decided to offer only customized avatars as well as a third-person perspective in-game as this combination has shown the strongest effects. Further, we followed a similar protocol like the prior manuscripts and ran a crowd-sourced online study. In this study, 385 users participated and were recruited using Amazon Mechanical MTurk [12] and Prolific [425].

To answer the prior introduced research questions, we adapted the task of Manuscript 4 for this task and implemented the same game mechanic: Players were first exposed to the NPC's emotion, then were required to approach them and stop at a comfortable distance (similar to IPD measurement tasks of the literature about psychopathic traits and the violation of personal space [546]. Next, players had a chat with the NPC and asked for direction to the appropriate elevator door. Then the NPC answered the player either using friendly or angry language. Finally, players had to approach the final destination. These task components allowed us to assess the following in-game behaviours: The in-game movement around the NPC, the preferred interpersonal distance, the communication, and the perception of the NPC's emotion.

4.4 Manuscript 5: (Don't) stand by me: How trait psychopathy and NPC emotion influence player perceptions, verbal responses, and movement behaviours in a gaming task

4.4.1 Introduction

Social interactions within gaming—whether they be teaming up to fight a boss, competing against each other for resources and bragging rights, or emoting together in gaming lobbies—have helped propel multiplayer gaming into one of the most popular leisure activities [172]. Despite the many known benefits of social play (e.g., providing social support [515, 408], combating loneliness [154], and improving well-being [333]), social interactions within games can also cause harm (e.g., facilitate social exclusion [59], and expose players to verbal abuse [173] or cyberbullying [391, 302]). When players experience harm from interactions with other players, it can negatively affect their game enjoyment [517, 460] and performance [367]. Game companies are also affected, as harmful social behaviour has been shown to contribute to churn, when players who are exposed to harm leave the game in search of more benevolent gaming communities [398, 460].

Previous work looking to understand the origins of harmful social behaviour in online games has examined personality traits, which are then linked to specific harmful in-game behaviours. For example, the traits of toxic disinhibition [287] and moral disengagement [48] have been shown to predict toxic behaviours and rationalizations of harmful actions in online gaming contexts. In considering harmful social behaviours within

games, researchers have investigated a variety of personality traits, such as online disinhibition [48], social anxiety [312], and sadism [205]. However, outside of gaming contexts—such as in groups of workers [504], students [86], and within relationships [130]—researchers who investigate personality traits associated with harmful social behaviours often assess trait psychopathy [402, 488].

Psychopathy is characterized by a lack of remorse, an inability to feel empathy, and a degree of ruthlessness with a tendency to exploit others and violate social norms [222]. Although at its extreme end, people very high in psychopathic traits have been associated with personality disorders [64] or criminal activity [482], psychopathy is a personality trait that exists along a spectrum [488] in which the trait varies in severity from low to high within the general population. The "triarchic" model [403] of psychopathy suggests that the construct is comprised of three qualities: impulsivity or disinhibition, boldness, and meanness. For example, people low in meanness tend to be kind, sincere, and sensitive to the feelings of others, seeking to provide aid to those who are hurting or in need; whereas, people high in meanness tend to be egocentric, insensitive, and lacking in affection, expressing contempt for weakness and indifference to the suffering others [403].

Outside of games, elevated psychopathy has been associated with specific behaviours that are typical of harmful social interactions within gaming contexts; for example, retaliation for perceived provocation [261], swearing [503], harassment [369], trolling (in online dating contexts) [336], and violation of personal space [548, 546]. In the context of digital gaming, it is possible that elevated psychopathic traits might manifest in in-game behaviours that may be considered harmful or toxic by other players, such as toxic language or the violation of personal space. Research does show that people carry their beliefs [81], personalities [563], motives [418], and even their level of self-esteem [60] into their gaming behaviours. However, there are also reasons to believe that psychopathic traits may not manifest in gaming spaces as players are also known to sometimes behave unlike their material-world selves, as game worlds allow for the enacting of different identities [387] or expressions of ideal-self [426, 53] within the magic circle afforded by games [248]. As people high in psychopathy often present themselves as charming to others [509], their in-game responses may also follow this pattern. The little work that has investigated links between psychopathy and gaming has focused on elevated interest in violent games [205, 254, 210] and not on behaviours that manifest during gaming.

To inform our understanding of how psychopathic personality traits—i.e., boldness, meanness, and disinhibition—manifest in social interactions within gaming contexts, we first assess these traits and then measure how they affect social perception and social in-game behaviours toward a non-player character (NPC) after exposure to neutral and negative social interactions. Specifically, we assessed participants' (n=385) trait-level boldness, meanness, and disinhibition using a validated scale of tripartite psychopathy [403], and asked them to engage in a series of social interactions with an NPC in a game scenario. The NPC was either neutral in its emotional display (facial expression and body emotes) and dialogue, or was angry and insulting. Participants approached the NPC, asked them a question relevant to the game scenario using a text box, and then moved their avatar around them to access elevator doors. We measured the participants' perception of the NPC's emotion, the social content and prevalence of swearing within their dialogue, the interpersonal

distance (IPD) at which they initiated dialogue with the NPC, and movement path characteristics as they moved around the NPC.

Our findings indicate that psychopathic traits affect various aspects of in-game behaviour. We observed that:

- Players with higher boldness and meanness rated the emotion of the NPC as more angry, regardless of its emotion; for disinhibition, this relationship only held for the angry NPC;

- Players with lower boldness, meanness, and disinhibition used more social words in their interactions with the NPC, and this relationship was stronger for the neutral NPC;

- All players used more swear words for the angry than the neutral NPC; however, when interacting with the angry NPC, players with higher boldness also used more swear words;

- All players regulated their interpersonal distance to the NPC based on its emotion, stopping farther from the angry NPC than the neutral one;

- Players higher in boldness and lower in disinhibition stopped closer to the NPC in general;

- When interacting with the angry NPC, players higher in meanness stopped closer to the NPC;

- Players with elevated boldness and meanness altered their movement path around the NPC, staying consistently closer to the NPC when moving past them.

Games research continues to produce evidence suggesting that players carry their social habits, biases, and interaction styles with them into digital games—whether these personal dispositions yield benefit or harm to others. Our findings provide new insights into how trait psychopathy manifests in social behaviours within digital games, expressed in our study through player perceptions, use of language in communicating with the NPC, and violation of the NPC's personal space. An initial step in preventing problematic gaming communities is to understand how, and for whom, harmful social interactions unfold. Our work adds to this understanding, with the hope of leading toward safer gaming spaces that all players can access to receive the myriad benefits of social gaming.

4.4.2 Related Work

We will present the underlying related work from three related perspectives: Gaming as a way to socialize, trait psychopathy, and behavioural biases from psychopathy.

Gaming as a way to socialize

Social needs and the feeling of belonging are essential for human beings. Over the last decades, digital games have become a popular way to socialize with others [159]. However, there is an ongoing debate whether socializing through digital games is desirable, stemming from the still existing stereotype of "gaming nerds"

with low social competences who are mostly lonely and socially isolated [290, 465]. In particular, some research argues that in-game relationships are potentially of low-quality in terms of providing social support [83] or that in-game social bonds may displace physical-world social ties [496, 290]. However, in-game relationships should not necessarily be valued as of "lower" quality than physical ones [154, 292]. Through the lens of well-being, research has shown that in-game social interactions are positively associated with the player's self-esteem [53], perception of social competence [294], reduction of loneliness [337, 132], and increased relatedness [154]. However, when investigating the interplay of relationships enacted within physical or digital spaces, researchers have suggested that the line between physical and digital friendships has become blurred in recent years: Online platforms, such as digital games, have become a powerful tool to maintain existing social connections and to spend time together over a distance [154]. Further, many players form new social ties in digital games that eventually get transferred into the physical world [515].

Many online games feature multiple ways to socialize: Usually, players get access to multiple chat channels in-game as well as on gaming platforms, such as the Epic Games client, Steam, U-Play, or Origin, that provide stores but also social features [147]. In-game chats are adapted to the situation of the game, where chats exist for the local environment, globally, and for teams. Furthermore, many online games include a self-representation of the player, called an avatar. Through this avatar, players can also express themselves, for example through custom animations or poses to react to certain in-game events. Prior work shows that players with a customized avatar feel more socially present within the digital realm [178]. Social presence describes the phenomena that players feel that other entities in the game are human beings, which can help to satisfy their need to socialize [178].

Even though socializing in games may be beneficial [337, 132, 154], there are growing risks of experiencing anti-social behaviour online: Interactions online are not always friendly and helpful but can also be negative or even "toxic" [302]. In a recent literature review, Moor et al. [369] described how personality traits may link to antisocial online behaviours, such as cyberbullying, trolling, or other forms of harassment that found their way into the realms of digital gaming. These antisocial behaviours can have many severe consequences for the targets [522] and harm the overarching gaming community in the long term [564].

Although digital games have an inherent escapism component that allows players to assume roles and identities unlike their physical-world realities [387], Eastwick et al. [165] provide evidence that social biases, such as racial biases, may transfer from the physical into the digital world, suggesting that similar transfer is possible for personality traits that could predict harmful behaviours, including psychopathic traits.

Psychopathic traits

To better understand harmful behaviour within multiplayer online games, we consider the personality trait of psychopathy, characterized by a lack of remorse, an inability to feel empathy, and a degree of ruthlessness with a tendency to exploit others and violate social norms [222, 85]. Recent discussions regarding the concept of psychopathy lean towards a multidimensional conceptualization that includes "successful" psychopathy,

which does not limit the concept to clinical populations, focuses on socially adaptive/non-adaptive traits, and includes research in non-clinical populations [402]. In this conceptualization, psychopathy manifests in social interactions as a tendency to show superficial charm, grandiose overconfidence, and a lack empathy with a tendency to exploit others. Furthermore, Patrick et al. [403] suggest an alternative but similar perspective on psychopathy, in which the construct of psychopathy is comprised of three distinct phenotypic constructs: boldness, meanness, and disinhibition. Boldness focuses on the aspects of social dominance; Meanness is characterized as aggressive resource seeking where others are ignored; and Disinhibition reflects a general tendency towards impulsive behaviour [402, 403].

Although there has been significant work on social harm within multiplayer games (e.g., see [240]), the relationship between trait psychopathy and gaming is underexplored. In experiments using econometric games, participants with higher levels of psychopathic traits show adaptive social behavior; they are less sensitive to unfair behavior of others [389] and achieve relatively higher game scores, sometimes by exploiting social game mechanisms [365]. In the context of digital gaming, people higher in psychopathic traits have also displayed an elevated interest in violent games [205, 254]. Further, Tang et al. [506] show that psychopathy relates to increased motivation to play online games and problematic gaming use. This is partly motivated by escapism, but more surprisingly also by a motivation to engage in social activities. At first, this may seem paradoxical, but psychopathic traits do not foster long-lasting social bonds but weak ties that are instrumental in attaining short-term social gains [506]. These results on how social relationships are formed within digital games mirrors findings from real-world social interactions [32]. Therefore, psychopathic traits can be considered a multidimensional personality trait with socially adaptive and non-adaptive effects that change how players make use of social aspects in online social games.

Behavioural biases from psychopathic traits

Prior work has suggested several biases regarding the behaviour of people with psychopathic traits, including the perception of emotion, communication strategies with others, and behaviour within and around the social space of others. Here, we present several of these biases relevant to the context of online gaming, in which players are expected to react to other players, communicate with them, and move in a 3D space around others.

Biased Perception of Others' Emotion: In the context of psychopathic behaviour, prior research suggests there is evidence that psychopathic traits may cause a biased perception of others' emotion: Researchers found that children with psychopathic traits have more trouble recognizing sad and fearful facial expressions and sad vocal tones [500]. Blair et al. [66] show that individuals with psychopathic traits need more intense stimuli to detect the emotion in facial expressions. Further, individuals with elevated psychopathic traits were shown to be less accurate in detecting disgust [288], fear [66], and sadness [158] in images [368]. According to Blair's emotion-based theory of psychopathy [65], this deficit is caused by the lack of experience with fear and sadness of others being something averse to avoid, resulting in individuals with psychopathy failing to learn how to avoid causing these emotions [224]. Additionally, prior work suggests that individuals with

psychopathic traits may also be less affected by negative conditioning, such as through fear [326] or stress [204].

Communication Characteristics:

Prior work characterizes the communication style of individuals with higher levels of trait psychopathy as more aggressive, including the more frequent use of angrier facial expressions as well as emotional gestures and body language [509, 200]. However, prior work focusing on communication skills in the work environment shows that managers with psychopathic traits show good communication skills but also a lack of teamwork and low performance ratings [26].

Personal Space and In-game Movement: When interacting with strangers, we keep a personal space around ourselves, which is not to be intruded on by others. Prior observational studies suggest four circular regions of egocentric spaces, defined by increasing radii, which are reserved for social interactions, referred to as proxemics: Intimate proxemic for partner or family (0–45 cm), personal proxemic only entered by close friends (45–120 cm), and social proxemic for interaction with strangers (120–365 cm) [219, 545]. More recently published experimental investigations revealed a slightly smaller personal space with a radius of one meter [230]. Violation of personal space norms can cause discomfort and arousal [547, 228], along with counter reactions to balance the distance to the other by stepping farther away, aborting the social interactions [487], or signalizing to the other person to move away by body realignment, angry facial expression, or gaze aversion [17].

An explanation for why people approach or try to stay farther away is offered by Approach-Avoidance-Theory [117]: Approach behaviour is characterized by an energy and direction towards positive concepts such as motivation, reward, or incentive. Avoidance behaviours are focused on keeping away from any negative consequences, punishments, or other social threats [548]. According to this definition the average person would approach a social situation in which others are sending positive and welcoming signals; however, they would also avoid social encounters that are perceived as hostile or potentially harmful. Personality traits affect approach-avoidance motivation and thus can shift preferences for appropriate interpersonal distance as well as perception of others' social spaces: Research about social anxiety, which is characterized by the fear of social interactions and judgement of others [491, 322], suggests that socially anxious individuals perceive others as relatively too close. This biased distance estimation causes social anxious individuals to prefer a larger distance to others. These preferences can also transfer into the digital realm, such as virtual reality simulations [305] and desktop applications like video games [146]. As a result, it is possible that similar transfer happens for psychopathic traits, which is also evidenced by prior work.

For example, Welsch et al. [548] show that individuals with elevated psychopathy traits may violate others' social spaces in a virtual reality simulation, depending on their facial expressions.

In summary, prior work shows that people higher in psychopathic traits—i.e., boldness, meanness, and disinhibition—may satisfy their needs for social interaction through online gaming. However, prior work does not provide enough evidence as to whether or not typical antisocial behaviours associated with psychopathy manifest within digital games.

