Exploring the Use of Social Robots in Promoting University Students' Mental Well-Being

by

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Examining Committee Membership

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Author's Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Statement of Contributions

This thesis incorporates content from peer-reviewed published or in-press papers, one manuscript accepted for journal publication and published online, and one journal manuscript in preparation. For J1-J3 and C1-C3, Samira Rasouli was the main investigator and first author.

Journal Articles:

[J1] Samira Rasouli, Garima Gupta, Elizabeth Nilsen, and Kerstin Dautenhahn. Potential Applications of Social Robots in Robot-Assisted Interventions for Social Anxiety. *International Journal of Social Robotics*, 14(5):1–32, 2022. https://doi.org/10.1007/s12369-021-00851-0

Samira Rasouli wrote the first draft of the manuscript. Ms. Garima Gupta contributed to the writing of the sections on social anxiety disorder and treatments for it. Prof. Elizabeth Nilsen and Prof. Kerstin Dautenhahn reviewed and edited the manuscript and also guided the research. The research is presented in Chapters 2 and 3.

[J2] Samira Rasouli, Moojan Ghafurian, Elizabeth Nilsen, Kerstin Dautenhahn. University Students' Opinions on Using Intelligent Agents to Cope with Stress and Anxiety in Social Situations. Accepted for journal publication and published online in *Computers in Human Behavior*, doi:10.1016/j.chb.2023.108072 2023.

All authors contributed to the design of the study. Samira Rasouli performed the experiment and data analysis and wrote the first complete draft of the manuscript. Prof. Moojan Ghafurian, Prof. Elizabeth Nilsen, and Prof. Kerstin Dautenhahn reviewed and edited the manuscript. The research is presented in Chapter 4.

[J3] Samira Rasouli, Moojan Ghafurian, Kerstin Dautenhahn. User evaluation of a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety. (Manuscript in Preparation)

All authors contributed to the design of the study. Samira Rasouli implemented the apparatus, performed the experiment, conducted the data analysis, and is writing the first complete draft of the manuscript. Prof. Moojan Ghafurian and Prof. Kerstin Dautenhahn will review and edit the manuscript. The research is presented in Chapter 6.

Conference Papers:

[C1] Samira Rasouli, Garima Gupta, Moojan Ghafurian, and Kerstin Dautenhahn. Proposed Applications of Social Robots in Interventions for Children and Adolescents with Social Anxiety. Proceedings *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '22, New York, NY, USA, 2022. Association for Computing Machinery. https://doi.org/10.1145/3490149.3505575

Samira Rasouli performed the experiment, conducted the data analysis and wrote the complete draft of the manuscript. All other co-authors reviewed and edited the manuscript.

[C2] Samira Rasouli, Moojan Ghafurian, and Kerstin Dautenhahn. Students' Views on Intelligent Agents as Assistive Tools for Dealing with Stress and Anxiety in Social Situations. Proceedings *10th International Conference on Human-Agent Interaction*, HAI '22, pp. 23–31, New York, NY, USA, 2022. Association for Computing Machinery. https://doi.org/10.1145/3527188.3561932

All authors contributed to the design of the study. Samira Rasouli performed the experiment, conducted the data analysis, and drafted the manuscript. Prof. Moojan Ghafurian and Prof. Kerstin Dautenhahn reviewed and edited the manuscript. The research is presented in Chapter 4.

[C3] Samira Rasouli, Linda Johnston, Jennifer Yuen, Moojan Ghafurian, Leah Foster, and Kerstin Dautenhahn. Co-design of a Robotic Mental Well- Being Coach to Help University Students Manage Public Speaking Anxiety. Proceedings *International Conference on Human-Agent Interaction* (HAI '23), December 4–7 2023, Gothenburg, Sweden, pp. 200-208. ACM, New York, NY, USA.
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Samira Rasouli implemented the apparatus, performed the experiment, conducted the data analysis, and wrote the complete draft of the manuscript. Dr. Linda Johnston, Ms. Jennifer Yuen, and Ms. Leah Foster assisted with the co-design of the system and reviewed the manuscript. Prof. Moojan Ghafurian and Prof. Kerstin Dautenhahn reviewed and edited the manuscript. The research is presented in Chapter 5.

Other Contributions:

Samira Rasouli also collaborated on two other projects related to her research area. The first and second articles listed below are the outcomes of the MASc research project of Delara Forghani. This research was an extension of this Ph.D. thesis research. Samira Rasouli, based on the results of her survey studies, suggested the application of a public speaking coach to the MASc student, and provided mentorship for this project alongside Prof. Moojan Ghafurian, Prof. Chrystopher L. Nehaniv, and Prof. Kerstin Dautenhahn, and contributed to the project by collaborating on study design, implementation, and data analysis. The third and fourth articles are the outcomes of a project dedicated to conducting a systematic review of social robots for health and well-being. Samira Rasouli collaborated on this project by full-text screening of more than 200 articles and data extraction from the included articles.

- Delara Forghani, Moojan Ghafurian, Samira Rasouli, Chrystopher L. Nehaniv, and Kerstin Dautenhahn. What Do People Think of Social Robots and Voice Agents as Public Speaking Coaches? Proceedings *32nd IEEE International Conference on Robot and Human Interactive Communication* (RO-MAN), 18-31 August 2023, Busan, Republic of Korea, 2023, pp. 996-1003

- Delara Forghani, Moojan Ghafurian, Samira Rasouli, Chrystopher L. Nehaniv, and Kerstin Dautenhahn. Evaluating People's Perceptions of an Agent as a Public Speaking Coach. (Under review for publication in a journal)

- Moojan Ghafurian, Kerstin Dautenhahn, Arsema Teka, Shruti Chandra, Samira Rasouli, Ishan Baliyan, and Rebecca Hutchinson. Human-Robot Interaction Studies with Adults in Health and Wellbeing Contexts - Outcomes and Challenges. Proceedings *15th International Conference on Social Robotics* (ICSR 2023), 3-7 December 2023, Doha, Qatar, pp. 130-142.

- Moojan Ghafurian, Shruti Chandra, Rebecca Hutchinson, Angelica Lim, Ishan Baliyan, Jimin Rhim, Garima Gupta, Alexander M. Aroyo, Samira Rasouli, Kerstin Dautenhahn. Systematic Review of Social Robots for Health and Wellbeing: A Personal Healthcare Journey Lens. (Under review for publication in a journal)

Abstract

Mental health problems within university student populations are a growing concern. In recent years, university students have reported increased symptoms of stress and anxiety, which can negatively impact their mental well-being and academic performance. However, many students do not seek or receive support for these challenges. With recent technological advances in social robots and their expanding capabilities, there is potential for social robots to extend and complement mental health care interventions and enhance access to care. This thesis introduces a novel application of social robots in robot-assisted interventions for addressing stress and anxiety in social situations.

As an initial step to developing effective technology-based interventions, it is essential to identify design elements and functionalities that are perceived as engaging and useful by students. Therefore, our first study explores students' perceptions of, and preferences for, using different types of intelligent agents (e.g., virtual agents, social robots, etc.) to support their mental well-being, specifically to cope with feelings of stress and anxiety in social situations typically encountered within a university context (e.g., engaging in a group discussion, delivering presentations, expressing opinions, etc.). Two online surveys were conducted: a pilot study on Amazon Mechanical Turk (N = 85) and a larger study at the University of Waterloo (N = 1054). The results provide insights into different design elements (e.g., confidentiality, accessibility and enjoyment) as well as social and technical capabilities (e.g., ability to understand conversation) to consider when designing intelligent agents to help address stress and anxiety among university students. The results also showed that public speaking is one of the most anxiety-provoking social situations at university, and animal-like robots were the most selected agents among the given choices of different types of intelligent agents to use for managing anxiety related to the students' most anxiety-provoking social situations. Participants also endorsed a variety of activities that they thought could be beneficial for managing anxiety related to their most anxiety-provoking situation, including receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation and yoga), getting help with thinking calming or positive thoughts, and getting help with building confidence, for which they indicated to be willing to use an intelligent agent.

In the next step, we used the findings of our first study to design a robotic mental well-being coach aimed at assisting university students in managing public speaking anxiety. To this end, in our second study, we conducted collaborative co-design sessions with five mental health professionals (the envisioned secondary users) to identify the design-related needs, including robot behaviours and interactions. We employed a co-design approach to ensure that the design of the robot's behaviours and functionalities is grounded in

evidence-based practices and aligns with the best practices of psychological support in this application area that can be delivered by a robotic coach. Furthermore, we carried out a participatory study involving six university students (the envisioned primary users) to gather their opinions for further improvements to the robotic coach. Students provided feedback on the behaviours and functionality of the robot and generally found the robot engaging, relaxing, knowledgeable, and beneficial for learning relaxation exercises.

Lastly, after implementing final improvements to the behaviour and functionalities of the robotic coach based on feedback from students and with the assistance of mental health professionals, we conducted our third study with university students (N=50) to evaluate the usability and acceptability of the robotic mental well-being coach designed in the second study to help university students manage their public speaking anxiety. The findings demonstrated a usability score of 84.05 for the robotic coach and high acceptability among university students who perceived the robot as competent and knowledgeable. In addition, a significant improvement in participants' self-reported moods was observed following the study. The qualitative analysis suggests that university students had a positive impression of the robotic mental well-being coach and their interaction. Overall, the findings of this study are encouraging and indicate the potential of social robots as mental well-being coaches to support university students' public speaking anxiety. Future research should investigate the users' experiences and the effectiveness of the robotic mental well-being coach in assisting university students to cope with public speaking anxiety in the long term over multiple interaction sessions.