The Scope of this study

Social interactions in games are important but can sometimes be harmful. To address harmful social interactions and make games safer and healthier environments, it is important to understand the origins of such behaviours. Prior work has suggested psychopathic traits as constructs that can explain harmful social behaviours in the physical and digital world. While there is evidence that personality traits from the physical world manifest in digital worlds, including within games, this has not been studied for psychopathic traits. To address this gap, we conducted a study exploring whether trait boldness, meanness, and disinhibition affect perceptions of, verbal responses to, and movement behaviours.

4.4.3 Methods

We conducted an online experiment to investigate how boldness, meanness and disinhibition manifest in a social interaction in a gaming task. Participants' main task consisted of interacting with a non-player character (NPC) and moving to a given destination point. The experiment consisted of three blocks: 1) a character editor, 2) a gaming task, and 3) answering questionnaires about personality traits as well as demographic information. Although we considered using a social interaction with another player, or a confederate player, we chose to use an NPC to better standardize the experience across trials and participants, as little is known about how trait psychopathy expresses in gaming behaviours.

Character editor

As a first step in the experiment, participants had to create a customized avatar for the gaming task. Prior work shows that customized avatars lead to many improvements in terms of game experience, but also increase the player's social presence as well as the connection between the player and the in-game content [58, 264, 61, 146]. In the character editor, participants had to select the avatar's gender, adjust the height, weight, muscle, head offset, and breast size for the avatar's body, as well as hair-, eye-, and skin colour. Next, participants had to shape the avatar's face using 34 sliders to adjust the distinctiveness of elements, such as eye, nose, and mouth. Participants could choose the outfit of their avatar by selecting clothing for the upper body, the lower body, shoes, and accessories (e.g., glasses, face mask). To further enhance the participant's identification with their avatar, we asked participants to describe the personality of their avatar by adjusting five 7-point Likert scales, which each represent one personality trait based on the 10-item short version of the Big Five Inventory (BFI-10) [428]. We asked participants to spend at least 4 minutes with the character editor. After that, a button appeared that allowed participants to move to the next step of the experiment. Figure 4.1 shows the editor.

Figure 4.1: Character editor steps from left to right: (1) selection of gender, (2) adjustments of the body shape and the face, (3) selecting of clothing and accessories, (4) personality traits

Gaming task

First, we introduced the game's background story and the control scheme: As a new intern at a large company, participants had to deliver documents to different teams in a building, with teams named after Greek letters. These teams were shuffled in the beginning of the experiment and assigned to one of two sides (left; right) and a floor number to every team (right: floor number 1–10; left: floor number 11–20). Participants had to interact with an NPC to find out on which side of the building the team sits. This NPC stood centered 5 meters before two elevator doors. The NPC was introduced as a *stranger* to the player within the gaming context. We did not used any explicit implications that this NPC is another human player (See Figure 4.2). First, a text box showed the name of the team that participants had to look for. Next, the camera focused the NPC, which either showed a friendly or threatening gesture. Additionally, we showed either a friendly message from the NPC or an insulting message. Figure 4.2 shows the two emotions, the beginning gesture, and the introduction of the NPC in the neutral and the angry condition. In all trials, the NPC had the same skin and eye colour, but different hairstyles (out of 20) and one randomly selected hair colour.

Figure 4.2: Task steps, from left to right: (1) instructions, (2) exposure to the emotion, (3) approach to the NPC, (4) interaction with the NPC, (5) answer of the NPC, (6) approach the destination

We then asked participants to move towards the NPC and stop at a comfortable distance to start a conversation. Players had to confirm the comfortable interpersonal distance by hitting the spacebar, which triggered a conversation with the NPC. The NPC greeted the player in either a friendly manner or by insulting them and then asking participants "what they want". After typing their question into the text field, the NPC reacted either friendly or aggressively and revealed the searched floor number. After that, players had to move

to the corresponding elevator and hit the spacebar to accept their decision. Finally, we asked participants to rate the emotion of the NPC on a scale from 0 (= *"very friendly"*) to 100 (= *"very angry"*). Per side (left, right), we had 5 positive NPCs interactions and 5 negative interactions resulting in 20 trials (2 sides x 2 emotions x 5 repetitions). Every trial had one individual team name and no team name was repeated. The gaming task was implemented using Unity Engine [518] combined with the asset bundle "Advanced People Pack 2" [315] and deployed using the Bride of Frankenstein framework [257]. 4.3 visualizes the steps of the first trial.

Figure 4.3: Task steps, from left to right: (1) instructions, (2) exposure to the emotion, (3) approach to the NPC, (4) interaction with the NPC, (5) answer of the NPC, (6) approach the destination

Participants and procedure

We recruited 410 participants on Amazon Mechanical (MTurk) [12] and Prolific [425]. For this study, we recruited participants who indicated that they live in Canada or the United States of America and have an interest in digital gaming. While prior work shows the potential and benefits of these platforms there are several shortcomings, which may have affected the results. As prior work outlines, there are several potential threats to the data quality, such as the lack of proper security tools, which facilitates the risk of fraudulent behaviour within the studies (e.g., using an VPN connection to overcome country restrictions) [153]. Additionally, prior work emphasize that MTurk and Prolific are suffer from biases, which may limit the generalizability of results within the context of mental health and personality traits [226, 98, 535]. We excluded participants who did not finish the experiment, e.g., due to technical difficulties or incomplete data collection, or showed negligent behaviour, such as rushing through the questionnaires and selecting random answers ($n = 25$). We identified such negligent behaviour by analyzing how much time participants spent on responding to one of the scales that we used. After applying this filter, we had complete data for 385 participants (218 women, 157 men, 9 non-binary, 1 preferred to not answer) aged $18 - 77$ ($M = 28.740$, $SD = 10.075$). All participants received $9 compensation for participating in this study, which took approximately 45 minutes to complete. Participants were told a cover story that the goal of this study is to analyze the effects of network latency on the game experience to justify why we asked them to repeat a movement task 20 times as well as to reduce the risk that they behaved differently as a result of knowing the real goal of the study. After that, the task started by asking the player to create their own avatar in the previously described character editor. After the 20 trials were recorded, we assessed the participants' trait psychopathy using the Triarchic Psychopathy measure (TriPM) [403], and demographic information. Finally, we debriefed participants about the goal of the study and provided additional support resources and a link to pictures of

baby animals to reduce potential negative effects on participants. This procedure was approved by the ethics board of the University of Saskatchewan. Table 4.1 summarizes the characteristics of the sample.

Variable	Categories	n	%	M	SD	Min	Max
Age		385		28.740	10.075	18	77
Gender	Woman	218	56.62 %				
	Male	157	40.77 %				
	Non-Binary	9	2.03 %				
	Prefer Not To Answer	1	0.25 %				
Income Per Year	Less than 10.000 USD	23	5.97 %				
	Between 10.000 USD - 25.000 USD	57	14.80 %				
	Between 25.001 USD - 45.000 USD	66	17.14 %				
	Between 45.001 USD - 65.000 USD	62	16.10 %				
	Between 60.001 USD - 85.000 USD	56	14.54 %				
	Between 85.001 USD - 100.000 USD	31	8.05 %				
	Between 100.000 USD - 150.000 USD	50	12.98 %				
	More than 150.00 USD	22	5.71%				
	Prefer Not To Answer	18	4.67%				
Marital Status	Single	247	64.15 %				
	Married or Domestic Relationship	126	32.72 %				
	Divorced	11	2.85 %				
	Widowed	1	0.25 %				
Ethnicity	American Indian or Alaskan Native	1	0.25 %				
	Asian	38	9.87 %				
	Black or Afro American	19	4.93 %				
	Hispanic/Latino	26	6.75 %				
	Native Hawaiian or Other Pacific Islander	1	0.25 %				
	Two or more categories	16	4.15 %				
	White	282	73.24 %				
	Prefer Not To Answer	2	0.51 %				
TriPM Boldness Score		385		25.145	9.929	0	53
TriPM Meanness Score		385		10.078	7.939	0	46
TriPM Disinhibition Score		385		15.322	8.753	0	48
PIS Similarity Identification		385		2.997	0.636	0	4
PIS Embodied Identification		385		2.339	0.886	0	4
PIS Wishful Identification		385		1.964	0.847	0	4

Table 4.1: Summary of the demographic information, TriPM, and PIS data.

In-game measurements

We focus on the following aspects of in-game social behaviour to better understand how trait psychopathy affects gaming behaviours:

Perceived emotion of the NPC After each trial, we asked participants to rate the emotion of the NPC who was present in the trial on a scale ranging from 0 (= *"very friendly"*) to 100 (= *"very aggressive"*). This measurement was adapted from prior work [148, 145], in which users rated the severity of perceived and expected social stress of a social interaction in a gaming task on a scale from 0 (not stressful) up to 100 (very stressful). However, as we were only interested in the perceived anger (vs friendliness) of the NPC, we focused only on this measurement and asked participants to rate emotions on this continuum.

Communication characteristics We were curious whether trait biases also manifest in the communication of participants. Therefore, we recorded the participants' questions they posed to the NPC, in which they asked for the floors, and analyzed the psycho-linguistic features using the LIWC-2015 tool, which analyses text using a bag-of-word approach [406]. We focused on whether participants were social toward the NPC and thus used the social subcategory, which includes all non-first-person pronouns and verbs related to human interaction [406]. Further, we analyzed how many swear words were used, which has been argued as an indicator of online social disinhibition and is related to toxic interactions [112].

Movement behaviour around the NPC Based on prior work, we focus on two aspects of in-game behaviour: The interpersonal distance between the player and the NPC as well as the movement behaviour around the NPC:

Interpersonal distance (IPD). As previously introduced, the interpersonal distance (IPD) may be influenced by personality traits, including psychopathic traits, in the context of virtual reality simulations [562, 375, 548]. Therefore, we were curious if these effects manifest within the gaming context. We included this aspect into the task by asking participants to walk towards the NPC and press the spacebar once they were standing at a comfortable distance to start a social interaction with the NPC.

Movement Features. After the conversation with the NPC ended, we started to record the position of the player's avatar with a frequency of 20 Hz. We focused on the effects of psychopathic traits on the skew and kurtosis of the distribution of the distance between the player and the NPC across the recorded samples in a trial. Prior work in the context of social anxiety suggests that personality traits might manifest in these behavioural indicators: Socially anxious participants walked farther and with a more consistent path around an NPC, resulting in higher skew and kurtosis respectively [146].

Expected behaviour

Based on the literature about trait psychopathy and social behaviour, we expect the following:

Perceived emotion of the NPC: We expect individuals with higher levels of psychopathic traits to rate the emotion of the NPC as less intense due to the previously introduced cognitive bias.

Communication characteristics:

We expect that participants will use fewer swear words when confronted with a neutral NPC and may use more when confronted with an angry NPC, and that this relationship might be amplified for those higher in trait psychopathy. We based this assumption on the previously-introduced potentially manipulative aspect of psychopathy. However, we expect that individuals with elevated psychopathic traits will use fewer social words, as they are more focused on themselves and their own goals rather their social environment [36].

Movement Behaviour around the NPC: Prior work suggests that participants with higher levels of psychopathic traits may show a lower personal distance to the NPC [546] and may be regulated by the emotion of the NPC as well [548, 300]. Based on this prior work, we expect similar results for the movement path around the NPC: that elevated psychopathic traits will result in lower interpersonal distance. Regarding NPC emotion, participants may keep a larger distance around the neutral NPCs and acknowledge the personal space of the NPC. On the other hand, an angry NPC may cause them to walk closer towards them and ignore social norms in-game. Prior work also shows that individuals with psychopathic traits are more goal focused, which causes them to ignore other (social) clues around them, which could attenuate the influence of the NPC's emotion, due to these participants focusing on finishing the task [203]. These would suggest that higher levels of psychopathic traits would be associated with lower skew (closer path to the NPC) and lower kurtosis (a more consistent path).

Questionnaire-based measurements

Measurements of boldness, meanness and disinhibition: We used the Triarchic Psychopathy measure (TriPm) to measure the three aspects of psychopathy: boldness, meanness, and disinhibition [403]. The TRIPm consists of 58 items, split into three subcategories of meanness (19 items), disinhibition (20 items), and boldness (19 items), and can used in combination as measurement for certain personality traits, such as lack of empathy or cold-heartedness [402]. Participants had to answer how much they agree with each item on a 4-point Likert scale (0 = "False"; 3 = "True") and responses are them summed (higher=bolder). Meanness is associated with cruel, callous, predatory, and excitement-seeking behavior. Disinhibition is related to irresponsible, impulsive, oppositional, but also potential hostile behavior. The boldness sub-scale, related to dominance and low anxiousness [402] in the triarchic model, seems to be most relevant in distinguishing between antisocial personality disorder (ASPD) and psychopathy [534]. Prior work suggests that the TriPM seems to be unaffected by gender [326]. The scores for boldness ranged from 0 to 53 ($M = 25.145$; $SD = 9.929$), meanness ranged from 0 to 46 ($M = 10.078$; $SD = 7.939$), and disinhibition ranged from 0 to 48 ($M = 15.322$; $SD = 8.753$).

Avatar identification: After the customization, we asked participants to fill out the avatar-related subscales of the Player Identification Scale (PIS) [523]. With these subscales, participants had to rate their agreement to different statements about their relationship with their avatar, such as *"My character is like me in many ways."* on 5-point Likert scales from 0 (= *"strongly disagree"*) to 4 (= *"strongly agree"*).

Demographics: We recorded a variety of demographic factors including age, gender, income, marital

status, and ethnicity.

Data analysis

After removal of negligent participants as described earlier, we had per participant 20 trials, resulting in 7700 trials in our data. We discarded trials representing outliers in *IPD*, *Seconds Spent in Task*, *Minimum*, *Mean*, and *Maximum Distance* to the NPC, and *kurtosis* by applying a Tukey-filter to the measurements (1678 trials were removed; 21.79%). After applying these filters, 6052 valid trials remained for the following data analysis.

Next, we created several linear mixed models, using REML and nloptwrap optimizer, to predict the behaviour measurements with each of the psychopathic traits and the emotion of the NPC (formula: Behaviour measurement ~ Psychopathic trait measurement * Emotion of the NPC). To account for the hierarchical repeated-measures structure in our data, these models always included the participant, expressed through the participant ID, and the emotion of the NPC as random effects (formula: Emotion of the NPC — Participant). The emotion of the NPC was encoded as a contrast in the following way: 0 = Neutral Mood; 1 = Angry Mood. The analysis was done in R Studio Version 1.2.5033 using R 3.6.3 and the packages lmerTest and tidyverse. Per dependent variable we created a separate model.

4.4.4 Results

Perceived emotion of the NPC

We asked participants to rate the perceived emotion of the NPC on a scale from 0 (= *"very friendly"*) to 100 (= *"very aggressive"*). We will refer to this rating as *emotion rating* in the following section. We found a significant positive relationship between boldness and the perceived emotion rating. Further, we found a significant positive relationship between NPC emotion and emotion rating. The interaction effect between boldness and NPC emotion on emotion rating was significant and negative. This suggests that individuals who score high on boldness tend to rate a neutral NPC as angrier and an angry NPC as less angry. We found the same pattern of results for meanness and disinhibition, except the main effect of disinhibition was not significant. Table 4.2 summarizes the results and Figure 4.4 visualizes these results.

Rating of the Perceived Emotion of the NPC		beta	95 % CI	t	p	std. beta	95 % CI
Boldness	Boldness	0.25	0.14; 0.35	4.71	<0.001	0.06	0.03; 0.08
	NPC Emotion	89.71	84.36; 95.05	32.90	<0.001	1.70	1.62; 1.78
	Boldness NPC Emotion	-0.58	-0.75; -0.41	-6.81	<0.001	-0.13	-0.17; -0.09
Meanness	Meanness	0.37	0.24; 0.51	5.34	<0.001	0.06	0.04; 0.09
	NPC Emotion	85.34	81.33; 89.34	41.76	<0.001	1.70	1.63;178
	Meanness : NPC Emotion	-1.02	-1.25; -0.79	-8.73	<0.001	-0.18	-0.21 ; -0.14
Disinhibition	Disinhibition	0.21	-0.00541; 0.24	1.87	0.061	0.02	-0.00106; 0.05
	NPC Emotion	81.54	76.96 ; 86.12	34.90	<0.001	1.70	1.63; 1.78
	Disinhibition : NPC Emotion	-0.41	-0.62 ; -0.20	-3.88	<0.001	-0.08	-0.12 ; -0.04

Table 4.2: Summary of the models for the relationship between the perceived emotion rating and boldness, meanness, and disinhibition; Significant results are highlighted

Communication Characteristics

Swear words: We assessed how many swear words were used when communicating with the NPC. A higher value indicated a higher usage of curse words, which we will refer to as *swearing score*:

We found no significant relationship between boldness, meanness, or disinhibition, and the swearing score. However, for all three we found a significant positive relationship between NPC emotion and swearing score. This suggests that all participants used more swearwords when confronted with an angry NPC. Furthermore, we found one significant negative interaction effect between boldness and NPC emotion, which shows that the amount of swearing increases with trait boldness for the angry NPC, but not the neutral NPC. Table 4.3 summarizes these results and Figure 4.4 visualizes these results.

Communication Characteristics: Swearing		beta	95 % CI	t	p	std. beta	95 % CI
Boldness	Boldness	0.0000679	-0.01, 0.01	0.01	0.990	0.000201	-0.03, 0.03
	NPC Emotion	**1.38**	**0.80, 1.96**	**4.66**	**<0.001**	**0.23**	**0.15, 0.30**
	Boldness : NPC Emotion	**-0.02**	**-0.05, 0.00**	**-2.36**	**0.018**	**-0.07**	**-0.13, -0.01**
Meanness	Meanness	0.000227	-0.01, 0.01	0.03	0.975	0.000516	-0.03, 0.03
	NPC Emotion	**0.84**	**0.46, 1.22**	**4.38**	**<0.001**	**0.23**	**0.15, 0.30**
	Meanness : NPC Emotion	-0.00847	-0.04, 0.02	-0.61	0.545	-0.02	-0.08, 0.04
Disinhibition	Disinhibition	0.000760	-0.01 , 0.01	0.12	0.904	0.00196	-0.03, 0.03
	NPC Emotion	**0.61**	**0.15, 1.07**	**2.62**	**0.009**	**0.23**	**0.15, 0.30**
	Disinhibition : NPC Emotion	0.00942	-0.01 , 0.03	0.76	0.449	0.02	-0.04, 0.09

Table 4.3: Summary of the models for the relationship between swearing score and boldness, meanness, and disinhibition; Significant results are highlighted

Social words: We analyzed how many social words participants used in their communication with the NPC. A higher value indicates that participants used pronouns that point to the NPC, such as "you" and more social words (e.g., "talk"). We will refer to this measurement as *social score*:

For boldness, meanness, and disinhibition, the trait was negatively associated with social score, suggesting that individuals with higher levels of psychopathic traits use fewer social words. NPC emotion had a significant negative relationships with social scores, indicating that participants used more social words when communicating with neutral NPCs compared to angry NPCs. All interaction effects were non-significant. Table 4.4 summarizes these results and Figure 4.4 visualizes these results.

Communication Characteristics: Social		beta	95 % CI	t	p	std. beta	95 % CI
Boldness	Boldness	**-0.16**	**-0.23, -0.09**	**-4.46**	**<0.001**	**-0.09**	**-0.14, -0.05**
	NPC Emotion	**-2.50**	**-4.52, -0.47**	**-2.42**	**0.016**	**-0.11**	**-0.16, -0.06**
	Boldness NPC Emotion	0.03	-0.05, 0.10	0.67	0.500	0.02	-0.013, 0.06
Meanness	Meanness	**-0.20**	**-0.30, -0.11**	**4.21**	**<0.001**	**-0.09**	**-0.14, -0.05**
	NPC Emotion	**-2.48**	**-3.72, -1.24**	**-3.91**	**<0.001**	**-0.11**	**-0.16, -0.06**
	Meanness : NPC Emotion	0.06	-0.04, 0.16	1.25	0.210	0.03	-0.02, 0.07
Disinhibition	Disinhibition	**-0.20**	**-0.28, -0.12**	**-4.63**	**<0.001**	**-0.10**	**-0.15, -0.06**
	NPC Emotion	**-2.66**	**-4.19, -1.14**	**-3.42**	**<0.001**	**-0.11**	**-0.16, -0.07**
	Disinhibition : NPC Emotion	0.05	-0.03, 0.14	1.17	0.242	0.03	-0.02, 0.07

Table 4.4: Summary of the models for the relationship between social score and boldness, meanness, and disinhibition; Significant results are highlighted
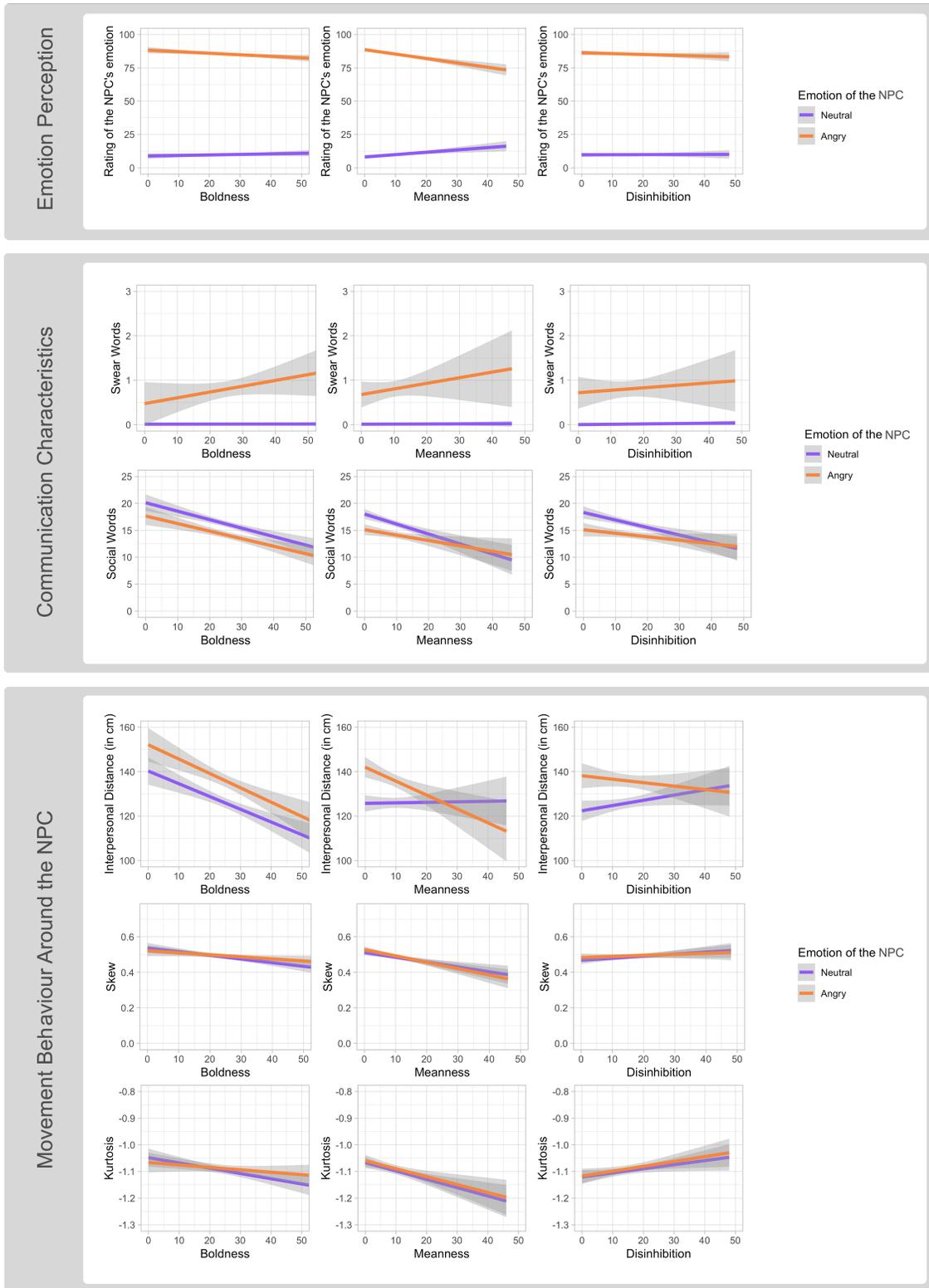
Figure 4.4: Relationship between psychopathic traits and emotion perception, communication characteristics, and movement behaviour.

Movement Behaviour around the NPC

In the following section, we will discuss the results of the three movement behaviour measurements: The interpersonal distance (IPD) and the shape of the movement trajectory when passing the NPC, expressed by the skew and kurtosis of the movement path.

Interpersonal distance:

We found a significant negative relationship between boldness and IPD. Further, we found a significant positive relationship between NPC emotion and IPD, but no interaction effect. These results suggest that bold individuals stopped closer to the NPC. Although they tended to stop farther from angry NPCs, people higher in trait boldness stopped closer to both angry and neutral NPCs. We found no significant relationship between meanness and IPD. However, we found a significant positive relationship between NPC emotion and IPD, showing the same result as with boldness. Further, we found a significant negative interaction effect between meanness, NPC emotion, and IPD, suggesting that individuals higher in meanness stopped closer to angry NPCs, but meanness did not affect IPD to neutral NPCs. We also found a significant positive relationship between disinhibition and IPD and a significant positive relationship between NPC emotion and IPD, showing the same result as for boldness and meanness. However, we found no interaction effect between disinhibition, NPC emotion, and IPD, which together suggests that individuals higher in trait disinhibition tend to stand closer to NPCs, regardless of their emotion. Table 4.5 summarizes the results.

Movement Behaviour: IPD		beta	95 % CI	t	p	std. beta	95 % CI
Boldness	Boldness	**-0.69**	**-0.97 ; -0.42**	**-4.96**	**<0.001**	**-0.10**	**-0.14; -0.06**
	NPC Emotion	**17.10**	**7.85; 26.36**	**3.62**	**<0.001**	**0.18**	**0.12; 0.24**
	Boldness : NPC Emotion	-0.17	-051 ; 0.16	-1.01	0.312	-0.02	-0.07; 0.02
Meanness	Meanness	0.22	-0.15 ; 0,59	1.15	0.252	0.02	-0.02 0.06
	NPC Emotion	**19.81**	**13.94 ; 25.69**	**6.61**	**0.001**	**0.18**	**0.12; 0.24**
	Meanness : NPC Emotion	**-0.72**	**-1.16 ; -0.28**	**-3.19**	**0.001**	**-0.08**	**-0.12; -0.03**
Disinhibition	Disinhibition	**0.34**	**114.57 ; 130.28**	**30.54**	**0.045**	**0.04**	**0.000987 ; 0.08**
	NPC Emotion	**18.08**	**0.01 ; 0.68**	**2.01**	**<0.001**	**0.18**	**0.12; 0.24**
	Disinhibition : NPC Emotion	-0.35	10.86 ; 25.31	4.9	0.082	-0.04	-0.09; 0.00540

Table 4.5: Summary of the models for the relationship between IPD and meanness, boldness, and disinhibition; Significant results are highlighted.

Skew and Kurtosis: Besides the interpersonal distance, we also analyzed whether psychopathic traits affect the movement behaviour around the NPC, which we assessed with the skew and kurtosis of the distribution of the distances to the NPC:

We found a significant negative relationship between boldness and skew. However, we found no significant relationship between NPC emotion and skew as well as no interaction effect. Similar effects were found for meanness, showing that players lower in trait meanness and boldness tended to give the NPC a wider berth. We found no significant effect for disinhibition and skew.

We found a significant negative relationship between boldness and kurtosis. However, we found no significant relationship between NPC emotion and kurtosis as well as no interaction effect. Similar effects were found for meanness, showing that players higher in trait meanness and boldness tended to take a more consistent movement path around the NPC. We found no significant effect for disinhibition and kurtosis.

Together, the movement path results suggest that individuals scoring high on boldness and meanness ignore the personal space of the NPC and walk closer around it, suggesting a more straight to the goal movement. Table 4.6 shows the results of the skew and kurtosis of the movement path around the NPC. Figure 4.4 visualizes the results of the previously discussed models.