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Dedication

This thesis is dedicated to my beloved mother, Talat, my father, Mohammad Hossein, my siblings and my husband.

To my loving mother, whom I was so unlucky to lose in the final year of my PhD studies. She was the kindest and most warm-hearted person I have ever known, a constant source of inspiration and energy to me. Her smile could light up the room, bringing warmth and joy. Her courage, unconditional love and support fill me with immense pride and gratitude for having been her daughter and having had the privilege of learning from her to be a better person. Words cannot adequately describe her; she is my ultimate role model. Her boundless optimism and enthusiasm for learning and exploring new experiences are etched in my memory.

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List of Abbreviations

AIC Akaike Information Criterion 130

ASD Autism Spectrum Disorder 21, 28, 30, 32–35, 39–41, 46

CBM Cognitive Bias Modification 14, 15

CBT Cognitive Behavioural Therapy 12, 14, 18, 35, 44, 47, 54, 101, 103, 105, 116, 117, 121, 168, 171, 174

GUI Graphical User Interface 95, 103, 104, 121, 162

HAI Human-Agent Interaction 5, 7, 170, 172, 174

HRI Human-Robot Interaction 5–7, 22–24, 123, 124, 163, 170–174, 176–178

IAP Institutional Analysis and Planning 72

MBSR Mindfulness-Based Stress Reduction 15, 16, 97, 101, 117

MHPs Mental Health Professionals 95–98, 100–103, 105, 116, 121, 159, 169, 178

PMR Progressive Muscle Relaxation 13

PPIs Positive Psychology Interventions 16

PRCA Personal Report of Communication Apprehension 120

PRCA-PS Personal Report of Communication Apprehension, Public Speaking Subscale 98, 99, 120, 122, 129

PTSD Post-Traumatic Stress Disorder 20

RCR Readiness for Change Ruler

RCT Randomized Controlled Trial 37

RoSAS Robotic Social Attributes Scale 124, 133, 158, 169

RR Readiness Ruler 120–122, 135, 158

SAC Survey Advisory Committee 72

SUDS Subjective Units of Distress Scale 104

SUS System Usability Scale 123, 129, 131, 132, 158, 169

TA Thematic Analysis 131, 139, 159

TAM Technology Acceptance Model 124, 169

TIPI Ten-Item Personality Inventory 120, 122

UTAUT Unified Theory of Acceptance and Use of Technology 123

WAI-SR Working Alliance Inventory-Short Revised 126, 135, 158, 163

Chapter 1

Introduction

1.1 Motivation

University years can be an exhilarating time for students, offering a variety of new experiences and opportunities. Nevertheless, research has shown that post-secondary years are a peak time for the first onset of several mental health issues, including mood and anxiety disorders due to personal and academic stressors (e.g., being away from home and family, loneliness, financial concerns, dealing with exams and assignments, etc.) [233, 119, 20]. High levels of stress and anxiety associated with these challenges can adversely impact university students' mental health and well-being, affecting their quality of life and impairing their academic performance [386].

In recent years, there has been an increase in mental health problems such as depression, stress, and anxiety among college and university students worldwide [283, 193, 34, 281]. According to a cross-national study conducted by the World Health Organization (WHO) in 19 colleges across eight countries, one-third of college students have experienced mental health problems such as mood, anxiety, and substance abuse disorders in the past 12 months [20]. In Canada, according to a 2019 survey of 55,284 graduate and undergraduate students, 68.9% of students have experienced overwhelming anxiety on at least one occasion in the last 12 months, and 51.6% felt so depressed that they found it hard to function at least once over a year [11]. Furthermore, a recent study of 11,322 Canadian university students in 2022 reported that 32% and 24.6% of students had been diagnosed with anxiety or depression, respectively [12]. Similarly, in the United States, several studies have shown an increase in the prevalence of mental health problems, most notably depression and anxiety among university and college students [344, 438, 281]. For example, a nationwide

mental health study conducted among students at 373 schools between 2013 and 2021 has revealed that in 2020-2021, over 60% of college and university students met the criteria for at least one mental health problem, which is an increase of almost 50% since 2013 [281]. This study also revealed that positive screens for depression and anxiety in college and university students surged by about 135% and 110%, respectively, from 2013 to 2021 [281].

The COVID-19 pandemic also exacerbated challenges to university students by increasing mental health problems such as anxiety and depression [494, 244]. In the United States, results of a survey of 30,725 undergraduates and 15,346 graduate and postgraduate students at nine public research universities a year from the onset of the COVID-19 pandemic revealed that the rates of major depressive disorder and generalized anxiety disorder were two times and 1.5 times higher, respectively than before the pandemic [94]. These findings are consistent with reports from other countries, indicating that the pandemic has significantly impacted post-secondary students' mental health worldwide [520, 274, 244].

Despite these prevalence rates, findings from existing studies reveal that students are often reluctant to seek help, and many do not receive adequate treatment [133]. There are several reasons for low treatment utilization among students. For example, many students may not recognize the need to treat the depression and anxiety symptoms they are experiencing but rather believe such symptoms are part of university stress and, therefore, do not seek help [134]. The perceived stigma, embarrassment, cost of treatment, lack of time, transportation and scheduling effort are also some other barriers to seeking mental health treatment for students [206, 133]. Moreover, in recent years, pandemic restrictions and social distancing have further limited students' access to mental health services and reduced their use of mental health care. In a related study, results from 18,764 college students on 14 campuses across the United States indicated that 60% of students found it more difficult to access mental health care during the pandemic [301].

In addition to suggesting that greater resources should be provided for traditional mental health support, the rising rates of mental health problems among university students and noted barriers to accessing mental health service providers call for innovative approaches in providing support and education regarding mental health and interventions for mental health challenges. Research suggests the potential of technology-based interventions, such as telepsychology, mobile apps, and intelligent agents (e.g., social robots, conversational agents, etc.) to improve the *scalability* and *reach* of mental health care interventions [367, 228, 229]. Literature defines "scalability" as the ability to reach a large number of people and "reach" as ensuring that mental health interventions can reach individuals who are unlikely to receive mental health services [229].

The use of assistive technologies such as online websites and mobile apps has been

shown to be beneficial in reducing stigma and enhancing access to mental health care [241]. Yet, despite their potential to help improve mental health, their user engagement and adoption rates were low [157]. One possible explanation for the low adherence rates may be attributed to the absence of a human-compatible manner in these technologies, such as social interaction capabilities.

Given recent technological advances in social robots and their expanding capabilities, such as communication via verbal and non-verbal behaviours, these agents have the potential to play an increasing role in extending and complementing mental health care interventions and enhancing accessibility. For instance, social robots can be programmed to provide personalized, adaptive, engaging interventions in a non-judgmental manner, thereby creating opportunities for incorporation into mental health care interventions. However, much empirical work is needed prior to forming conclusions about the short and long-term effectiveness and impacts of using social robots as tools for supporting mental health interventions. In this application area, social robots are designed not to replace human experts (clinicians, counsellors, etc.) but to complement their work by serving as tools, similar to other digital devices. An intelligent and user-centred design with iterative evaluations is an imperative first step to developing an effective solution [489, 296]. User-centred methods help researchers build products that are based on real user needs as opposed to researchers' assumptions about what the gaps and needs are [489, 296]. One common first step toward the user-centred design of a technology is to identify needs, gaps, and design features [489, 296].

In this research, we specifically explore the potential applications of social robots in robot-assisted interventions for social anxiety among mental health problems experienced by college and university students. Social anxiety or social phobia is a condition characterized by debilitating fear and avoidance of different social situations [13]. It is shown to be one of the most common anxiety disorders [503]. Moreover, many studies have shown that social anxiety is common among university and college students, and if left untreated, it may negatively impact the individual's performance [176, 30, 177, 519]. For example, high levels of social anxiety among university students are associated with a low quality of life and may lead to impaired academic performance and relationships [75]. In 2020, researchers investigated the prevalence of social anxiety among young people in seven countries around the world [210]. The study revealed that more than 1 in 3 (36%) of respondents met the threshold criteria for social anxiety, demonstrating significantly higher levels of social anxiety than previously reported. Furthermore, 1 in 6 (18%) respondents thought they did not have social anxiety, but they met the threshold for social anxiety. The data show that social anxiety is a concern for young people around the world, many of whom do not recognize the problems they may be experiencing [210]. Hence, it is crucial to provide

young people with proper education and intervention to alleviate the negative impact of social anxiety on their well-being and function.

1.2 Research Questions

The purpose of this thesis is to explore potential applications of social robots in promoting university students' mental well-being, specifically to cope with feelings of stress and anxiety in social situations. To this end, this work explores the four primary research questions. As my research project progressed, these research questions were formulated and expanded based on the results obtained from the studies conducted within this research and the relevant literature.

RQ1: What are the potential applications of social robots for social anxiety?

The application of social robots in the context of social anxiety represents a relatively novel area of research with limited existing studies. The key objective of this research is to explore the potential applications and roles of social robots in robot-assisted interventions for social anxiety to improve accessibility and standard of care for those in need, as well as outlining future steps in relation to this research direction.