Movement Behaviour: Skew and Kurtosis		beta	95% CI	t	p	Std. beta	95% CI
Skew	Boldness	**-0.00233**	**-0.00362; -0.00103**	**-3.52**	**<.001**	**-0.08**	**-0.12; -0.03**
	NPC Emotion	-0.00481	-0.05; 0.04	-0.23	0.821	0.04	-0.02; 0.09
	Boldness : NPC Emotion	0.000631	-0.000904 ; 0.00217	0.81	0.421	0.02	-0.03; 0.07
	Meanness	**-0.00348**	**-0.00519 ; -0.00177**	**-3.98**	**<.001**	**-0.09**	**-0.13; -0.04**
	NPC Emotion	0.02	-0.00294 ; 0.05	1.73	0.083	0.04	-0.02 ; 0.09
	Meanness : NPC Emotion	-0.00115	-0.00316; 0.000856	-1.12	0.261	-0.03	-0.08; 0.02
	Disinhibition	-0.000219	-0.00176; 0.00132	-0.28	0.780	-0.00628	-0.05, 0.04
	NPC Emotion	0.02	-0.01; 0.05	1.26	0.208	0.04	-0.02, 0.09
	Disinhibition : NPC Emotion	-0.000608	-0.00238;0.00116	-0.67	0.5	-0.02	-0.07, 0.03
Kurtosis	Boldness	**-0.00217**	**-0.00374 ; -0.000598**	**-2.71**	**0.07**	**-0.06**	**-0.10 ; -0.02**
	NPC Emotion	-0.00401	-0.05 ; 0.04	-0.16	0.871	0.03	-0.02 ; 0.08
	Boldness : NPC in Angry	0.000633	0.00115 ; 0.00242	0.69	0.487	0.02	-0.03; 0.07
	Meanness	**-0.00384**	**-0.00591; -0.00177**	**-3.63**	**<0.001**	**-0.08**	**-0.12 ; -0.04**
	NPC Emotion	0.02	-0.01 ; 0.04	1.01	0.314	0.03	-0.02 ; 0.08
	Meanness : NPC Emotion	-0.000318	-0.00266; 0.00202	-0.27	0.790	-0.00663	-0.06 ; 0.04
	Disinhibition	-0.0000353	-0.00190; 0.00183	-0.04	0.970	-0.000836	-0.04 ; 0.04
	NPC Emotion	0.00851	-0.03; 0.04	0.46	0.645	0.03	-0.02 ; 0.08
	Disinhibition : NPC Emotion	0.000203	-0.00185 ; 0.00226	0.19	0.847	0.00481	-0.04 ; 0.05

Table 4.6: Summary of the models for the relationship between skew and kurtosis with meanness, boldness, and disinhibition; Significant results are highlighted

4.4.5 Discussion

Summary of the Results

Our results revealed how personality traits related to psychopathy may manifest in-game:

Boldness: We show that individuals scoring higher on *boldness* rate the emotion of the NPC less intense, shown by a decreased aggressive emotion rating for an angry NPC and an increased aggressive emotion rating for neutral NPC. Further, we show that bold individuals use more swear words only when confronted with an Angry NPC, but a decreased use of social words when interacting with both NPCs. The IPD shows that the NPC's emotion had no significant effect, but that regardless of NPC emotion, bolder individuals stopped closer to the NPC. Similarly, the skew and kurtosis were not significantly affected by the NPC's emotion, but in either case, bolder individuals tended to walk closer around the NPC and more directly towards the goal behind the NPC.

Meanness: Participant scoring higher on *meanness* showed a less intense perception of the NPC's emotion, resulting in a lower emotion rating for angry NPCs and higher ratings for neutral NPCs. The usage of swear words was influenced only by NPC emotion, not meanness (i.e., higher when interacting with an angry NPC); however, the use of social words decreased for individuals scoring higher on meanness. The IPD showed no direct relationship between meanness and IPD, but the interaction with NPC emotion showed the people scoring higher on meanness stopped closer to angry NPCs (with no effect on neutral NPCs). Further, skew and kurtosis showed that individuals scoring higher on meanness walk closer around the NPC and more

directly toward their goal (expressed by a reduced skew and kurtosis), regardless of NPC emotion.

Disinhibition: Finally, we found no direct relationship between individuals scoring high on *disinhibition* and the emotion rating. Yet the main effect of NPCs emotion as well as the interaction effect between disinhibition and NPC emotion suggest that more disinhibited people rated angry NPCs less angry, but neutral NPCs still very friendly. Although the main effect of NPC on swearing showed that players used more swear words with angry NPCs, there we found no evidence that swearing was influenced by disinhibition. Like the other traits, players higher in disinhibition also used fewer social words, regardless of the NPC emotion. Similarly, the relationship between disinhibition and IPD showed that more disinhibited participants tended to stand farther away from the NPC, and in general stood farther from angry NPCs, but that disinhibition and NPC emotion did not interact to influence IPD. Finally, we found no significant relationship between disinhibition and skew or kurtosis, showing no evidence of a relationship between trait disinhibition and the movement pattern around the NPC.

Explanation of Findings

Our results lend support to the proposition that traits of psychopathy affect social gaming behavior and that we may be able to explain in-game behavior in terms of personality theory. On one side, we see that some psychopathy traits share similar expressions in-game as they are known to do in the physical world, such as the perception of the NPC's emotion, the increased swearing, and the decreased usage of social words. Prior work about psychopathy as a trait emphasizes a potential deficit in the ability to perceive and experience affect [150]; our results align with these findings, as all three psychopathic traits lead players to rate the emotion of angry NPCs as less angry and the emotion of friendly NPCs as less friendly. Similarly, prior work [509] shows that individuals with psychopathic traits are more likely to use angry language. Our findings agree with these results only partially as only angry NPCs elicited bolder participants to use more swear words in their communication. This effect may be explained by the normalization effect [48], as players only started to use more swear words once they experienced insults *from* the NPC and therefore began to normalize swearing within this gaming context. However, the reduced social word usage was shared by all three traits. Here, the overarching psychopathy trait may explain these results, as prior work provides evidence for a relationship between psychopathy and egocentric characteristics [469], which in our case expresses in fewer socially-oriented words in general.

The interpersonal distance findings were more nuanced in terms of how the different aspects of psychopathic traits were expressed in-game. According to Patrick et al. [403], *boldness* reflects social dominance and fearless resiliency as well as reduced stress reactivity [309]. These typical aspects of the boldness trait are shown to manifest within our gaming context, especially within interpersonal distance: the emotion of the NPC did not significantly affect the IPD and participants with a high boldness score stand closer to the NPC. On the other hand, we found a different IPD behaviour for *meanness*, which is characterized by aggressive resource seeking without concern for others, which includes aspects like hostility and exploitativeness [403].

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Our results align with these descriptions and similar results about the expression of meanness in other contexts [30, 68]: As the IPD shows, participants scoring high on meanness breach the personal space of angry NPCs. Finally, *disinhibition* reflects difficulties with impulse control, poor planning, and limitations in delaying gratification [403]. However, our results suggest that disinhibition was not significantly associated with anti-social behaviours, as the main effect between disinhibition and IPD was small and positive. In the context of psychopathy, prior work suggests that disinhibition is an essential part and needs to be combined with either boldness or meanness to fully unfold into psychopathy [534]; that our results for each trait's influence on IPD were unique does reinforce the potential triarchic structure of psychopathy [402].

The significant findings for skew and kurtosis related to meanness and boldness suggest a more focused movement towards the final destination (kurtosis), while also breaching the personal space of the NPC (skew). This behaviour may be explained by a lack of avoidance motivation when encountering threat [548, 548] and a tendency to ignore social norms while only focusing on how to be most efficient in finishing the task at hand [389] in general psychopathy. These tendencies reflect a bias among trait psychopathy to not integrate peripheral information of social cues into one's own behavior when engaging in goal-directed behavior, as proposed by the response-modulation hypothesis of psychopathy [323].

Implications for design

Our results show, that the psychopathic traits meanness, boldness and disinhibition may manifest within games, which might influence the gaming experience. Game designers try to evoke various emotions in the player, depending on genre, design or a certain topic; however, games can also be designed to avoid certain emotions, such as frustration, one of the core challenges of developing a great experience.

We show that psychopathic traits can bias the perception of emotions: individuals with higher levels of psychopathic traits rated the emotion of the NPC less intense, which may help explain how the expression of emotion in-game can be misunderstood. Many games offer ways to express emotions in-game to enhance the social interaction; however, some players may have bias in how they interpret these emotions, resulting in a negative or harmful reaction, like aggressive responses. Similarly to how feeling socially excluded increases the interpretation of neutral information as more hostile in gaming contexts [59], trait psychopathy might show a similar pattern in which neutral interactions are perceived as more aggressive. Further, as angry interactions were actually perceived as less aggressive, trait psychopathy may contribute to the normalizing of toxic interactions within gaming contexts [48]. Game designers need to provide tools that help presented emotions be interpreted correctly by players, even if emotional interpretation biases are present. However, even if such tools were provided, in-game behaviour could be misunderstood and elicit anti-social behaviour, e.g., players might not follow suggestions in-game because they are not familiar with the game rules, which can be misunderstood as an anti-social behaviour [168].

Prior work suggests that the normalization of toxicity in games creates a vicious cycle [48]. Players who engage in but also experience toxic behaviour are more likely to normalize this experience and start to engage

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in more toxic interaction in-game [287]. Our results show that players with psychopathic traits also used more swear words and less social words, especially when confronted with an angry NPC. This suggests that game designers may need to increase the awareness of rising toxicity in-game to break the cycle of toxic behaviour in-game. However, game designers need to be cautious when analyzing the communication in-game, as other factors, such the arousal induced by the game, may increase the probability to use rude language as a way to regulate the experienced stress [498, 499]. Our findings suggest several in-game behaviours that are consistently associated with higher levels of psychopathic traits, across boldness, meanness, and disinhibition (e.g., usage of swear words or social words). Using them as a way to detect "anti-social players" would not be helpful due to the large overlap and the blurred lines between traits and with other sources that elicit similar behaviours. For example, in-game situations, high arousal due to stress or bad mood as well as other factors, may cause individuals to use swear words as a coping mechanism. In line with this, previously failed attempts to reduce toxic behaviour by simple excluding toxic players showed little effect on the perceived toxicity in-game [329]. Moreover, designers need to be aware that many aspects of the game, but also aspects of the player and their personality traits, can lead to anti-social behaviour in games.

Ethical concerns about detecting personality traits

Measuring and assessing aspects of people using technology, including their personality traits, has become more prevalent as sensors enable us to easily capture data on people's habits and behaviours, e.g., [146, 474, 50, 182, 274, 353, 361] and has inspired an ongoing discussion about the ethics of such approaches [361]. Designers and researchers must be aware of potentially problematic aspects of these practices, including inferring identity, the breach of privacy, and how these practices may affect the person and their social environment. For example, prior work proposed ways how to detect psychopathy using gaze data and artificial intelligence [50]; however, as previously discussed, psychopathic traits may not be socially welcomed and even feared by others. As a result, individuals who are sub-forensic (i.e., have elevated psychopathic traits that are not necessarily problematic) may experience higher scrutiny by others due to the stigma and pop-culture stereotypes of psychopathy, when automated detection of these traits is applied without careful ethical considerations [361, 8]. As previously discussed, game designers should not exclude players due to *any personality trait*, as it has been shown to be not an effective way to solve the manifestation of anti-social behaviour in games. Moreover, we emphasize that game designers should seek novel ways to include and satisfy *all players* to create a more diverse community by assisting players with different traits to feel welcome in their communities, using in-game rules and tools to promote healthy social interactions among all players.

Limitations and Future Research

There are several limitations to the results of this study, which can be addressed by future work. First, our evaluation is based on an abstract social interaction in comparison to those prevalent in actual digital games. Future work could benefit from replicating the results in a more elaborated game environment, with a more

realistic task, and richer social interactions with an NPC. Further, extending our findings to social interactions with other players would provide additional knowledge around how trait boldness, meanness, and disinhibition express in social games. Second, our character editor did not include a non-binary option for players, due to limitations of our underlying technical framework. We emphasize that future work should include non-binary options for players to ensure that all players can express themselves fully through character creators. Third, in the task we only focused on two emotions, friendly and angry, which were emphasized multiple times during each trial. Future work should focus on more subtle social clues, as emotion perception and interpretation bias is elevated for more subtle and complex facial expressions [224]. Further, we suggest that researchers may investigate the relationship between psychopathic traits and in-game roles and preferences, similar to what has been done for other personality traits (e.g., [418, 417]) to maximize the enjoyment of role based games. Fourth, the effects of using online research platforms such as Amazon MTurk or Prolific. While these platforms allow researchers to reach out to a large user group, there are rising concerns about the data quality of these platforms [153, 226]. Prior work points out several threats to the data quality recorded on these platforms and some recent incidents [317] emphasize the vulnerability to trends and potential harm to the data quality. Therefore, future research may adapt the presented research and try to reproduce these findings in other in-person experiments to protect the data quality against potential fraudulent behaviour. Fifth, the role of the NPC. Although we did not explicitly introduce the NPC as the representation of another player, some participants may have perceived it as such. Therefore, they may have experienced elevated social presence [47], which may have caused them to behave differently. Future research may explore further the role of social presence and compare these findings about the interaction with a NPC with player's behaviour when interacting with other players' representations. Furthermore, we only used male NPCs in this experiment. However, prior work shows that the gender of the NPC may affect the way players interact with it and how threatening they perceive it [443]. Future work should explore more diverse gender and ethnicity representations in this experiment to better understand the role of gender and ethnic background on the social interaction in-game.

4.4.6   Conclusion

Social interactions within gaming have become an essential part of how we connect to others, both inside and outside of a game. These interactions provide a variety of benefits to players; however, when social interactions involve insults, taunts, trolling, or bullying, they cause serious harm to the wellbeing of players and gaming communities. In this paper, we considered how individual personality traits affect social behaviours in games. Specifically, we assessed participants' trait-level boldness, meanness, and disinhibition—which together comprise trait psychopathy—and asked them to engage in a series of social interactions with an NPC (who displayed either angry or neutral emotion) in a gaming task. Our findings demonstrate that the three traits significantly influence social behaviours, including the interpretation of NPC emotion, verbal responses to the NPC, stopping distance to initiate interaction with the NPC, and movement behaviours around the NPC.

Mounting evidence shows that players carry their personalities, motives, social habits, biases, and interaction styles with them into their interactions within digital games—whether these individual traits yield benefit or harm to others. Our findings provide new insights into how trait psychopathy manifests in social behaviours within digital games, expressed in our study through player perceptions, use of language in communicating with the NPC, and violation of the NPC's personal space.

To ensure that the myriad benefits of social gaming are accessible to all players, researchers and developers must continue to develop gaming cultures, norms, and tools that promote harm reduction. A first step in preventing harm is to understand how—and for whom—harmful social interactions unfold. Our work adds to this understanding, with the hope of leading toward safer gaming spaces for all players.

4.5   Summary

Manuscript 5 confirms that players with elevated self-report levels of certain psychopathic traits, such as increased boldness and meanness, show a biased perception of an NPC's emotion, resulting in the trend that these affected individuals rate the NPC as more angry compared to others. Furthermore, players high on scales assessing psychopathic traits used a more rude language when communicating with the NPC. The movement behaviour around the NPC as well as the interpersonal distance towards the NPC show that elevated psychopathic traits bias the movement and let players move closer around the NPC and stand closer to the NPC, depending on the NPC's emotion as well as the personal level of psychopathic traits, like boldness and meanness.