RQ2: What are the university students' opinions and preferences for using intelligent agents to cope with stress and anxiety in social situations?

The primary objective of this study is to conduct a thorough needs assessment to understand the requirements, opinions, and preferences of university students regarding the utilization of intelligent agents for managing stress and anxiety in social situations. The study encompasses a wide range of questions, addressing topics such as the experience of stress and anxiety in social situations, intelligent agent preferences, preferred mental well-being activities to address stress and anxiety in social situations, design aspects, and more. The aim of this study is to inform the design of an intelligent agent to help university students cope with stress and anxiety in social situations based on the genuine needs and preferences of potential users rather than relying on researchers' assumptions. This approach could ensure that the developed intervention is in line with the user's actual needs.

RQ3: How to design and develop robot-based interventions in a user-centred and co-design approach to support students in managing their stress and anxiety in social situations?

Integrating user-centred and co-design approaches into the development of technology-based mental health interventions could help identify end users' specific needs and preferences and thereby provide an opportunity to enhance the acceptability and effectiveness of such interventions [78, 369]. Therefore, considering the multidisciplinary nature of this work, it would be imperative to involve related experts in the mental health and well-being domain (the envisioned secondary users) in the design process of the intervention. Their involvement is essential for identifying the required design considerations and implementing them effectively within this context. Furthermore, a participatory study with university students (the envisioned primary users) would be necessary to ensure that the developed interventions align with the actual needs and expectations of the prospective users.

RQ4: What are the usability and acceptability of the robot-based intervention, developed through the co-design process, to support students in managing their stress and anxiety in social situations?

Finally, we evaluate the usability, acceptability and university students' perception of the robotic mental well-being coach that was developed in the previous study through co-design sessions with mental health professionals and university students (as informants in the design process) to help students manage their public speaking anxiety.

1.3 Thesis Contributions

This thesis aims to explore the use of social robots in promoting university students' mental well-being, specifically to cope with feelings of stress and anxiety in social situations. This thesis embodies interdisciplinary research and has made contributions to the fields of mental health and well-being, assistive robotics, Human-Robot Interaction (HRI) and Human-Agent Interaction (HAI) by addressing the following research gaps:

- **Potential Applications of Social Robots for Social Anxiety**

  This research is the first original contribution. In this work, we explored the potential applications of social robots in robot-assisted interventions for social anxiety, a relatively new field of research with limited available literature. Initially, we conducted a comprehensive literature review to gain insights into social anxiety disorder, evidence-based behavioural and cognitive treatment approaches for this condition, and the current assistive technologies for mental health interventions. Subsequently,

we proposed the incorporation of social robots in conventional behavioural and cognitive therapies for both children and adults with social anxiety, with the intention of enhancing and supporting the work of clinicians rather than substituting it. To achieve this, we categorized and discussed various therapeutic roles that social robots can potentially play in activities rooted in conventional interventions for social anxiety and presented their possible applications through four distinct scenarios. Finally, we highlighted the advantages and limitations of integrating social robots into conventional interventions and outlined future research directions. Researchers in the field of HRI and psychologists working with individuals experiencing social anxiety may find these knowledge contributions to be of interest, as there has been limited prior research exploring the potential applications of social robots in robot-assisted interventions for social anxiety.

- **University Students' Opinions on Using Intelligent Agents to Cope with Stress and Anxiety in Social Situations**

  As a first step towards the user-centred design of intelligent agents as assistive tools to help students manage their stress and anxiety in social situations, we conducted two studies involving university students to learn about their needs and preferences. Our first study was a pilot conducted through Amazon Mechanical Turk crowdsourcing platform[1] (N = 85), followed by a larger study at the University of Waterloo (N = 1054). The purpose of these studies was to (i) identify whether students experience stress or anxiety in social situations common at university, (ii) find out the most anxiety-provoking situations students experience at university,(iii) investigate students' perceptions of and preferences for the use of different intelligent agents (e.g., virtual agents, social robots, conversational agents), (iv) learn about activities that students believed would be beneficial for managing stress and anxiety, and they would be willing to use an intelligent agent for them, (v) explore students' opinions of the important characteristics of an intelligent agent in supporting their mental well-being, (vi) identify design factors and considerations that would make students more inclined to use an intelligent agent for helping with their most anxiety-provoking situation, and (vii) examine types of data that students would allow an intelligent agent to record to support their mental well-being. The findings of this study provide insights into university students' experience of stress and anxiety in social situations, needs, opinions and preferences regarding different social and technical capabilities, as well as design elements that need to be considered when developing intelligent agents to help address stress and anxiety among university students. These knowl-

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

edge contributions are likely to be of interest to psychologists, roboticists, as well as HRI and HAI researchers who are interested in developing technology-based interventions to support university students' mental well-being.

- **Co-Design of a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety**

  Another contribution of this research is conducting co-design sessions with five mental health professionals to identify the design-related needs (e.g., robot behaviour and interactions) for developing a robotic coach that can effectively assist university students' public speaking anxiety. We adopted a co-design approach to actively involve stakeholders, including prospective users and subject domain experts, such as mental health professionals, in the technology design process. This method aims to create a balance in decision-making power between researchers and stakeholders, ultimately ensuring that the resulting technology is aligned with the needs of end-users. To this end, we first conducted semi-structured interviews and co-design sessions with five mental health professionals as collaborators, actively engaging them in the design process. Through 17 collaborative co-design sessions with mental health professionals, we designed the robot's functionality and behaviour and tested it with them. Then, we conducted a study with university students to learn about their experiences and opinions about the robotic coach for further improvements in the robotic coach interaction and behaviours. This research involves discussing various design considerations important for developing mental health interventions for university students. This work will contribute to the growing body of knowledge on using social robots in mental health care, informing the design of interventions targeting university students' public speaking anxiety. This contribution to knowledge might be of interest to HRI researchers and roboticists.

- **Evaluating a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety**

  In our third study, we evaluated the robotic mental well-being coach designed in our second study by conducting a usability and acceptability study with university students (N=50). We further asked questions about user experiences and explored participants' opinions in more detail through open-ended questions at the end of the study. Conducting qualitative and quantitative analysis in this study yields promising results on the potential use of robotic coaches to help university students manage their public speaking anxiety. These findings offer valuable insights for designers, HRI researchers and roboticists in the creation of robotic well-being coaches and

have the potential to enhance the wider adoption and utilization of social robots for supporting university students' mental health.

1.4 Thesis Outline

This thesis is comprised of the following chapters. Chapters and studies/research pertaining to each research question are presented in Table 1.1.

Chapter 1 is the current chapter that explains research motivation and thesis contributions and presents the main research questions for this work.

Chapter 2 presents a background and literature review covering various relevant subjects, including social anxiety, evidence-based interventions typically employed for addressing social anxiety, and current applications of assistive technologies in mental health care and treatment.

Chapter 3 explains the fundamental characteristics of social robots and their role in clinical practises. In this chapter, we discuss the potential applications of social robots in robot-assisted interventions for social anxiety and describe four scenarios as examples of how social robots could be incorporated into conventional behavioural interventions for both children and adults who struggle with social anxiety.

Chapter 4 describes our first study regarding university students' opinions on using intelligent agents to cope with stress and anxiety in social situations.

Chapter 5 outlines the findings of our co-design studies with mental health professionals and a participatory study with university students aimed at developing a robotic mental well-being coach to help university students manage public speaking anxiety.

Chapter 6 focused on the final study, where we evaluated the developed robotic mental well-being coach for managing public speaking anxiety with university students as prospective users.

Chapter 7 concludes the thesis by providing a brief summary of the research and findings, highlighting the contributions of this research to the original knowledge, and discussing the limitations of the presented studies, followed by future research directions.

Appendix A includes the ethics clearance certificate and survey questions for study 1.

Appendix B contains the ethics clearance certificate, pre-study questionnaire and post-study interview questionnaire for study 2.

Appendix C presents the ethics clearance certificate and pre-experimental and post-experimental questionnaires for study 3.

Study/Description	Research Question (RQ)
Chapter 3: Potential Applications of Social Robots in Robot-Assisted Interventions for Social Anxiety This research explores the application of social robots as tools that could complement the support provided by clinicians in the context of intervention for social anxiety disorder by drawing attention to, and links between the activities within conventional treatment for social anxiety and the current applications of social robots in mental health care. The chapter is based on our research published in [J1].	RQ1
Chapter 4: Study1 _ University Students' Opinions on Using Intelligent Agents to Cope with Stress and Anxiety in Social Situations This study is a first step toward the user-centred design of an intelligent agent that could be used to assist university students in dealing with stress and anxiety related to social situations that may typically be encountered within a university context. The study's objective is to investigate students' needs, anxiety-provoking social situations and preferences concerning mental well-being interventions, the choice of intelligent agents, design considerations, and essential characteristics for intelligent agents that can effectively support their mental well-being in this specific context. The chapter is based on our research published in [C2] and [J2].	RQ2, RQ3
Chapter 5: Study2 _ Co-design of a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety Building on the findings from *study 1*, which explored aspects such as students' most anxiety-inducing situations and their preferred type of mental well-being interventions, the second study engages in co-design sessions with mental health professionals and a participatory study with university students to design a robot-based intervention. The chapter is based on our research published in [C3].	RQ3
Chapter 6: Study3 _ Evaluating a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety The aim of the third study is to evaluate the usability, acceptability, and university students' perception of the robotic mental well-being coach that was developed in the previous study through co-design sessions with mental health professionals and university students as informants. The chapter is based on our research in [J3].	RQ4

Table 1.1: Chapters and studies pertaining to each research question

Chapter 2

Background and Literature Review

2.1 Social Anxiety Disorder

Social anxiety disorder is a condition characterized by a marked and persistent fear of social situations in which feelings of embarrassment or humiliation can occur [340, 432, 447, 13]. In social anxiety disorder, the fear or anxiety about experiencing the scrutiny of others is so prominent that people with this condition either completely avoid social situations or endure them with extreme discomfort, despite their desire for social relationships [447].

The onset of social anxiety disorder typically occurs in childhood or early adolescence; 75% of individuals diagnosed with social anxiety disorder have an onset between the ages of 8 and 15 [13]. The onset of social anxiety disorder prior to the age of 11 years increases the risk of disorder persistence in adulthood [440, 1, 42, 502]. Behavioural inhibition, which is a consistent tendency to respond to novel situations with fear and withdrawal, predisposes children to the risk of developing maladaptive social anxiety [222, 458, 99, 340]. The course of social anxiety disorder can be chronic and lifelong [262, 13, 447, 211, 440, 340, 432]. Early diagnosis and intervention are critical for individuals with social anxiety disorder considering the risk of morbidity and disability [446, 432].

Symptoms of Social Anxiety Disorder: Individuals with social anxiety disorder find many situations of daily life and work difficult and fear- or anxiety-inducing [432, 43, 440, 372]. These include public speaking, being the center of attention, meeting new people, interviewing for employment, conversing with authority, working under others' observation, entering an already occupied room, attending social events, and even using public restrooms [447, 13, 211]. Individuals with social anxiety disorder often also experience distressing physiological symptoms (e.g., blushing, sweating, trembling, nauseousness,

dizziness, muscle tension, rapid heartbeat) during different social situations [211]. Other behavioural manifestations of social anxiety include inadequate assertiveness, rigid body postures, poor eye contact, trembling, speaking with an excessively soft voice, mumbling, stuttering, nail-biting, becoming self-conscious, and withdrawing from social groups or new settings [13, 340, 447]. Young children may express their fear or anxiety in different ways than adults, including crying, freezing, clinging, tantrums, shrinking, or not speaking [13].

Prevalence of Social Anxiety Disorder: Social anxiety disorder is one of the most common anxiety disorders, with a lifetime prevalence between 3 to 13% [262, 365, 235, 232, 236, 234, 404]. Prevalence rates differ based on various factors, including gender (i.e., higher rates for females than males) [340, 447, 13, 262, 211, 365], ethnic background (i.e., in comparison to individuals of European descent, higher rates have been reported among indigenous communities and lower rates among individuals of Latino, Afro-Caribbean descent, African American, and Asian) [13], marital status (i.e., higher rates among unmarried individuals) and income (i.e., higher rates for individuals from lower-income households) [13, 432].

Impact of Social Anxiety Disorder: Social anxiety can significantly affect individuals' overall quality of life [13]. For example, among children and adolescents with social anxiety disorder, lower school performance, refusal to attend school, leaving school prematurely, fewer friends and social isolation have been noted [340, 484, 13, 432, 326]. Despite the reported distress and impairment, only half of all individuals with social anxiety disorder seek treatment, commonly after 15-20 years of experiencing distressing symptoms [13, 262, 447, 493, 91]. Common reasons for treatment delay or avoidance include embarrassment, considering challenges as normative 'shyness' or social issue rather than a psychopathology, and anticipatory anxiety (i.e., anxiety from anticipating communication with someone) [262, 13, 225, 232, 326].

2.2 Treatments for Social Anxiety Disorder

This section discusses empirically supported interventions that address maladaptive behaviours, cognitions, beliefs, and biases related to social anxiety disorder. We focus on treatments that have demonstrated efficacy, such as cognitive behavioural therapy, cognitive bias modification, and mindfulness-based stress reduction. These treatments tend to be time-limited, goal-oriented and present-focused.

Cognitive Behavioural Therapy (CBT)

Cognitive models of social anxiety posit that the condition is caused and maintained by expectation and fear of negative evaluation from others [97, 374, 376] or revealing perceived flawed aspects of oneself to others [321]. As a result, individuals with social anxiety tend to reduce their anxiety through safety behaviours, such as avoiding others and anxiety-provoking situations. Drawing from models that connect individuals' cognitions with their emotions and behaviour, Cognitive Behavioural Therapy (CBT) is the most extensively studied psychological intervention [399, 269]. It is a time-limited and goal-oriented approach that focuses on the present and teaches patients the cognitive and behavioural competencies required to successfully function in their routine lives [188, 399, 269, 346]. The behavioural interventions incorporated in CBT strive to decrease maladaptive behaviours and promote healthier behavioural responses by modifying their precursors and consequences and using consistent practice [269, 346, 18]. The cognitive interventions aim to modify patients' maladaptive automatic personal interpretations, cognitions, self-statements, or beliefs [269, 346]. A joint effort of the therapist and the patient is an integral component of CBT [399, 269]. This treatment can be delivered both individually and in group sessions [414]. For children, CBT can be delivered in school settings, which offer the benefit of being a natural environment with opportunities for facilitating skill generalization [414, 155, 302]. CBT can also include sessions for parents to teach them anxiety management, communication, and problem-solving skills that could promote their child's progress [399, 414]. For social anxiety disorder, CBT is considered a first-line intervention [447]. CBT incorporates different techniques to address the symptoms of social anxiety disorder. These techniques include but are not limited to: exposure therapy, applied relaxation, cognitive restructuring, and social skills training [188, 399, 269]. In regards to effectiveness, a meta-analysis by Scaini et al. [414] on the effectiveness of CBT for social anxiety disorder in children and adolescents reported that CBT can lead to significant improvement in social anxiety symptoms in both clinical and social settings. Further, a meta-analysis of psychological treatments for social anxiety by Powers et al. [359] found that CBT resulted in better post-treatment outcomes in comparison to being on the wait-list, psychological placebo or pharmacological placebo. Research suggests that gains from CBT are maintained at follow-up [359, 399, 220]. There is also evidence suggesting that, in comparison to pharmacological treatments for social anxiety disorder, the effects of CBT last longer [447, 158, 191]. However, there are several factors that can compromise the effectiveness of CBT, such as poor homework compliance, lower expectancy for improvement, diagnosis of generalized form of the social anxiety disorder, and comorbidity with avoidant personality disorder, mood disorder, substance use disorder, and/or other anxiety disorders [399].

- **Exposure Therapy:** This technique is based on the premise that repeated interactions with the fear-inducing situation will gradually initiate the conditioning process of habituation and extinction that is involved in fear reduction [188, 146]. During this intervention, the individual with social anxiety disorder and the therapist work together to create a hierarchy of feared situations (e.g., starting a conversation, speaking in a meeting, presenting in front of a group of people, etc.) that moves from least feared to highly feared situations [188, 399, 326]. The patient then confronts the anxiety-inducing situations through role-plays, out-of-session exercises, imagination, and between-session homework assignments [188, 399, 326]. Such confrontation challenges and disconfirms the patients' unrealistic and maladaptive beliefs about the feared situations and generates a new understanding that competes with the learned fear responses [188, 399, 326, 146]. However, subtle forms of avoidance on the patients' behalf can compromise the effectiveness of the treatment [188, 399, 146]. Therefore, therapists invest time in identifying safety behaviours and other maladaptive coping strategies that the patients might use during exposure therapy to manage their anxiety [326]. Explicit instruction to maintain focus on the feared situation has also been shown to increase the effectiveness of this intervention [188, 496].

- **Relaxation Training:** Relaxation training instructs patients on managing their physiological arousal before or while facing feared social situations by using techniques such as Progressive Muscle Relaxation (PMR) [49, 188, 399]. PMR entails tensing specific muscles for 5-10 seconds and then releasing the tension [188, 106, 3]. Patients begin with exercising specific, small muscle groups and gradually move to exercise larger muscle groups to accomplish rapid relaxation [188]. By performing this exercise, individuals with social anxiety disorder learn the difference between the sensation of muscle tension and relaxation [188]. This understanding helps them with detecting and releasing muscle tension by remembering the sensations experienced during their relaxed state [188]. Eventually, patients learn cue-controlled relaxation, in which a certain word, often 'relax,' is paired with the sensations of relaxation [188]. The cue is then used to initiate rapid relaxation during social interactions [326]. Findings suggest that relaxation training is not effective without an 'applied' component to it [188, 399, 342]. In applied relaxation, patients are taught the application of progressive muscle relaxation and cue-controlled relaxation in anxiety-provoking situations, making it a combination of relaxation training and exposure therapy [342, 188].