4.6   Comparison of the movement behaviour between social anxiety and psychopathic traits

As previously discussed, some researchers argue that social anxiety and psychopathic traits can be seen as a spectrum from being highly social fearful, referring to social anxiety, to being highly social fearless, referring to characteristics of psychopathy [245]. Comparing the results of Manuscript 3, 4, and 5, we see opposite behaviours. While highly socially-anxious individuals tend to walk farther around the NPC, individuals with elevated psychopathic traits tend to ignore and violate the social space of the NPC, resulting in a more straight movement behaviour towards the destination point. This opposite behaviour can also be found in similar experiments in VR simulations: While individuals with elevated social anxiety tend to prefer a larger interpersonal distance [201, 407, 305], individuals with elevated psychopathic traits show a reduced interpersonal distance preference [548].

4.7   Contextualization

The goal within the context of this dissertation for Manuscript 5 was to test how the found digital behaviour markers could be applied to similar problems within the context of assessing mental health concerns by harnessing data from digital games. Through the lens of social anxiety, we saw that elevated social fearlessness led to the expected opposite behaviour compared to socially-anxious individuals, when compared to the results of Manuscript 3 and 4.

However, the results of Manuscript 5 emphasizes that digital games can be more than just a pure entertainment activity, because the in-game behaviour can reveal personal information about the user, like their own personality traits or potential mental health concerns, like social anxiety. As discussed in Manuscript 5, the users as well as developers of (assessment) games need to be aware of the ethical implications and how to protect the user's privacy.

5 Discussion

The presented work contributes insights about the overarching question of whether we can harness in-game behavioural data as a new way to assess trait social anxiety. The presented work builds on prior understanding about the relationship of (problematic) gaming behaviour and social anxiety and explores how characteristics of social anxiety bias the preferences and in-game activities of gamers. Further, this thesis shows how the movement around an in-game character in particular can offer insights about the personal level of social anxiety and how the self-representation and the in-game perspective affect the manifestation of social anxiety through in-game behaviour. Finally, we explore not only the context of social anxiety, but also whether other aspects like personalty traits, may affect these movement behaviours.

5.1 Summary of the manuscripts

While all five papers have their own discussions and explanations as well as design recommendations, we will focus in the following chapters on a brief summary of the results and contextualize them within the perspective of social anxiety assessment.

5.1.1 Manuscript 1

The results we demonstrate in Manuscript 1, showing that people with elevated social anxiety are drawn to social games, stand in contrast to core concepts of social anxiety, like the avoidance of social interaction with others. A potential explanation may lie in the technologies used within games. For example, prior work shows that socially-anxious users prefer chat-based interaction over in-person communication [413]. However, while chats allow users to interact asynchronously, social games, like MMORPGs, rely on synchronous interaction. Does this mean that social anxiety doesn't enter the "magic circle" of games and therefore players with social anxiety feel lees anxious when interacting in games with others? Manuscript 1 provides answers based on the results of a crowd-sourced online experiment. In this study, participants answered several questionnaires about their preferences and in-game activities as well as an adapted version of the LSAS [322]. Manuscript 1 shows that although the fear and avoidance of social interactions in the physical and the digital realm are related, they differently affect preferences, behaviours and experiences. Social anxiety in the physical world affects the reasons to play, yet in-game social anxiety affects behaviours, reducing participation in activities linked to social interaction and difficult in-game challenges. Further, Manuscript 1 provides an adapted version of the LSAS [322], mapped to the context of social interaction in online multiplayer games.

5.1.2 Manuscript 2

If social anxiety manifests in-games, the follow up question raised is whether we can affect the experience of in-game social anxiety through game mechanics? As prior work shows, some game mechanics may affect the engagement of players, such as via customized avatars. Further, prior work confirms that customized avatars increase identification not only in games but also in therapeutic scenarios. However, it is not clear whether the customization may also increase the experience of social anxiety because the customization may reveal personal preferences, which could be negatively judged by other players. The underlying conflict of social anxiety between the mental self-representation and perceived social norms may be intensified through the customized avatar, which would justify that a potential audience not only judges the player's performance, but also their own appearance. In the context of assessment, the selection of the self-representation may affect whether social anxiety manifests in-game and therefore potential in-game behavioural markers may become empirically measurable. Therefore, in Manuscript 2, we conducted an online exposure task in which participants had to solve a math riddle in front of an simulated audience. They either selected a predefined avatar or were allowed to customize their self-representation. The results of Manuscript 2 confirm that the self-representation does affect the experience of social fear before and after an online exposure task. These results emphasize that certain core aspects of the game design should be carefully considered when harnessing in-game information for the assessing of social anxiety.

5.1.3 Manuscript 3

In the physical world as well as in the simulated realm of virtual reality assessment, prior work shows that the movement path around others may be biased through the experience of social anxiety [305, 201]. However, whether this occurs in the realm of digital games has not been explored. Therefore, Manuscript 3 builds on the results of prior work and provides insights into which aspects of in-game behaviour around a character can be useful for the assessment of social anxiety. However, as previously shown, the customization may affect the experience of social anxiety. Further, not all digital games use a first-person camera perspective, but also use a third person camera perspective. In order to better understand whether the the camera perspective affects the experience of social anxiety, we used a movement task adapted from a VR experiment proposed by prior work [305]. In this experiment, we crossed the camera perspective (first person perspective, third person perspective) and avatar customization (predefined avatars, customized avatars) to create four conditions in which we explore how social-anxiety influences movement behaviours around an in-game character. The results of Manuscript 3 reveal that social anxiety affects the in-game movement around the NPC. We see that the preference for larger distance, explained by social anxiety, also manifests in-game. Manuscript 3 also replicated our prior findings by showing that customized avatars intensify the expression of social anxiety. Similarly, the camera perspective also affects the manifestation of social anxiety. The results of Manuscript 3 suggests the combination of customized avatars and third person perspective as the strongest combination for

the assessment of social anxiety.

5.1.4   Manuscript 4

As previously introduced, social anxiety may cause many biases towards others. Besides the movement around others, social anxiety may also cause individuals to wrongly estimate the distance to others [407]. However, prior work focused mostly on assessing these effects in the physical wold or in virtual reality simulation, not in digital games. Assessing these insights in digital games could strengthen assessment through behavioural data from games. Therefore we adapted the experiment procedure from Manuscript 4 and included the measurement of the preferred stopping distance in front of an NPC as an additional measurement. Building on the results of Manuscript 3, we focused on the replication of the findings and comparing them with the distance preference measurement. Further, we were curious if we can use the found digital biomarkers for the prediction of social anxiety. Therefore, we deployed a digital gaming task in which we asked participants to approach an NPC, chat with the NPC, and ask for directions and bypass the NPC to a goal behind it. We measured the interpersonal distance to the NPC, as well as the movement behaviour of the players around the NPC. The results confirm our prior findings from Manuscript 3, and further show that the interpersonal distance as well as the movement behaviour around the NPC can be used for the assessment of social anxiety. Combined, these four manuscript provide supporting evidence for the overarching question of whether we can use digital biomarkers of a gaming task for the assessment of social anxiety.

5.1.5   Manuscript 5

While the prior presented manuscripts focus on social anxiety, this manuscript expands the usage of in-game digital behavior markers to related research areas in mental health assessment. Prior work conceptualizes psychopathy as an opposite construct to social anxiety, due to the characteristic resilience to social stress resulting in increased socially-fearless behaviour [245]. Prior work suggests that individuals with psychopathic character traits may ignore the social space of others, resulting in a decreased interpersonal distance. However, the question remains of whether psychopathic character traits may only affect explicit measurements, like the interpersonal distance or if more subtle, implicit measurements like the movement path around the NPC are also affected by the character trait. Therefore, we conducted the same experiment as in Manuscript 4, in which players had to approach a NPC, interact with it and bypass it. However instead of focusing on players with social anxiety, we assessed the player's level of psychopathic traits *boldness, meanness, and disinhibition*. The results of Manuscript 5 confirm this hypothesis: Players with psychopathic character traits show a decreased personal distance to the NPC, but also use a more rude self-centered language and bypass the NPC closer, ignoring the social space of the NPC. These results open up the usage of digital in-game behaviour not only within the context of social anxiety, but also to other potentially related socially driven mental health concerns.

5.1.6 Contextualization in theory

The prior introduced model of social anxiety by Heimberg et al. [235] suggests three major categories of symptoms for social anxiety: Physiological, Behavioural, and Cognitive. Within the context of evidence-based assessment techniques, prior work suggests that assessment should include two perspectives: First, the subjective perspective of the patient. As previously discussed, many questionnaires and standardized interviews are the golden standard and are an inexpensive and rapid way to gain subjective insights from the patient and related peers, such as parents or close friends. Yet these subjective measurements may be influenced by personal biases, which could be caused by social anxiety itself or the desire to please [143]. Therefore, prior work suggests to gain empirical data to reduce the risks of biased conclusions. Over the last decade, many researchers, motivated by the rapid price decline of various sensor devices, suggested ways to harness physiological data from various sensors to assess the severity of social anxiety [253, 549, 304]. However, even with these advances, only a minority of people with social anxiety who meet clinical criteria for social anxiety disorders receive proper interventions [454]. Further, prior work emphasizes that current assessment technique oversee a large time gap between the onset of social anxiety and the individual actually receiving help [238, 505, 419]. Furthermore, 36% of people suffer under the severe effects of social anxiety for more than a decade before reaching out for help [454].

As discussed earlier, games could help to bridge existing gaps in current assessment techniques and guide help-seeking players towards the needed help [334]. Further, games reveal many bits of information about their players directly and indirectly. Some researchers argue that off-the-shelf games may be helpful to recover from severe mental stress or trauma [106, 40, 412]. Additionally, Mandryk et al. [335] outline the great potential of harnessing digital game data for the matter of mental health assessment. Within the context of social anxiety, this approach may be beneficial. As previously discussed, this dissertation builds on the evidence that socially-anxious individuals prefer games as a coping mechanism, resulting in an increased vulnerability to problematic gaming behaviour [312, 395, 192]. Prior work in the context of virtual reality simulations reveals that characteristics of social anxiety manifested in these experiments, and that researchers were able to differentiate low versus highly socially-anxious behaviour [305, 145]. Yet, virtual reality simulations use various sensors to immerse players into an accurate simulation of simulations like head-mounted displays, and tracking sensors and suits. But games, on the other hand, use simpler input and output devices, such as desktop screens and mouse and keyboard inputs. As such, games may face a challenge to immerse players into the feeling of being "onself" in the game [100, 373].

Yet, the results of the presented work show that in-game data can actually provide us behavioural data as well as information that could reveal cognitive biases. An explanation of why social anxiety may manifest in-game is given by the media equation theory [440]: This theory proposes that individuals react to computers with social responses [440]. Based on media equation theory, along with the concept of social presence [178, 47], the experience that a virtual space is shared with other individuals (see Manuscript 2) can be explained. However, players may also enact and explore different roles than their own [73]. But why does a "simple

game" induce fear to humans? Prior work suggests that one of the main reasons why the media equation occurs is the human mind itself: The human brain evolved in a world in which all perceived stimuli were "real" and could cause harm in extreme cases [313]. With the rise of media, humans began to adapt media platforms as an "extension", which allowed them to transfer their thoughts and presence over these media platforms. Media content became accepted as an extension of other human beings [452]. But not only humans and their understanding of media overall evolved over time, but our social spaces and games have undergone huge changes. As recent work shows [214, 272, 187], digital games have evolved from a niche topic into a central popular-cultural phenomena, which is used not only as a way to entertain oneself but also as a place to socialize with others [172]. Furthermore, when confronted with stimuli, we still have the strong tendency to promptly accept any stimuli as if true, unless there is strong counter evidence. The explanation for this tendency lies again in the evolution of the human brain: quickly processing incoming stimuli helped our ancestors to take quick responses to potential threats, improving changes of survival. Taking all the evidence together, we see that socially-anxious players prefer to satisfy their needs through digital social games, like MMORPGs. Within digital games, players may express themselves during the play session. Game developers may harness game data, such as the movement behaviour, the communication strategies or even the perception of another player's emotion in-game. These data form the foundation for the assessment of in-game digital biomarkers, which allow us to assess social anxiety.

5.2   Methodology

Throughout the five presented manuscripts, we made many methodologically similar choices, which were explained and justified in the manuscripts themselves. However, we would like to use this section to discuss certain recurring themes that emerged during this research.

5.2.1   Internal versus external validity

When designing experiments, researchers always need to balance between controlling every little detail in an experiment (i.e., internal validity) versus the contextualization of this research in everyday life (i.e., external validity). Prior work argues that immersive virtual environments, such as digital games, provide the technology to replicate the real world in the digital realm. [67] Within the given context of this dissertation, we first need to rephrase this question about internal versus external validity into the question of whether we should use off-the-shelf digital games or implement custom gaming tasks in order to find evidence that social anxiety can be measured through in-game behaviour? As Mandryk et al. [335] already suggest, digital games on their own already offer a rich source of data and potential game behaviour, so why did we choose to use a custom gaming task instead of an off-the-shelf commercial game?

We argue that using off-the-shelf games as a start point for this investigation would have included the risk that the underlying game mechanics overshadow the assessment. As discussed earlier, games allow players to

enact many roles and underlying game rules easily can force players to enact different roles. For example, certain game mechanics force players to stand on certain positions next to each other or bind them together so they must stand close to each other all the time. However, other aspects may not be affected by the game mechanics in the first place, such as the chosen roles in the game or the selected genres, which allow socially-anxious players to interact with other players in a more comfortable way. As shown in Manuscript 1, players with social anxiety still love to play MMORPGs but in their own unique ways. Also Manuscript 2 confirms that biases of social anxiety can manifest in games, which could cause players to choose certain roles and designs for their self-representation, likely less customized ones, in order to hide insights about themselves. Further, in many games, the interaction with NPCs is a core component and players have a huge variety of options how to interact with them. Manuscripts 3, 4, and 5 provide insights into how social anxiety and psychopathy affect fundamental aspects of gaming behaviour. Therefore, this dissertation should be seen as a starting point toward assessment using off-the-shelf games. We show that in-game behaviour is actually affected and cognitive biases of social anxiety also manifest in the games, enabling future research to investigate more advanced digital biomarkers.