- **Cognitive Restructuring:** The premise of cognitive restructuring is rooted in Aaron Beck's cognitive model, which postulates that biased thoughts, evaluations and

beliefs contribute to the development and persistence of psychopathology [96, 38, 39]. Hence, in cognitive restructuring, the clinicians and patients collaborate to identify and eliminate inaccurate thoughts experienced during feared situations as well as the beliefs that trigger maladaptive thinking [326, 96]. After identification of inaccurate thoughts, patients evaluate the accuracy of those thoughts by checking data from Socratic questioning or behavioural experiments. Both of these activities are designed to diminish the patient's negative beliefs about the social situation [188]. Socratic questioning is identified as an essential component of CBT interventions [98] and is defined as "a method of guided discovery in which the therapist asks a series of carefully sequenced questions to help define problems, assist in the identification of thoughts and beliefs, examine the meaning of events, or assess the ramifications of particular thoughts or behaviours" [40, p. 401]. Video and photography feedback may be utilized to correct distorted self-images [326]. Through this process of identification and evaluation, the therapists model disputation of automatic thoughts for the patients [399]. Patients are then encouraged to practise identification and disputation of maladaptive thoughts both during and outside of the session and replace them with more adaptive and balanced thoughts [399, 326].

- **Social Skills Training:** According to the skills deficit model of social anxiety disorder, individuals with social anxiety disorder have deficiencies in appropriate social behaviour [399]. These deficiencies elicit negative reactions from others and make social situations anxiety-provoking [326, 188, 399]. As well, findings suggest that individuals with social anxiety disorder tend to underestimate the adequacy of their behavioural performance [188, 375, 450]. Social skills training is often implemented as an intervention for social anxiety disorder. In this intervention, the therapist teaches verbal (e.g., initiating conversations, giving feedback to others) and non-verbal (e.g., maintaining eye contact and an attentive posture) social skills to individuals with social anxiety disorder by modelling the behaviours, engaging in behavioural rehearsal, and providing corrective feedback and positive reinforcement [188, 399, 326]. Commonly, elements of exposure and cognitive restructuring are included to further reduce social anxiety [188, 399]. For example, modelled social behaviours are practised through role-plays during therapy sessions or homework assignments [326].

Cognitive Bias Modification

According to the cognitive models of social anxiety disorder, individuals with social anxiety "automatically and selectively attend to socially threatening information (attention bias) and interpret emotionally ambiguous events as threatening (in-

terpretation bias)" [284, p. 2]. Several findings have reported promising results of Cognitive Bias Modification (CBM) as an intervention for social anxiety disorder [178, 284, 37]. A growing body of research suggests that social anxiety can be reduced using CBM [178, 284, 37]. Findings indicate that CBM might be beneficial as a complementary treatment to traditional psychotherapy [178, 284]. According to the literature, CBM reduces social anxiety by targeting attention and interpretation biases through different experiential tasks [443, 36, 14, 35, 178]. CBM targeting attention biases (CBM-A) typically entails a modified dot-probe task [37, 284, 293]. In this dot-probe task, the participant is required to identify, as precisely as possible, the location of a target stimulus that is presented in the place of either a previously presented threatening or positive/neutral stimulus [284, 293, 35, 178]. A quicker response to targets that replace the threatening stimulus indicates an attention bias towards threatening stimuli [284, 293, 178]. In order to modify this bias and teach the participants to attend to the positive/neutral stimulus, practitioners manipulate the frequency with which the target replaces the threatening stimulus [284, 293, 178]. For example, practitioners manipulate the target stimulus to replace the positive/neutral stimuli 80 to 100% of the time [284, 178]. In contrast, CBM targeting interpretation biases (CBM-I) typically uses ambiguous phrases or paragraphs and requires participants to be generative [284, 178]. For example, in the scenario paradigm by Mathews and Mackintosh [305], patients are presented with a short scenario that is ambiguous until the final word, which is a fragmented word that disambiguates in a positive or negative manner [35, 178]. After solving the word fragment, participants are asked comprehension questions that reinforce the forced positive/negative interpretation [35].

Mindfulness-Based Stress Reduction

Rooted in the Buddhist tradition of meditation, mindfulness has been defined as "non-judgemental awareness of the present moment experience" [198, p. 2]. Mindfulness-Based Stress Reduction (MBSR) is one of the most commonly implemented mindfulness-based interventions [522]. MBSR is a highly accessible and inexpensive intervention since it can be delivered in diverse settings and can also be self-taught through the use of books and audiotapes [252]. Typically, MBSR entails different forms of mindfulness practices, such as formal and informal meditation and hatha yoga [522, 169, 168, 197]. Formal meditation practices include breath-focused attention, body scans, attending to different sensory modalities, monitoring moment-to-moment experience, and sitting, walking, and eating meditation [169, 83]. In contrast, informal meditation

practices entail intentionally shifting attention to present moment awareness and becoming mindful in routine activities [169, 83]. Finally, hatha yoga is a practice of different physical yoga postures [360]. Through these mindfulness practices, patients learn to redirect their attention, thoughts, emotions, and physical sensations, which ultimately assists in anxiety management during stressful situations [198]. Research suggests that MBSR can relieve anxiety, stress, and depression symptoms through altering emotion regulation abilities [169]. Specifically for individuals with social anxiety, learning to intentionally focus attention on external social situations can reduce preoccupation with self-critical cognitions that exacerbate anxiety [252]. Furthermore, practising formal meditation exercises can assist in managing distressing physiological symptoms experienced during feared social situations. Findings suggest that there is a 45% response rate among individuals who complete MBSR [252]. People who complete the treatment have reported increased self-esteem, lower anxiety, and depression, as well as a positive impact on their functionality and quality of life [252].

Adjunct Treatment Approaches

According to Carr et al. [85], people continue to experience dissatisfaction with their lives even after becoming symptom-free through traditional psychological interventions. Hence, introducing positive psychological interventions is useful for enhancing well-being and quality of life for people after the traditional therapies have culminated. The overall goal of these interventions is not to replace traditional clinical psychological interventions, but to complement them [427, 85]. Positive Psychology Interventions (PPIs) seek to enhance well-being by focusing on subjective experiences, particularly "contentment, and satisfaction (in the past); hope and optimism (for the future); and flow and happiness (in the present)" [424, p. 280]. Common PPIs include activities such as improving the use of character strengths, finding flow, expressing gratitude and optimism, practising kindness and forgiveness, and/or strengthening relationships [85, 348, 449].

Research suggests that under and overuse of specific strengths can result in depressive symptoms [150, 504]. Specifically, among individuals with social anxiety disorder, the under- or overuse of social intelligence, self-regulation, zest, humour, and humility were apparent [150]. Under- or overuse of social intelligence is consistent with the under- or over-awareness of these individuals in social situations [150, 374]. Underuse of self-regulation corresponds to the low perceived emotional control commonly theorized in individuals with social anxiety disorder [150, 250]. Under-use of zest is

indicative of the debilitating effects of social anxiety disorder on life and the avoidance behaviours of individuals with social anxiety disorder [150]. Under-use of humour is consistent with the tendency to interpret negative cues more readily than positive ones among individuals with social anxiety disorder [150, 255]. Finally, overuse of humility corresponds to the tendency to avoid both positive and negative external evaluation among individuals with social anxiety disorder [150]. Considering such findings, it would be beneficial to incorporate positive psychological interventions that could facilitate the development of and/or improvement in specific character strengths [150].

2.3 Assistive Technologies for Mental Health

The field of mental health care has been facing major challenges in connecting people in need of therapeutic services with the available health care providers. There are multiple barriers that limit and/or restrict access to mental health treatments and services. First of the many barriers that limit the accessibility of mental health services is "the dominant model of treatment delivery" itself [228, p. 457]. In this model, treatment is provided in person, either one-to-one or in a group, by a highly trained mental health professional within a clinical setting. The reliance of this model on trained professionals has become a problem due to the lack of mental health service providers, especially in remote and rural areas [102, 154, 192, 472, 311, 228, 467]. However, in the recent times, telepsychology, which entails the provision of conventional mental health services using telecommunications technology, such as telephones, smartphones, and virtual conferences, has significantly increased and improved access to treatment services [58, 102, 174, 352, 467, 156]. Studies have shown that telepsychology is a reliable method of treatment and people both in rural and urban areas are receptive to it [352, 58, 174]. Despite the increase in telepsychology, the shortage of mental health providers continues to be a problem. The second barrier to accessing mental health services is the financial costs associated with them [16, 167]. For example, in Canada, many community-based, non-physician-provided mental health services are not included in the universal health care system [324]. Therefore, unless families and individuals are receiving treatment through hospitals or other government-funded agencies, they either require third-party insurance for mental health coverage or pay out-of-pocket [310, 79]. A third barrier restricting the accessibility of mental health services is the perceived stigma [271, 16, 167]. Due to the stigmatization of mental illnesses, people in need of professional intervention tend to either completely avoid treatment, delay pursuing treatment, or fail to participate during treatment [104, 165, 246, 495]. In recent

decades, technological advancements, such as the introduction of telepsychology, Artificial Intelligence (AI)-based smartphone applications, virtual agents and social robots, have provided a way to mitigate some of these barriers.