5.2.2 Measurements

The presented work in this dissertation evolves around the idea of completing traditional assessment techniques with digital tools to enhance existing techniques. Therefore, we relied heavily on standardized and well-studied questionnaires, like the LSAS [322] and the PIS [523]. However, as previously introduced, social anxiety can evolve around very specific feared situations, which inspired us to adapt existing questionnaires for the context of online gaming in Manuscript 1. This adaptation helped us to better understand the specific needs of online gamers with social anxiety and how their anxiety biases their preferences. As shown, in-game social anxiety and out-of-game social anxiety are highly correlated (see Manuscript 1), yet some players experience high social anxiety in the physical realm and low in-game social anxiety. In the later projects, we relied on standardized questionnaires in order to fulfill the goal of completing existing standardized procedures with our behavioural measurements. However, we did not include qualitative assessments and interviews as a way to assess the personal level of social anxiety in any of the manuscripts. In order to validate through statistical procedures that our found digital behavioural markers actually can be helpful for the assessment of social anxiety, we required a large sample size. Using qualitative screening and assessment techniques would have been unrealistic to obtain this sample size. However, we were not able to explore the nuanced forms of social anxiety and how individual characteristics may affect the strength of our markers, which could be a rich source for future researchers to explore how various sub categories of social anxiety manifest in digital games.

5.2.3 Online studies

All presented manuscripts relied on crowd-sourced data collection using tools like Amazon Mechanical Turk and Prolific to recruit and pay participants. However, while the usage of online platforms offer many advantages

to in-lab approaches, it has not been without criticism [153] and has its own risks. We will discuss some aspects and current challenges we encountered during the development of our in-game digital biomarkers on these platforms.

Characteristics of the participants

The main advantage of these online platforms is the easy access to a wide variety of user groups. Over the span of this dissertation, we recruited around 2000 participants for all experiments and pre-screens with diverse backgrounds. Compared to traditional in-person studies, we were able to recruit not only students or participants close to the academic context. This means that we not only had young adults in the samples but also a more diverse group over factors like age, gender identity, ethnicity and socioeconomic status in our experiments. We faced similar problems as mental health professionals during the recruitment: On one side, in-person experiments would have allowed us to use additional sensors to include physiological symptoms of social anxiety. However, there is still an ongoing discussion about the reliability, such as skin conductance as a measurement for social anxiety. Furthermore, socially-anxious individuals may have not showed up because they feel too much discomfort participating in an in-lab study [476, 143, 280]. Yet using online studies would allow us to reach out to a broader audience and lower the barricades for socially-anxious players: They didn't have to show up at the experiment and could participate inside their own comfort zone. Therefore, we choose online studies as the foundation for this work.

This decision to gather data online was made in 2019, when we conducted the data collection for Manuscript 1. In the context of accessing a large sample of gamers, our experience has shown that online collection tools work very well to gather data from this group. However, for Manuscripts 2 through 5, the decision was also partially informed by the COVID-19 pandemic. We had planned to gather data from participants online and also from a collaborating clinic for Manuscripts 2, 3, and 4; however, restrictions around the pandemic forced us to pivot to online-only data collection. In future work, we plan to replicate our findings with participants recruited from clinical contexts, using data gathered in person.

Data quality

The increased accessibility to a larger audience also comes with an increased effort. As prior work as well as our work emphasizes, online studies require researchers to carefully examine the recorded data and needs more effort to filter out neglectful participants [226]. Further, we face raising technical challenges during the experiments, such as the participant selection: While MTurk allows researchers to use classifiers to filter for certain demographics and regions, such as only English speaking countries, some participants use virtual private networks or the usage of multiple accounts to breach the filtering. Additionally, external effects may affect the quality of the recorded data as well as the demographics. For example: Due to a video posted on the social media platform TikTok, many young female participants flooded the platform Prolific, causing a huge bias in the demographics of experiments hosted during that time frame [317]. These examples show that

while online experiments are a powerful and comfortable tool, they come with their own challenges, which researchers need to be aware of to insure the validity of their data.

5.3 Contribution of this dissertation

As previously outlined, the dissertation builds on three main goals, which I converted into five underlying research questions: First, we wanted to better understand the relationship between social anxiety and in-game behaviour as well as the influence of in-game mechanics on the experience of social anxiety. Second, we sought to identify behavioural changes induced by social anxiety, which could be harnessed for the assessment of social anxiety through in-game behaviour. Finally, we were explored how the found digital behavioural biomarkers may be used to better understand the players' behaviours in-game from other points of view, in our case the influence of personality traits.

5.3.1 Understanding about the manifestation of social anxiety in-game and out-of-game

As previously introduced, prior literature focused mostly on the relationship between *social anxiety* and *problematic gaming behaviour* [123, 395, 192]. One main argument for why socially-anxious players may be drawn to digital games is the need to socialize [292]. However, this dissertation—especially Manuscript 1—emphasizes that social anxiety is not bound to the physical realm, but also manifests in-game. We showed that socially-anxious individuals tend to translate their fear of evaluation by others into the gaming context, resulting in withdrawing from social interactions with others in-game as well as the preference for easier in-game activities. However, players with elevated social anxiety still enjoy games with a strong social component, such as MMORPGs. The presented results of Manuscript 1 suggest that there are other personal as well as environmental aspects that may cause socially-anxious players to develop problematic gaming behaviours. Continuing to understand this relationship between social anxiety and gaming behaviour may inform the design of in-game mechanics to increase the well-being of players suffering from social anxiety, and when players cross a line and play may become harmful. Further, the previously-introduced cognitive model of social anxiety by Heimberg [235] defines three major classifications of symptoms of social anxiety: Physical, behavioural, and cognitive. The results of this dissertation about the preferences of socially-anxious players may be seen as a cognitive symptom, similar to other biases of socially-anxious individuals. As outlined earlier in this dissertation, socially-anxious individuals may be more critical and worried about their own performance [355] and how others may perceive them [244], but also experience an increased frequency of distorted self-imagery [471]. The results of this dissertation provide evidence that suggest that these cognitive biases also manifest in-game, but perhaps slightly weaker. On one side, players actually avoid highly challenging activities and also avoid social interactions in-game, depending on the level of in-game social anxiety (GSAS). While these results are promising, more in-depth explorations are required to better

understand how cognitive symptoms of social anxiety may manifest in the digital realm.

However, the results of this dissertation show that certain game mechanics may cause players to experience social anxiety in-game. Recent work about combating attrition in online mental health interventions suggests avatar customization as a way to increase the user's engagement with the intervention and to keep them motivated over the procedure [62, 438]. While these results are promising, most of this work focuses only on the potential benefits of customized self-representation in-game. However, our work shows that for users affected by social anxiety, these proposed benefits may vanish due to their elevated experience of social anxiety, which intensifies through the more elaborated self-representation by customized avatars. As previously introduced, social anxiety may lead to an distorted self-imagery and self-perception of the personal performance and attractiveness to others [195, 235, 491]. In recent years, game designers have started to allow players to customize their in-game representation to harness the prominently discussed benefits of self-representation in-game. The results of this dissertation emphasize that designers need to be aware about the potential risks of certain design strategies: While some users may feel more attached to the game, as prior work shows, some other players may feel less comfortable and even experience elevated (in-game) social stress due to their fear of being evaluated for their custom character. However, offering both customized and predefined characters may lead to other social risks for players. For example, in some popular game franchises (e.g., Fortnite [320]), players without a custom skin may be excluded by others, because customized avatars are only accessible for more advanced players compared to others [401]. Therefore, the results of this dissertation emphasize that game designers need to be careful when crafting game mechanics as they may decrease the accessibility of their game to certain users as well as may induce some hidden social status symbols, which can lead to unwanted anti-social behaviour in-game.

From the lens of mental health, these results show how game mechanics may be adapted for usage in online interventions, such as in exposure therapy. As outlined earlier in Manuscript 2, the use of customized versus predefined avatars may enable users to explore different roles. For example: Recent work investigated about the efficacy of different role-playing techniques to restructure negative thoughts about one's own performance [1]. The authors showed that participants who acted in anxiety-provoking social situations first in their own role and later acted the same social situation with reversed roles, had a reduced negative cognition, decreased their cost estimates of negative judgements by others, and had a lower probability of negative cognition estimations [1]. Back in the context of online assessment, users may explore different roles and perspectives on certain social situations through a game-based intervention. As prior work shows, players use games to explore roles and self-images. Harnessing this idea may help designers of mental health interventions to build stronger and more efficient exposure tasks to help users to overcome their personal fears.

5.3.2 Digital behavioral biomarkers for assessing social anxiety

Considering again the three categories of symptoms of social anxiety (physical, behavioural, cognitive) [235], the second category focuses on behavioural changes of individuals, such as the withdrawal and avoidance

of social interactions or to endure them with elevated stress, which results in physiological reactions of the body (e.g., sweating or blushing [533, 46]). As prior work emphasizes, digital games offer a rich but still under-explored environment in which players produce various data during their time in the game [332]. Building on the previously- discussed results, we were able to show, that describing behavioural symptoms of social anxiety may manifest in-game, such as the preferred distance to strangers [201], as well as the increased IPD to others. Building on these results, this dissertation confirms that implicit measurements, such as the characteristics of the movement path, as well as explicit measurements, such as the preferred interpersonal distance, can be used in-game to predict the personal level of social anxiety. However, as previously discussed, there are several limitations to this approach, such as the question of which games are suitable. Yet this dissertation provides a new gaming task that can be used to explore how users may behave in simulated social interactions. Further, this dissertation contributes not only the in-game behaviour but also provides evidence that shows how the in-game behaviour, the communication, and the perceived emotion of the NPC may be useful for the assessment of mental health concerns, such as social anxiety.

5.3.3 The influence of psychopathic character traits on social interactions in-game

As described earlier, Manuscript 5 is an application of the developed social interaction task to explore how a player's attributes, such as their personality as well as their social skills, may alter in-game communication with a stranger, the movement around a stranger's avatar and the respect of the social space as well as the perception of emotion in-game. The presented results show that the presented task not only works in the context of social anxiety, but also in other social interaction contexts, such as the realm of psychopathy. As described in Manuscript 5, we were able to show that players with psychopathic character traits show a decreased personal distance to the NPC, but also use a more rude self-centered language and bypass the NPC closer, therefore ignoring the social space of the NPC. This shows that we successfully built not only a way to detect potential social anxiety, but also provide a new tool for future researchers who want to investigate the relationship between player's traits and mental health and the manifestation of these traits in-game in social interactions.

In summary, this dissertation provides new insights about the relationship between social anxiety and social behaviours in-game. We show that certain game mechanics, such as the customized self-representation in-game, affect the players not only in a positive way, but may also cause players to experience elevated social fear in-game. Building on these results we proposed, developed, and successfully deployed this social interaction gaming task to predict social anxiety and to better understand how individuals with psychopathic character traits perform. We show that socially-fearless individuals and socially-anxious individuals behave quite the opposite in our social task, allowing us to assess the severity of social anxiety. Taken together, we explore the three proposed symptom categories of Heimberg's model of social anxiety [235, 435] and provide evidence that these symptom categories may also manifest within the realm of digital games.

5.4 Future research directions

Future research may build on this dissertation in various directions, which we discuss in this section.

5.4.1 Better understanding of social anxiety

Building on the evidence of Manuscripts 1 and 2, future researchers may explore the relationship between different core game mechanics as well as how the narration of the game may affect the manifestation of social anxiety. Many games weave an epic story around the player's avatar, in which the player may become a famous and powerful hero. However, as previously described, enacting a different role in-game may weaken the presence of social anxiety, which can affect the visibility of in-game social anxiety based behavioural and cognitive biases. Understanding the role of narration may help designers to enhance digital assessment and intervention tools using a powerful underlying story, which does not distort the player's in-game behaviour too much. Further, Manuscript 1 opened up a variety of research questions to better understand how socially-anxious individuals may satisfy their needs online. While we saw that players *indicated* their in-game preferences, the question remains of whether socially-anxious players follow these preferences or endure social events in-game with elevated stress, similar to social interactions in the physical realm. Finally, while Manuscript 1 focused mostly on MMORPGs, these results may differ for other more performance-oriented genres, like real-time strategy or first-person shooter games. Future research may explore social anxiety within these genres to find more insights about the overarching relationship between digital games, preferences, and the influence of social anxiety.

5.4.2 In the wild: in-game behaviour in commercial games

As previously discussed, there are different approaches to using digital games within the context of mental health. Building on these results, we enable future researchers to explore whether these results may manifest in a similar way in commercial games, with less control about the social context and the presence of a more elaborated narrative in-game, which can alter the perception of oneself. Enabling mental health professionals to assess the severity of social anxiety using in-game data may help to provide fast and efficient assessment and guide affected players more easily towards the required help. However, other aspects of "in-the-wild" gaming behaviour may become interesting for the assessment of social anxiety, such as the usage of in-game communication tools, genre preferences, and other accessible data. Harnessing and adding meta information beyond a single game may allow designers and researchers to better understand how digital games may become a powerful tool for tackling the rising mental health crisis.

5.4.3 The role of co-morbid mental health concerns

As previously discussed, social anxiety is highly co-morbid with other mental concerns, such as depression [410, 494, 381]. Future research may explore how these co-morbid and sometimes overlapping mental health diagnoses may affect the proposed behavioural biomarkers. Understanding how different mental health concerns may affect in-game behaviour will strengthen the assessment using in-game behaviour markers and allow designers to harness digital games as a powerful tool to deliver fast assessment.

5.5 Application of the results

In this dissertation we focused on the assessment of social anxiety. However, during the development of the manuscripts we also explored adjunct topics which build on the results of this dissertation.

5.5.1 Video game streaming as exposure task for social anxiety

Building on the results of Manuscript 1-4 we explored the benefits of video game streaming as an online exposure for social anxiety [187]. As previously discussed, assessment as well as interventions for social anxiety require that the patient stays focused and engaged during the task [111]. One of the most effective interventions for social anxiety builds on exposing the patient to threatening stimuli [341]. However, this approach can be overwhelming not only for the patient but also for the mental health professional [382, 445]. Additionally, several barriers, such as logistical issues [187] and the experience of stigma [118], or simply boredom let individuals withdraw from the exposure task. Therefore, prior work has been exploring alternatives to deliver effective intervention approaches, such as the usage of improvisation theatre in the school-context [179]. In the digital context, video game streaming may offer a cheap and adaptable solution to deliver an online exposure especially for adolescents. Therefore, we explored in this research how video game streaming may satisfy the requirements for an effective exposure task. In two online studies we provide evidence that video game streaming may be suitable for developing an exposure task.

5.5.2 Social Anxiety in the context of online video chat

As discussed in Manuscript 1, social anxiety is context sensitive and individual: While one individual may feel social anxiety during a presentation at a conference, the same individual may not feel the social stress while giving the same talk online. During recent years, video chats and online communication became a major component of our social life and for some individuals almost the only way to satisfy their social needs. However, as Manuscript 1 shows, social anxiety manifests in the digital realm as well and may cause players to show similar symptoms as in the physical world [147]. In order to find out how the video chat interface affects the experience of social anxiety in a video chat context, we carried out two studies. In study one, we used a get-to-know-you task to show that when a person's own video feedback was disabled, higher social

anxiety is associated with more public self-awareness, use of 2nd person pronouns, and experienced anxiety. Further, higher social anxiety led to a broader range of discussion topics, but discussing more topics only elicited higher self-disclosure and trust for people scoring low on social anxiety. In study two, we assessed the same effects using a presentation layout video chat interface. We observed no effect of social anxiety on public self-awareness, 2nd person pronoun use, or number of topics discussed; no effect of feedback on experienced anxiety; and no link between number of topics and self-disclosure. Building on these results, we show that user interface designers must consider the effects of different interface layouts in order to avoid the experience of elevated social stress during a video chat [358].