Emerging from the concept of telepsychology is mHealth or mobile health, which includes applications on smart devices [352]. Smartphone application developers and mental health researchers have capitalized on the proliferation of smartphone ownership and attachment and have developed applications for assessing and treating mental health conditions such as depression and anxiety. A review by Temkin and Schild [469] outlined 14 smartphone applications for the assessment and treatment of anxiety and related disorders. Assessment applications, including CopeSmart, G-moji, Mobile Mood Diary. Mobiletype, PETE and Sensus, strive to provide self-help to the clients and data to practitioners for better tailoring the more conventional interventions for their clients [469]. Users and practitioners have ranked these applications moderate to high in ease, satisfaction, and providing assistance [469, 231, 109, 308, 382, 383, 71]. However, a decline in user engagement over time has also been identified [469, 231, 382]. Treatment applications, such as Anxiety Coach, MindShift, REACH, SmartCAT, StudiCare Stress, and Woebot, provide psychoeducation, relaxation therapy, exposure therapy, and/or cognitive restructuring to reduce anxiety symptoms [469]. Analogous to assessment applications, users ranked treatment applications moderate to high in ease of use, acceptability, and satisfaction [469, 500, 501, 499, 270, 327, 349, 350, 361, 362, 435, 143, 182, 514]. However, further research is required to assess the efficacy of the treatment applications when used without conventional interventions [469].

While the aforementioned applications reduce anxiety symptoms, none of them, with one exception, directly target social anxiety. Presently, the Challenger App, which is an unguided, internet-based, self-help application that incorporates the principles of CBT and gamification, is the only smartphone application that targets social anxiety [298, 315, 66]. The application is organized as a game board, and the clients move from one end of the board to the other while accomplishing self-selected goals, overcoming customized challenges, and receiving psycho-education and community supports [298, 315, 66]. The Challenger App also suggests exposure exercises based on the location of the client and the people they might be interacting with [66, 315]. This makes the application particularly useful for implementing exposure therapy [66]. Preliminary studies suggest that participants benefited from using this application [298, 66]. The study found that the number of challenges completed on the application correlated with the treatment outcomes [66].

In comparison to conventional mental health interventions, mobile health applications can be beneficial innovations due to their high accessibility. The expense associated with the aforementioned applications is minimal compared with traditional psychotherapy [469].

Moreover, smartphone applications allow users to track and share data with health care providers relatively easily, which makes therapy provision more convenient [469]. While mobile health applications have shown success in promoting therapeutic outcomes, such as the reduction of depression and/or anxiety symptoms among users, most of these applications lack evidence-based content and/or input from psychologists and tend to suffer from a decline in user engagement over time [469, 76, 231, 382, 354, 353, 157]. Developers have strived to ameliorate this issue through the incorporation of game-based approaches in mobile health applications. The term "applied games" refers to the games that employ "design concepts and qualities from the game world" for serious purposes such as health, education, or social situations [419, p. 101]. Applied games are known to have a considerable impact on improving engagement with mental health interventions and motivating behaviour change because of their *appealing*, *engaging*, and *effectiveness* potentials [144]. Serious games and gamification are examples of applied games. Serious games involve computerized games focusing on serious purposes rather than mere entertainment [312]. This approach uses gaming as a central and primary medium [145]. In contrast, gamification is a technique that utilizes "game design elements in non-game contexts" to improve the user's engagement and motivation to adopt specific behaviours [124, p. 1]. An excellent example of a gamified application is the aforementioned Challenger App. Research suggests that participants show better engagement with interventions that are game-like due to their interactive nature [157]. Particularly, games can induce increased engagement and a more sustainable behavioural change because they are intrinsically motivating [406, 218]. Several studies have illustrated the potential of utilizing game-based approaches to increase the impact of online mental health and well-being related interventions [218, 144]. Research shows that game-based approaches can result in social, emotional, and cognitive benefits, such as the development of positive social relationships, a sense of belonging, self-esteem, pride, and strategic abilities, such as problem-solving [373, 2, 288, 413, 481].

Even though incorporating gamification is beneficial for mobile health applications, research suggests that the decline in engagement and poor adherence may be a consequence of digital applications' limited social presence [143]. Social presence, whether of an embodied (physically present) or disembodied (software or virtual) agent, influences the level of engagement and overall success of the social interaction [266]. To further address the challenges associated with engagement and social presence in mobile health applications, the use of socially interactive technologies, such as conversational agents, virtual agents and social robots, to deliver or supplement psychosocial interventions has been explored [363, 422, 421, 254, 125]. Findings suggest that a socially assistive agent, with a relatively higher social presence than that apparent in mobile health applications, can be effective in developing relationships with users, gaining their acceptance and trust, and facilitating therapeutic outcomes [186, 24, 138]. Socially assistive agents are built to interact

with other agents (i.e., humans) and to perceive their environment and react to it in a timely manner [402]. High degrees of interaction (e.g., using natural language and expressing a variety of verbal and nonverbal behaviours) and intelligence (e.g., the ability to adapt and personalize agents' behaviour over time, and perform complex tasks through learning, planning, and reasoning) are some unique advantages of intelligent agents over other technological-based interventions [294]. In the past two decades, several studies have demonstrated the potential benefits of integrating intelligent agents such as social robots, conversational agents and virtual agents into mental health and well-being interventions, including full-time availability, reduced impression management, and potential anonymity (depending on the implementation of the agents), which has been shown to decrease fear of self-disclosure (e.g., see [172, 317, 6]). Intelligent agents also improved adherence to therapy [363] and enhanced social presence [242, 337], which is shown to be an effective factor in improving the degree of engagement and overall outcome of social interactions involving agents, whether they are physically present or virtual [266]. In light of the growing capabilities of intelligent agents, these agents may play an increasing role in mental health care, for example, as a preventive measure by coaching individuals to healthy behaviour change or assisting clinicians with therapeutically relevant functions such as instructing clients through tasks/activities, monitoring symptoms and treatment progress, or assisting with treatment compliance (e.g., medication adherence) [367, 263].

Conversational Agents: Conversational agents (e.g., Amazon Alexa, Apple Siri, Google Assistant) are examples of AI-based technologies that have been increasingly used in the mental health and well-being domain [153]. The growing availability and use of conversational agents have highlighted the potential of these agents to provide mental health support for their users by offering various applications such as providing psycho-education and self-management strategies, symptom monitoring and tracking, and cognitive behavioural therapy [153]. For example, in a previous study, a conversational agent — Amazon Alexa — served as a public-speaking coach to help alleviate public speaking anxiety among students by engaging them in cognitive reconstruction exercises [492]. The findings of this study with 53 college students with moderate to intense levels of fear of public speaking showed improvement in pre-speech state anxiety after interacting with Alexa. However, participants discussed weaknesses of Alexa as a public speaking coach, including the lack of anthropomorphization and personalized feedback, the machine-like interaction, and the inflexibility of response time for each individual participant [492].

Virtual Agents: Compared to conversational agents, virtual agents may provide a more realistic interaction through their embodied virtual characters. Virtual agents can take various visual appearances ranging from a simple animated character [55] to a highly detailed human avatar [391]. Several studies have investigated the potential of employing

virtual agents in mental health interventions for addressing mental health problems such as anxiety [317], depression [389, 429], and Post-Traumatic Stress Disorder (PTSD) [390]. For example, virtual agents as coaches for practising presentations have been shown to reduce public speaking anxiety and increase confidence for non-native English speakers [480]. In addition, virtual agents have been effectively used to deliver conventional, evidence-based interventions, including exposure therapy and cognitive-behavioural therapy (e.g., dealing with irrational thoughts) to help alleviate phobias (e.g., public speaking) and anxiety [15, 243, 317].

Social Robots: Unlike virtual agents, social robots are physically present during an interaction, which makes social robots more engaging and interesting [111]. It has also been shown that the physical presence of robots improves task compliance and increases positive understandings of interactions [25]. In fact, a review of 33 experimental studies which compared people's interaction with physical robots and virtual agents showed that physically present robots were perceived as more persuasive and positive than virtual agents, and they induced better user performance and more salient behavioural and attitudinal responses [273].

A recent systematic review of social robot-based interventions in psychological domains found that social skills, mood, and well-being (e.g., alleviating stress and anxiety levels) are the three areas that may benefit from such interventions [130]. A social robot can be used to facilitate psychosocial interventions for different populations, such as older adults, adults, children, and specific user groups, such as students [398, 422, 130, 89]. For example, the literature suggests the effectiveness of social robot-assisted interventions in improving the well-being of older adults and promoting the quality of life by decreasing stress, anxiety, and loneliness in individuals with dementia or cognitive impairment [364, 161]. Furthermore, social robots have been found to be helpful in providing educational and therapeutic interventions for children with Autism Spectrum Disorder (ASD) [105, 205, 506]. Similarly, several studies have indicated the benefits of using social robots in delivering psychological interventions such as mindfulness practices, meditation, and positive psychology to decrease individuals' anxiety and stress and improve their moods and psychological well-being [10, 212, 304, 213]. Such findings hint at the potential social robots have in facilitating therapeutic outcomes and, consequently, mitigating the current challenges experienced in accessing mental health services. Yet, the main challenge in providing mental health-related interventions to young people has been shown to be making such interventions accessible and engaging to those needing them the most [157]. Similar to the other application areas, user-centred design is a highly useful approach to encourage engagement and improve adherence to technology-based mental health interventions [345, 78], and is an imperative initial step to developing an effective solution [489, 296].

2.4 User-Centred Design

Incorporating a user-centred design into the process of developing assistive technologies to deliver mental health interventions has been proposed as an effective approach to identify and meet the specific needs and preferences of end users, and thereby improve users' engagement and acceptability of technology-based mental health interventions [78, 369]. User-centred design was first defined by Norman and Draper [335] as "a philosophy based on the needs and interests of the user, with an emphasis on making products usable and understandable".