6 Conclusion

Social anxiety is a prevalent and sometimes severe mental health concern, but is under-diagnosed due to several barriers to existing assessment and intervention approaches. As previous work shows, the assessment of this mental health concern is a highly-challenging task due to the characteristics of social anxiety, such as the high comorbidity with other mental disorders, the elevated fear of potential negative consequences of social interactions, and the social withdrawal of affected individuals. Games have been shown to be a helpful tool to bridge some potential shortcomings of existing tools in the realm of mental health assessment, as well as intervention. Further, traditional interventions need novel ways to overcome existing barriers. Within this context, digital interventions show promising results, but haven't harnessed the full potential of digital games. One reason for this lack of progress is missing understanding about the relationship between social anxiety and gaming preferences, and the effects of social anxiety on the development of problematic gaming behaviour. This dissertation contributes to a better understanding of how digital games may help to enhance existing techniques for the assessment of and interventions for social anxiety:

First, we provide a better understanding of how social anxiety affects the preferences of socially-anxious players within the digital gaming context. We further explore the relationship between social anxiety and in-game avatar representations, which would be used in both future assessment and intervention designs. These insights informed the development of assessment tools and may provide explanations as to why socially-anxious players—who are at higher risk of developing more severe coping strategies, including problematic game usage—prefer social games, such as MMORPG titles.

Second, this dissertation contributes ways on how to assess social anxiety through digital in-game behavioural biomarkers. Further, we provide design recommendations for a social interaction task to analyze the social behaviour and competence of users using a gaming task. We show how explicit measurements, such as the measurement of preferred interpersonal distance, and implicit measurements, such as the player's movement path around a character, can be used to assess the severity of social anxiety of a person.

Third, the dissertation explores how psychopathic character traits may affect the proposed behavioural measurements, including the in-game movement, perception of emotions, and the communication with an NPC.

With these new insights, researchers and designers will be able to design novel approaches for the assessment of one of the most severe mental issues of modern society, and help affected individuals to build brides towards a more satisfying life.

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Appendix A

Supplementary Materials

A.1 Consent forms

The following section summarizes the consent forms for the five presented manuscripts.

A.1.1 Manuscript 1

Title: Player Preferences in Massively Multiplayer Online Role Playing Games (MMORPG)

Researcher(s):

- **Martin Dechant**, martin.dechant@usask.ca

- **Susanne Poeller**, s1supoel@uni-trier.de

- **Colby Johanson**, colby.johanson@usask.ca

- **Katelyn Wiley**, kathelyn.wiley@usask.ca

- **Dr. Regan Mandryk**, regan.mandryk@usask.ca

Purpose(s) and Objective(s) of the Research:

The purpose of this project is to understand MMORPG preferences and how they relate to personality and social interaction.

Procedures

In this study, you will be asked to complete several surveys, asking you some questions about yourself, including questions about your well-being, and personality.

Funded by

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

Potential Risks

- There are no known or anticipated risks to you by participating in this specific research project.

- There is always a risk of minor anxiety or stress associated with participating in an experiment.

- Some of the survey questions may prompt you to reflect on your life and feel emotional discomfort as a result of that process.

Potential Benefits

Your participation will help us to design technology, including serious games.

Compensation

- To thank you for participating, we will provide you with a $3 honorarium.

- The entire experiment should take approximately 15 minutes to complete.

Confidentiality

- Confidentiality will be maintained throughout the study. The entire process and data will be anonymized. Data will only be presented in the aggregate and any individual user comments will be anonymized prior to presentation in academic venues.

- Only the principal researcher and her research assistants will have access to the data to ensure that your confidentiality is protected.

Storage of Data

- Data (including survey and interview responses, logs of computer use) will be stored on a secure password-protected server for 7 years after data collection.

- After 7 years, the data will be destroyed. Paper data will be shredded and digital data will be wiped from hard disks beyond any possibility for data recovery.

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 Martin Dechant (martin.dechant@usask.ca).

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 or call (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

A.1.2 Manuscript 2

Title: The effects of avatars on the enjoyment of gamified shopping experience.

Researcher(s):

- **Martin Dechant**, martin.dechant@usask.ca

- **Dr. Max Birk**, m.v.birk@tue.nl

- **Dr. Youssef Shiban**, shiban@pfh.de

- **Dr. Knut Schnell**, knut.schnell@med.uni-goettingen.de

- **Dr. Regan Mandryk**, regan.mandryk@usask.ca

Purpose(s) and Objective(s) of the Research:

The purpose of this project is to better understand how gamification affects the overall shopping experiences in the web.

Procedures

In this study, you will be asked to play a digital game and complete several surveys, asking you some questions about yourself, including questions about your well-being, and personality.

Funded by

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

Potential Risks

- There are no known or anticipated risks to you by participating in this specific research project.

- There is always a risk of minor anxiety or stress associated with participating in an experiment.

- Some of the survey questions may prompt you to reflect on your life and feel emotional discomfort as a result of that process.

Potential Benefits

Your participation will help us to design technology, including serious games.

Compensation:

- To thank you for participating, we will provide you with a $6 honorarium.

- The entire experiment should take approximately 30 minutes to complete.

Confidentiality

- Confidentiality will be maintained throughout the study. The entire process and data will be anonymized. Data will only be presented in the aggregate and any individual user comments will be anonymized prior to presentation in academic venues.

- Only the principal researcher and her research assistants will have access to the data to ensure that your confidentiality is protected.

Storage of Data

- Data (including survey and interview responses, logs of computer use) will be stored on a secure password-protected server for 7 years after data collection.

- After 7 years, the data will be destroyed. Paper data will be shredded and digital data will be wiped from hard disks beyond any possibility for data recovery.

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 Martin Dechant (martin.dechant@usask.ca).

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 or call (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

A.1.3 Manuscript 3 and Manuscript 4

Title: Input lags in digital games

Researcher(s):

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Purpose(s) and Objective(s) of the Research:

The purpose of this project is to better understand the design of non-player characters (NPCs) in digital games under differing amounts of network lag.

Procedures

In this study, you will be asked to play a digital game and complete several surveys, asking you some questions about yourself, including questions about your well-being, and personality.

Funded by

Potential Risks

- There are no known or anticipated risks to you by participating in this specific research project.

- There is always a risk of minor anxiety or stress associated with participating in an experiment.

- Some of the survey questions may prompt you to reflect on your life and feel emotional discomfort as a result of that process.

Potential Benefits

Your participation will help us to design technology, including serious games.

Compensation:

- To thank you for participating, we will provide you with a $6 honorarium.

- The entire experiment should take approximately 20-30 minutes to complete.

Confidentiality

- Confidentiality will be maintained throughout the study. The entire process and data will be anonymized. Data will only be presented in the aggregate and any individual user comments will be anonymized prior to presentation in academic venues.

- Only the principal researcher and her research assistants will have access to the data to ensure that your confidentiality is protected.

Storage of Data

- Data (including survey and interview responses, logs of computer use) will be stored on a secure password-protected server for 7 years after data collection.

- After 7 years, the data will be destroyed. Paper data will be shredded and digital data will be wiped from hard disks beyond any possibility for data recovery.

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 Martin Dechant (martin.dechant@usask.ca).

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 or call (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

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Title: Input lags in digital games

Researcher(s):

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A.2 Measurements

This section summarizes the used questionnaires for all manuscripts, which were referred in each method section.

A.2.1 Liebowitz Social Anxiety Scale (LSAS)

The LSAS [322] consists of 24 items, split into two categories, which describe different social situations and interactions: social interaction (11 items; e.g., "Giving a party") and public performance (13 items e.g., "Eating in a public place"). These items are rated on two 4-point Likert scales, one to measure the fear (0 = "none", 3="severe") and a second on how often these items were avoided in the last 2 weeks (0 ="0% / never", 3 = "usually/68-100%"). The answers are summed together to estimate the level of trait social anxiety, between 0 and 144, where higher values indicate a higher level of social anxiety.

MMORPG User Preference Study

This measure assesses the way that social phobia plays a role in your life across a variety of situations. Read each situation carefully and answer two questions about that situation.

Pleace rate <u>how anxious or fearful you feel in the described situation</u>. If you come across a situation that you ordinarily do not experience, imagine 'what if you were faced with that situation,' and then, rate the degree to which you would fear this hypothetical situation.

	None	Mild	Moderate	Severe
Going to a party.	○	○	○	○
Talking with people you don't know very well.	○	○	○	○
Taking a test.	○	○	○	○
Writing while being observed.	○	○	○	○
Speaking up at a meeting.	○	○	○	○
Eating in public places.	○	○	○	○
Drinking with others in public places.	○	○	○	○
Resisting a high pressure salesperson.	○	○	○	○
Talking to people in authority.	○	○	○	○
Meeting strangers.	○	○	○	○
Trying to pick up someone.	○	○	○	○
Looking at people you don't know very well in the eyes.	○	○	○	○
Returning goods to a store.	○	○	○	○
Giving a party.	○	○	○	○
Being the center of attention.	○	○	○	○
Expressing a disagreement or disapproval to people you don't know very well.	○	○	○	○
Entering a room when others are already seated.	○	○	○	○
Giving a report to a group.	○	○	○	○
Working while being observed.	○	○	○	○
Urinating in a public bathroom.	○	○	○	○
Participating in small groups.	○	○	○	○
Acting, performing or giving a talk in front of an audience.	○	○	○	○
Calling someone you don't know very well.	○	○	○	○
Telephoning in public.	○	○	○	○

Pleace rate how often you <u>avoid the situation.</u> If you come across a situation that you ordinarily do not experience, imagine 'what if you were faced with that situation,' and then, rate the degree how often you would tend to avoid it..

	Never (0%)	Occasionally (1-33%)	Often (34-66%)	Usually (67-100%)
Talking to people in authority.	○	○	○	○
Participating in small groups.	○	○	○	○
Drinking with others in public places.	○	○	○	○
Acting, performing or giving a talk in front of an audience.	○	○	○	○
Entering a room when others are already seated.	○	○	○	○
Calling someone you don't know very well.	○	○	○	○
Giving a party.	○	○	○	○
Urinating in a public bathroom.	○	○	○	○
Trying to pick up someone.	○	○	○	○
Working while being observed.	○	○	○	○
Looking at people you don't know very well in the eyes.	○	○	○	○
Talking with people you don't know very well.	○	○	○	○
Resisting a high pressure salesperson.	○	○	○	○
Telephoning in public.	○	○	○	○
Writing while being observed.	○	○	○	○
Expressing a disagreement or disapproval to people you don't know very well.	○	○	○	○
Being the center of attention.	○	○	○	○
Speaking up at a meeting.	○	○	○	○
Returning goods to a store.	○	○	○	○
Taking a test.	○	○	○	○
Giving a report to a group.	○	○	○	○
Eating in public places.	○	○	○	○
Going to a party.	○	○	○	○
Meeting strangers.	○	○	○	○

Continue

A.2.2 Game Social Anxiety Scale (GSAS)

Building on the LSAS [322], the GSAS is an adapted version, which focuses on the context of massive multiplayer online roleplaying games. Similar to LSAS it consists of 24 items, which are grouped into the same categories: social interaction (11 items) and public performance (13 items). Like the LSAS the items are rated on two 4 point Liker scales, one to assess the fear (0 = "none", 3="severe") and the second on how often these items were avoided in the last 2 weeks (0 ="0% / never", 3 = "usually/68-100%"). Again, the answers are summed together to estimate the level of in-game social anxiety, between 0 and 144, where higher values indicate a higher level of in-game social anxiety. This questionnaire was original published by Dechant et al. [147].

MMORPG User Preference Study

This measure assesses the way that social phobia plays a role across a variety of situations while you are playing MMORPGs . Read each situation carefully.
Please base your ratings on the way that the situations have affected you in *your gaming* experiences.

How much anxiety or fear do you feel (or would you feel) in the following in-game situations?

	None	Mild	Moderate	Severe
Trying to flirt with another player.	○	○	○	○
Asking your team for a short break in a dungeon or raid.	○	○	○	○
Expressing a disagreement or disapproval to people you don't know very well.	○	○	○	○
Getting caught up in a social conflict.	○	○	○	○
Leaving or changing a guild when you don't like it there.	○	○	○	○
Performing a special task where other players rely on you.	○	○	○	○
Resisting a high pressure recruitment.	○	○	○	○
Being the center of attention.	○	○	○	○
Joining a group where everyone else already knows each other.	○	○	○	○
Starting your own group or guild.	○	○	○	○
Talking with people you don't know very well.	○	○	○	○
Meeting strangers.	○	○	○	○
Having someone in the game world watch you perform a task.	○	○	○	○
Being observed in the game world.	○	○	○	○
Finding out that somebody on your team is streaming.	○	○	○	○
Using unusual builds or talents that could lead to you being criticized.	○	○	○	○
Participating in small groups.	○	○	○	○
Starting or joining a voice chat to socialize.	○	○	○	○
Speaking up in a group.	○	○	○	○
Contacting another player you don't know well.	○	○	○	○
Expressing yourself with a character that stands out.	○	○	○	○
Drawing the attention of players who might insult you.	○	○	○	○
Losing connection during a group activity.	○	○	○	○
Talking in a group voice chat while gaming with other players.	○	○	○	○
Making a mistake in a raid.	○	○	○	○
Joining a group of other players in a fun activity in the open world (e.g. dance parties).	○	○	○	○
Being invited for a trial run / dps test (etc.) to prove your skills.	○	○	○	○
Talking to people in authority.	○	○	○	○
Contributing to an in-game group discussion.	○	○	○	○
Comparing your performance with that of other players (e.g., leaderboards).	○	○	○	○

How often do you (or would you) <u>avoid or take action to avoid</u> the following in-game situations?