This approach helps to better understand users' perspectives, expectations, and needs by actively involving different stakeholders (e.g., relevant domain experts and prospective users) in the design processes [489, 296]. This multidisciplinary design approach is known to be essential from the early stages of the design process for developing an effective solution [489, 296]. User-centred design involves an iterative design and evaluation process, and it has been widely regarded as the key to the usability and usefulness of products [296].

In fact, there are various approaches in which designers can benefit from involving users across design phases while working in interdisciplinary design teams [300, 444]. For example, user involvement can be seen as a spectrum, ranging from consultation, informants or testers to co-designers [300, 444, 141]. It is also important to consider the diverse range of design projects, from time-sensitive commercial product-oriented projects to research-based projects that are more focused on the process. These different types of projects can result in diverse levels and types of user involvement. Hence, given varying levels of user involvement, different methods have been introduced to implement user-centred design, such as participatory design and co-design [194]. In participatory design, stakeholders act as informants to the research team to identify appropriate designs or enhance existing products, rather than collaborators actively joining the decision-making process of design (e.g., see [409, 21]).

Co-Design Methodology: The main difference between participatory design and co-design is the level of user engagement [194]. In contrast to participatory design, Co-design approaches involve stakeholders most actively in the design process. Co-design empowers stakeholders to contribute their experiences and expertise to the design process directly. This technique aims to achieve a balance between the decision-making powers of researchers and stakeholders, ensuring that the resulting technology aligns with the needs of the end users [370].

Co-design plays an integral role in technology design and serves as a valuable technique to actively involve stakeholders, including prospective users and subject domain experts,

such as mental health professionals, as co-designers [411, 445]. In recent years, researchers have increasingly adopted these methodologies to design human-robot interaction HRI (e.g., [343, 17, 149]). In the mental health and well-being domain, the co-design methodology has been widely employed in developing social robots for different applications. For example, co-design has been used to enhance the mental health of teenagers [61] and to support emotional well-being in school children with autism [328]. These studies employed methods such as conducting interviews and workshops with prospective users and relevant stakeholders to gather information for designing the social robot.

2.5 Design Elements Affecting Intelligent Agents' Acceptance and Adoption

To create a more user-centred and engaging experience, it is essential to understand the design elements and characteristics that affect the users' acceptance and adoption of such interventions. A recent systematic literature review on design elements affecting intelligent agents' acceptance has identified a variety of factors influencing users' experiences, which can be essential to the success of such assistive technologies [136]. Some of these factors are related to the agent (e.g., visual appearance, design, embodied presentations, intelligence), and some are related to the users (e.g., attitude, perceived social presence, perceived ease of use, perceived usefulness, and perceived trust including credibility or privacy perceptions) [136]. User's personality is also another factor that has been identified as a predictor of robot acceptance in the HRI literature [137]. For example, individuals who exhibit higher levels of agreeableness, extroversion, and openness are more inclined to accept a robot.

The agent's visual appearance is particularly important to consider since it can facilitate humans' tendency to engage with and attribute social characteristics to it. A user study with 18 students investigated the influence of different robot morphologies (e.g., animal-like, humanoid, or mechanistic) on user acceptance [32]. In this study, participants interacted with five different robots freely and outside of any specific context. Findings showed that the agent's appearance can affect individuals' perceptions of and preferences for social robots [32]. Further, a survey comparing physically present robots, telepresent robots, and virtual agents indicated that physically present robots have more authority, are more persuasive, and are perceived more positively compared to telepresent robots and virtual agents [273]. Moreover, physical presence was shown to have a beneficial effect on a variety of attitudinal measures, such as social presence, user enjoyment, trust toward the agent, and agent utility [273]. Other influential factors for intelligent agents'

acceptance include, but are not limited to, adaptability [187, 121], intelligence [33], ease of use [187, 120, 279], companionship ability [267, 121], sociability [121, 285], as well as users' enjoyment [187, 217, 121, 279], perceived usefulness [187, 279], and feelings of social presence [56, 185].

In general, several factors are likely to affect users' acceptance and adoption of intelligent agents, including the ability to exhibit specific behaviour that users prefer [160], not requiring much maintenance [160], performance-related concepts (e.g., effectiveness, efficiency) [407, 127], user engagement [230, 116], and ability to learn users' behaviours [407] and be adaptive to the users' changing needs [187]. Previous studies have also highlighted the importance of social capabilities for intelligent agents, such as the ability to show emotions (e.g., positive, neutral or negative) [59, 159, 290], the ability to recognize users [160], ability to demonstrate social intelligence (e.g., recognizing some of human's emotions and responding appropriately) [290], ability to understand the natural language [407], and the ability to engage in conversations verbally and non-verbally, e.g., using gaze, facial expressions, body movements, hand movements, or head orientation, depending on the intelligent agent's capabilities and affordances [290, 279]. Prior research has also demonstrated the importance of making eye contact in designing virtual agents and social robot behaviours [257, 249]. It has been shown that eye contact can have a positive impact on the perceived sociability of the agent and the quality of human-agent interaction (e.g., attracting and maintaining users' attention to the agent, improving the user's engagement in the task, etc.) [403, 4, 249].

In addition, research in human-agent interaction suggests the importance of having a sense of humour for intelligent agents to establish a natural and realistic interaction and improve users' perception of the agent and users' evaluation of the interaction [331, 329, 330, 338, 339]. Moreover, a systematic review of digital mental health interventions for anxiety and depression in young people (aged 12-25) revealed that interventions with game-like features were more highly regarded by users and demonstrated enhanced engagement levels due to their interactive nature [157]. Specifically, games have the potential to induce greater levels of engagement and establish more sustainable behavioural change for health and well-being as they are intrinsically motivating [218].

Note that some of the design factors identified above, such as users' enjoyment, the ability to show emotions and social intelligence, and the ability to engage in conversations verbally and non-verbally were discussed in the context of mental health and well-being, but others (e.g., making eye contact) were not.

2.6 Building Rapport

Creating and maintaining social rapport with the user is a crucial skill for social robots [74]. Social rapport is established through interaction between individuals, resulting in a strong interpersonal influence and responsiveness that is based on mutual attentiveness, responsiveness and positivity [48, 261]. In collaborative activities, the ability to build a good rapport often leads to enhanced outcomes. For example, the rapport between healthcare professionals and clients is a key factor in predicting better health outcomes, clients' adherence to treatment plans, and overall satisfaction with their healthcare [366]. Within the context of psychotherapy, the establishment of a strong rapport and a therapeutic alliance between a therapist and a client is regarded as vital for the effectiveness of the therapeutic process [151, 491]. Namely, building a strong rapport has been proven to enhance client outcomes in their ability to deal with depression and stress [366]. Researchers in the fields of HRI have also explored the capacity of social robots to establish rapport with individuals [388, 212, 214]. In a recent study, the companion-like robot designed for delivering psychological well-being interventions was shown to be effective in building a positive therapeutic alliance with people, resulting in improved well-being and readiness for change for better well-being among participants [214]. Enhancing rapport also enables social robots to offer individuals effective forms of social support. Social support is recognized for its significant impact in assisting individuals in achieving personal objectives and better results across various areas, including education, mental and physical health, aging, coping, and beyond [74]. To enable technological agents to build rapport with people, they are equipped with social skills inspired by the findings of human psychology research [473]. These skills encompass a wide range of verbal behaviours (e.g., vocal prosody and intonation), as well as non-verbal behaviours, such as head movements, facial expression, smiling, back-channelling cues, making eye contact, and mimicking [388, 286].

2.7 Final Research Questions

In Chapter 1, we have outlined the research questions. As my research project progressed, the primary research questions extended to comprehensively investigate the various facets and implications that emerged from the literature review. These questions need to be thoroughly investigated to determine the potential of social robots as assistive tools for supporting the mental well-being of university students, specifically to cope with feelings of stress and anxiety in social situations.

RQ1: What are the potential applications of social robots for social anxiety?

RQ2: What are the university students' opinions and preferences for using intelligent agents to cope with stress and anxiety in social situations?

- **RQ2-1:** To what extent do students report experiencing stress and anxiety in various social situations within an academic context?
- **RQ2-2:** What do students report as their preferred type of intelligent agent for potentially helping them manage their anxiety related to their most anxiety-provoking social situation?
- **RQ2-3:** What activities do students endorse as being potentially beneficial for managing their anxiety related to their most anxiety-provoking social situation within an academic context, and for which of those activities are they willing to use an intelligent agent?
- **RQ2-4:** What characteristics and factors do students think are important in an intelligent agent for supporting mental well-being?
- **RQ2-5:** What types of data would students allow an intelligent agent to record to help address their most anxiety-provoking social situation? For example, would students allow an intelligent agent to recognize and keep track of their emotional states and/or moods (e.g., using external sensors, wearable).

RQ3: How to design and develop robot-based interventions in a user-centred and co-design approach to support students in managing their stress and anxiety in social situations?

RQ4: What are the usability and acceptability of the robot-based intervention, developed through the co-design process, to support students in managing their stress and anxiety in social situations?