	Never (0%)	Occasionally (1-33%)	Often (34-66%)	Usually (67-100%)
Asking your team for a short break in a dungeon or raid.	○	○	○	○
Participating in small groups.	○	○	○	○
Expressing yourself with a character that stands out.	○	○	○	○
Resisting a high pressure recruitment.	○	○	○	○
Trying to flirt with another player.	○	○	○	○
Joining a group of other players in a fun activity in the open world (e.g. dance parties).	○	○	○	○
Drawing the attention of players who might insult you.	○	○	○	○
Finding out that somebody on your team is streaming.	○	○	○	○
Starting your own group or guild.	○	○	○	○
Talking to people in authority.	○	○	○	○
Speaking up in a group.	○	○	○	○
Making a mistake in a raid.	○	○	○	○
Contacting another player you don't know well.	○	○	○	○
Using unusual builds or talents that could lead to you being criticized.	○	○	○	○
Starting or joining a voice chat to socialize.	○	○	○	○
Getting caught up in a social conflict.	○	○	○	○
Talking in a group voice chat while gaming with other players.	○	○	○	○
Comparing your performance with that of other players (e.g., leaderboards).	○	○	○	○
Meeting strangers.	○	○	○	○
Having someone in the game world watch you perform a task.	○	○	○	○
Expressing a disagreement or disapproval to people you don't know very well.	○	○	○	○
Being invited for a trial run / dps test (etc.) to prove your skills.	○	○	○	○
Joining a group where everyone else already knows each other.	○	○	○	○
Losing connection during a group activity.	○	○	○	○
Being observed in the game world.	○	○	○	○
Performing a special task where other players rely on you.	○	○	○	○
Contributing to an in-game group discussion.	○	○	○	○
Being the center of attention.	○	○	○	○
Talking with people you don't know very well.	○	○	○	○
Leaving or changing a guild when you don't like it there.	○	○	○	○

Continue

A.3 Reasons and Preferences in-game of MMORPGs

This questionnaire contains several questions about the reasons for players to engage in digital games as well as the activities their prefer in the MMORPG context. Details about the development and the items can be found in manuscript 1.

MMORPG User Preference Study

How likely would you be to do the following while playing an MMORPG?

	Very unlikely	Unlikely	Not sure	Likely	Very likely
Join a guild voice chat channel.	○	○	○	○	○
Take your time experiencing the story line.	○	○	○	○	○
Work on improving a guild.	○	○	○	○	○
Grind.	○	○	○	○	○
Earn in-game currency by trading goods.	○	○	○	○	○
Chat with players you don't know.	○	○	○	○	○
Play with a group of strangers.	○	○	○	○	○
Run old or lower level raids on your own.	○	○	○	○	○
Join a random group for an easy dungeon.	○	○	○	○	○
Pay for an advantage or to make up for your shortcomings.	○	○	○	○	○
Join a static raid group for a difficult dungeon.	○	○	○	○	○
Join a static raid group for an easy dungeon.	○	○	○	○	○
Engage in side-content that many players ignore.	○	○	○	○	○
Record your gameplay for a video or live stream.	○	○	○	○	○
Run old or lower level raids with others.	○	○	○	○	○
Chat privately with players you know very well.	○	○	○	○	○
Try to get to know other players.	○	○	○	○	○
Join a guild.	○	○	○	○	○
Complete as many daily and weekly quests as possible.	○	○	○	○	○
Move through the story line as fast as possible for rewards.	○	○	○	○	○
Organize a raid.	○	○	○	○	○
Collect mounts and/or pets.	○	○	○	○	○
Join a PvP group activity.	○	○	○	○	○
Collect outfits and accessories for your avatar.	○	○	○	○	○
Decorate private spaces such as your own house.	○	○	○	○	○
Obsess over factions, the lore, and the story of the game.	○	○	○	○	○
Try to complete as many achievements as possible.	○	○	○	○	○
Spend your time to assemble the perfect equipment for your character.	○	○	○	○	○
Participate in solo PvP activities.	○	○	○	○	○
Try to solo a hard dungeon.	○	○	○	○	○
Try to duo a hard dungeon.	○	○	○	○	○
Spend time customizing your avatar's appearance.	○	○	○	○	○
Join a random group for a difficult dungeon.	○	○	○	○	○
Spend your time helping new players.	○	○	○	○	○
Engage in role-playing with other players.	○	○	○	○	○
Try to work your way up in a guild's hierarchy.	○	○	○	○	○

Continue

Please indicate which of these genres you have played in the past

	Never	Seldom	Occasionally	Often	All the time
MMORPGs (Massively Multiplayer Online Role-Playing Games)	○	○	○	○	○
FPS (First-Person-Shooters)	○	○	○	○	○
MOBAs (Multiplayer Online Battle Arena Games)	○	○	○	○	○
RTS (Real Time Strategy Games)	○	○	○	○	○
Battle Royale Games	○	○	○	○	○
Single-Player Games	○	○	○	○	○

Please indicate which of these genres you have played in the past year

	Never	Seldom	Occasionally	Often	All the time
MMORPGs (Massively Multiplayer Online Role-Playing Games)	○	○	○	○	○
FPS (First-Person-Shooters)	○	○	○	○	○
MOBAs (Multiplayer Online Battle Arena Games)	○	○	○	○	○
RTS (Real Time Strategy Games)	○	○	○	○	○
Battle Royale Games	○	○	○	○	○
Single-Player Games	○	○	○	○	○

Please state how much you enjoy playing games of these genres

	Not at all	Mostly not	Somewhat	Mostly	Very much	Can't say
MMORPGs (Massively Multiplayer Online Role-Playing Games)	○	○	○	○	○	○
FPS (First-Person-Shooters)	○	○	○	○	○	○
MOBAs (Multiplayer Online Battle Arena Games)	○	○	○	○	○	○
RTS (Real Time Strategy Games)	○	○	○	○	○	○
Battle Royale Games	○	○	○	○	○	○
Single-Player Games	○	○	○	○	○	○

Please state how likely you think you are going to play these genres in the future

	Very unlikely	Unlikely	Not sure	Likely	Very likely
MMORPGs (Massively Multiplayer Online Role-Playing Games)	○	○	○	○	○
FPS (First-Person-Shooters)	○	○	○	○	○
MOBAs (Multiplayer Online Battle Arena Games)	○	○	○	○	○
RTS (Real Time Strategy Games)	○	○	○	○	○
Battle Royale Games	○	○	○	○	○
Single-Player Games	○	○	○	○	○

Please indicate which MMORPGs you have experience playing

☐ Neverwinter
☐ Star Trek Online
☐ Rift
☐ ArcheAge
☐ Blade & Soul
☐ Guild Wars 2
☐ MapleStory 2
☐ Final Fantasy XIV
☐ Skyforge
☐ TERA
☐ Elder Scrolls Online
☐ Runescape
☐ Lord of the Rings Online
☐ Star Wars: The Old Republic
☐ Secret World Legends
☐ Eve Online
☐ World of Warcraft
☐ Black Desert Online
☐ Planetside 2
☐ Final Fantasy 11
☐ Other

Continue

What do you think is the main difference in <u>how you experience</u> the in-game digital world while playing MMORPGs as compared to the physical world?

> I think the main difference between the two is ...

Please indicate how often you have thoughts similar to these while playing an MMORPG...

	Never	Seldom	Occasionally	Often	All the time
In an MMORPG, I feel more secure than in the physical world.	○	○	○	○	○
In an MMORPG, I feel more socially competent than in the physical world.	○	○	○	○	○
I like to play different games with the same online friends.	○	○	○	○	○
I feel less affected by what happens in an MMORPG than by what happens in the physical world.	○	○	○	○	○
In an MMORPG, if someone is rude to me it does not get to me as easily as in the physical world.	○	○	○	○	○
If I feel uncomfortable in an MMORPG, I can always switch to another one.	○	○	○	○	○
In an MMORPG, I can decide to engage in certain content and ignore other parts.	○	○	○	○	○
In an MMORPG, I find it easier to find ways to make up for my shortcomings.	○	○	○	○	○
In an MMORPG, I can leave my social circle from the physical world behind me.	○	○	○	○	○
In an MMORPG, I feel less judged by others than in the physical world.	○	○	○	○	○
In an MMORPG, I feel more welcome than in the physical world.	○	○	○	○	○
Sometimes the in-game world makes more sense to me than the physical world.	○	○	○	○	○
In an MMORPG, it feels easier to start an activity than in the physical world.	○	○	○	○	○
In an MMORPG, I can easily meet new people and interact with them.	○	○	○	○	○
In an MMORPG, I can explore social interactions in a safe way.	○	○	○	○	○
If it is not going well for me in a guild, I can just move to another guild.	○	○	○	○	○
In an MMORPG, I can avoid activities that I don't like.	○	○	○	○	○
In an MMORPG, I feel more competent than I do in the physical world.	○	○	○	○	○
In an MMORPG, I can be my true self.	○	○	○	○	○
If anything goes wrong in an MMORPG, I can easily quit and be done with it.	○	○	○	○	○
In an MMORPG, I can be who I want to be.	○	○	○	○	○
In an MMORPG, I feel less social pressure than in the physical world.	○	○	○	○	○
The in-game world feels less broken to me than the physical world.	○	○	○	○	○
I have more friends in the in-game world than I do in the physical world.	○	○	○	○	○
I think meeting other players face-to-face is (or would be) great.	○	○	○	○	○
In an MMORPG, social structures make more sense to me than those in the physical world.	○	○	○	○	○
In an MMORPG, I can escape the judgment of others.	○	○	○	○	○
The existence of ignore and mute options in MMORPGs make me feel more secure.	○	○	○	○	○
I feel good about taking MMORPG friendships to an out-of-game context.	○	○	○	○	○
If I am unhappy in a raid group, I find relief in knowing I can just find another group.	○	○	○	○	○

Please indicate whether you feel <u>more anxiety</u> about the following things happening <u>in the physical world or in-game digital world</u> (set slider to the middle if you feel equally anxious or non-anxious about both contexts)

Somebody insulting you for your performance.

physical world   digital world

Somebody insulting you for who you are.

physical world   digital world

Making a mistake.

physical world   digital world

A social interaction going completely wrong.

physical world   digital world

Someone criticizing your choices.

physical world   digital world

Someone judging your performance.

physical world   digital world

Performing in front of others.

physical world   digital world

Other people observing you.

physical world   digital world

Continue

Player Identification Scale (PIS)

The Player Identification Scale contains 17 items which measure three aspects of the player's identification with their in-game representation: Similarity identification, embodied identification, and wishful identification. It was originally published by Van Looy et al. [523].

Triarchic Psychopathy measure (Tri-PM)

The TRI-PM consists of 58 items, split into three subcategories of meanness (19 items), disinhibition (20 items), and boldness (19 items), and can used in combination as measurement for certain personality traits, such as lack of empathy or cold-heartedness [402]. Each item is rated on a 4-point Likert scale (0 = "False"; 3 = "True") and responses are them summed (higher=stronger effects). Meanness is associated with cruel, callous, predatory, and excitement-seeking behavior. Disinhibition on the other side is related to irresponsible, impulsive, oppositional, but also potential hostile behavior. The boldness sub-scale relates to dominance and low anxiousness [402] in the triarchic model. It was originally published by Patrick et al. [402]

Input lags in digital games

This questionnaire contains statements that different people might use to describe themselves. For each statement, select the answer that describes you best. There are no right or wrong answers; just choose the answer that best describes you. Please work rapidly and do not spend too much time on any one statement.

	True	Somewhat True	Somewhat False	False
I have good control over myself.	○	○	○	○
I'm afraid of far fewer things than most people.	○	○	○	○
I never worry about making a fool of myself with others.	○	○	○	○
I would enjoy being in a high-speed chase.	○	○	○	○
I am sensitive to the feelings of others.	○	○	○	○
I don't stack up well against most others.	○	○	○	○
I have taken money from someone's purse or wallet without asking.	○	○	○	○
I sometimes insult people on purpose to get a reaction from them.	○	○	○	○
I'm optimistic more often than not.	○	○	○	○
I have had problems at work because I was irresponsible.	○	○	○	○
People often abuse my trust.	○	○	○	○
It doesn't bother me to see someone else in pain.	○	○	○	○
I don't like to take the lead in groups.	○	○	○	○
I have missed work without bothering to call in.	○	○	○	○
For me, honesty really is the best policy.	○	○	○	○
I have conned people to get money from them.	○	○	○	○
I don't think of myself as talented.	○	○	○	○
I stay away from physical danger as much as I can.	○	○	○	○
I have a hard time waiting patiently for things I want.	○	○	○	○
I often act on immediate needs.	○	○	○	○
Things are more fun if a little danger is involved.	○	○	○	○
It worries me to go into an unfamiliar situation without knowing all the details.	○	○	○	○
I've gotten in trouble because I missed too much school.	○	○	○	○
Others have told me they are concerned about my lack of self-control.	○	○	○	○
It's easy to embarrass me.	○	○	○	○

I don't see any point in worrying if what I do hurts someone else.	○	○	○	○
I can convince people to do what I want.	○	○	○	○
I'm not very good at influencing people.	○	○	○	○
I sympathize with others' problems.	○	○	○	○
I get scared easily.	○	○	○	○
I often get bored quickly and lose interest.	○	○	○	○
How other people feel is important to me	○	○	○	○
I jump into things without thinking.	○	○	○	○
I have a hard time making things turn out the way I want.	○	○	○	○
I keep appointments I make.	○	○	○	○
I don't care much if what I do hurts others.	○	○	○	○
I have no strong desire to parachute out of an airplane.	○	○	○	○
I enjoy pushing people around sometimes.	○	○	○	○
I have lost a friend because of irresponsible things I've done.	○	○	○	○
I've often missed things I promised to attend.	○	○	○	○
My impulsive decisions have caused problems with loved ones.	○	○	○	○
I don't have much sympathy for people.	○	○	○	○
It doesn't bother me when people around me are hurting.	○	○	○	○
I return insults.	○	○	○	○
I can get over things that would traumatize others.	○	○	○	○
I've injured people to see them in pain.	○	○	○	○
I don't mind if someone I dislike gets hurt.	○	○	○	○
I have robbed someone.	○	○	○	○
I have a knack for influencing people.	○	○	○	○
I'm a born leader.	○	○	○	○
It's easy for me to relate to other people's emotions.	○	○	○	○
I taunt people just to stir things up.	○	○	○	○
I get in trouble for not considering the consequences of my actions.	○	○	○	○
I am well-equipped to deal with stress.	○	○	○	○
I have stolen something out of a vehicle.	○	○	○	○
I have taken items from a store without paying for them.	○	○	○	○
I function well in new situations, even when unprepared.	○	○	○	○
I enjoy a good physical fight.	○	○	○	○

Continue

A.3.1 General Gaming Preferences

The Play Behaviour Questionnaire focuses on the frequency of play time in the present, frequency of play in the past, self-identification as a gamer, dominant hand, preferred genres, and used devices.

A.3.2 Demographics

The demographics questionnaire asks users to indicate their age, gender, household income, martial status, and ethnicity. Furthermore the open summary of the experiment was used to detect potential negligent participants.