- **RQ4-1:** How do participants evaluate the usability of the robotic mental well-being coach for managing public speaking anxiety?
- **RQ4-2:** What is the user acceptance rate of the robotic mental well-being coach for managing public speaking anxiety?
- **RQ4-3:** How do participants evaluate the social attributes of the robotic mental well-being coach for managing public speaking anxiety?
- **RQ4-4:** Does the use of the robotic mental well-being coach have the potential to impact students' moods?

RQ4-5: Can the robotic mental well-being coach influence students' willingness to make behaviour changes to manage their public speaking anxiety?

RQ4-6: How do participants evaluate their working alliance with the robotic mental well-being coach for managing public speaking anxiety?

RQ4-7: What are the participants' user experiences (e.g., satisfaction, engagement, enjoyment, etc.) of their interaction with the robotic mental well-being coach for managing public speaking anxiety?

RQ4-8: How do participants' personality traits affect their intention to use the robotic mental well-being coach for managing public speaking anxiety?

Chapter 3

Potential Applications of Social Robots in Robot-Assisted Interventions for Social Anxiety

3.1 Introduction

With consideration of the low rates of treatment utilization among individuals with social anxiety disorder due to factors like embarrassment and anticipatory anxiety, it is essential to identify solutions that address and alleviate the barriers to accessing treatments for individuals with social anxiety who could benefit from intervention. Given the technological advancement, one possible avenue to explore is social robots. By definition, 'social robot' refers to robots that have been designed specifically to interact and communicate with people in a human-centric and human-compatible manner [74]. "Social robots communicate and coordinate their behaviour with humans through verbal, non-verbal, or affective modalities" [73, p. 3527]. The research finding suggests that interactions with social robots could alleviate anxiety and tension in both persons with and without social anxiety, demonstrating the efficacy of human-robot interactions [333]. Moreover, individuals with social anxiety tend to experience less anticipatory anxiety when they are meeting with a robot than a human [333].

While certain research projects aim to develop robots that are indistinguishable in appearance and behaviour from humans, the most successfully used social robots across many application areas are robots with a relatively simplistic appearance, but still providing a rich repertoire for verbal and non-verbal interaction and communication with

people [74]. For example, such robots can use gaze, facial expressions, body movements, hand gestures, head orientation, control of interpersonal distance (proxemics), and speech to engage people. They can be used in scenarios where they show predictable behaviour in a non-judgmental manner, providing motivating and positive feedback to humans [74]. Robots are programmable machines, they do not show immediate judgmental feedback, as humans would show, unless they are programmed to do so (e.g., a raised eyebrow, changing eye gaze, body posture or prosody). Social robots are typically fully programmable and can thus express a variety of different behaviours that might be augmented with learning and adaptation mechanisms in order to personalize the robot's behaviour and allow it to change behaviours over time, for example, during the course of treatment. We posit that these attributes of social robots make them potentially useful as treatment tools in conventional behavioural interventions for social anxiety disorder and that further inquiry in this area is warranted.

In this research, we propose the application of social robots as tools that could complement the support provided by clinicians in the context of intervention for social anxiety disorder. We do so by drawing attention to, and links between, the activities within conventional treatment for social anxiety and the current applications of social robots for interventions in other domains (e.g., work with individuals with ASD. The purpose of applying social robots in social anxiety treatment interventions is not only to get people into therapy but also to maximize the effectiveness of therapy through increased engagement and continued support outside the therapy sessions. That is, while the ultimate goal of therapy would be to decrease individuals' anxiety within human interactions, there may be roles a social robot could adopt to assist in the process of getting to that point.

3.2 Research Question

This chapter addresses our first research question:

RQ1: What are the potential applications of social robots for social anxiety?

3.3 Fundamental Characteristics of Social Robots

Social robots are robots that are "designed to interact with people in human-centric terms and to operate in human environments alongside people" [74, p. 1936]. These systems interact with humans by following the behavioural norms and expectations that are defining features of social interaction, such as emotional expressiveness, verbal communication,

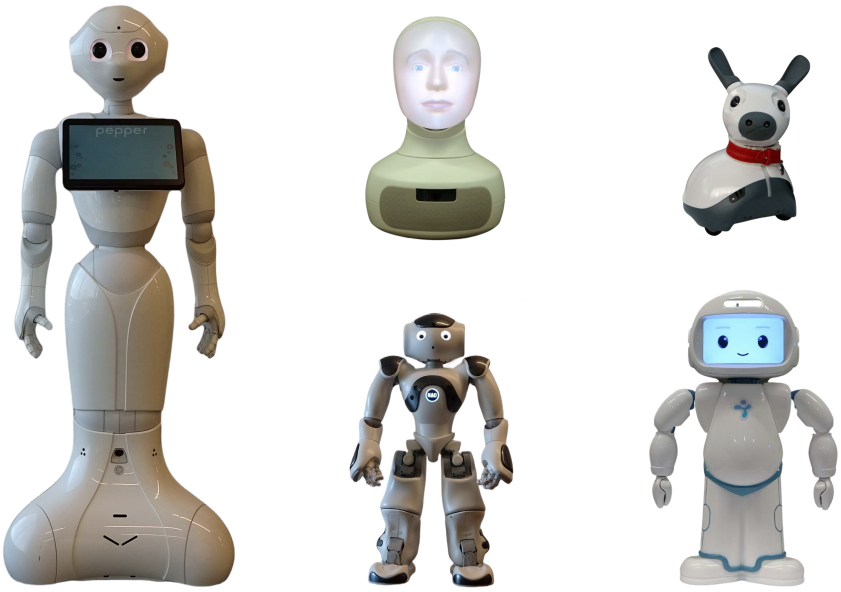


Figure 3.1: Images of the social robots (from left to right, top to bottom): Pepper[1], Furhat[2], Miro[3], NAO[1], and QT Robot[4].

user engagement, and an appealing physical appearance [416]. Due to their physical appearance, physical availability, and direct interaction in the physical space, interactions with social robots are more natural and engaging compared to other forms of interactive technology [485, 115]. The physical appearance of social robots falls on the continuum of human-like (humanoids) to non-humanoids. Humanoids often have expressive faces with oversized, simple features, whereas non-humanoids can be zoomorphic (animal-like), caricatured, or have a purely functional appearance (related to a robot's tasks) [147]. Examples of social robots are shown in Figure 3.1.

Research on the current trends in robot-assisted therapy shows that present interactive robots are either androids (human-like), mascots (human form with cartoon-like features), mechanical robots (human form with visible mechanical features), animal-like robots, or non-humanoid mobile robots [387]. Furthermore, social robots can be either teleoperated (remote-controlled), semi-autonomous, or fully autonomous. While a remote-controlled robot can adapt to the abilities of the participant and social circumstances, this mode of

[1] https://www.softbankrobotics.com
[2] https://furhatrobotics.com/
[3] http://consequentialrobotics.com/
[4] https://luxai.com/

operation is challenging in the long-term [416, 485] since it requires an operator accompanying the robot. In contrast, an autonomous robot functions without manual operation from a third party and reacts to a current situation based on its perception and analysis of the social circumstances [204]. These robots can either follow pre-programmed scripts or use more complex computational architectures for their decision-making, such as including short-term and long-term memory. Ideally, a social robot's functionality can also be adaptive and shaped by learning. For example, new skills could be taught to a robot by its owner [147]. While each of these operation modes has its limitations, researchers are aiming to develop autonomous robots that are able to respond in a contingent manner since such robots can reduce the costs associated with traditional therapies as well as the workload of the therapist [105].

3.4 Roles of Social Robots in Clinical Interventions

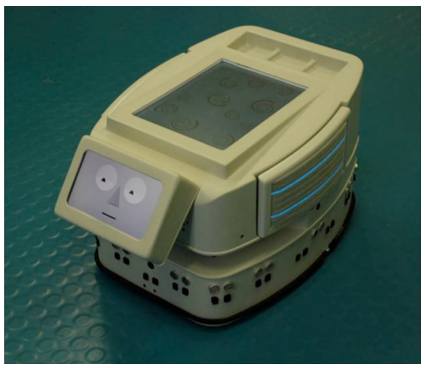
The use of social robots in delivering mental health care interventions for children with ASD and older adults, especially those with dementia, has been widely studied [323, 486]. Studies in these two areas have shown that social robots can effectively engage users and contribute to improvements in their mental health, such as improving their mood, increasing perceived social support, and enhancing the quality of life. Table 3.1 provides examples of social robots that have been used for therapeutic and other assistive applications in mental health care and well-being.

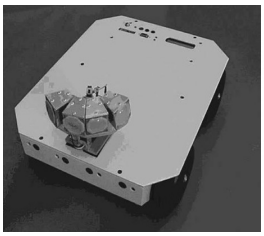
Social robots can have different roles in delivering such psychological interventions. According to the review by Diehl et al. [128], there are three potential clinical uses of interactive robots in the particular context of autism therapy. The first clinical application entails eliciting participants' behaviours for different purposes, such as diagnosis [128]. The second clinical application includes using interactive robots as tools for teaching, modelling, or practising behaviours and skills [128]. The final clinical application of social robots that the authors discuss presents them as tools for providing redirection, reinforcement, and encouragement during triadic social interactions between the child, robot, and the parent/therapist [128].

The available research on the clinical application of social robots points out three major roles for robots in robot-assisted psychotherapy: robots acting as (a) therapists/coaches, (b) mediators, or (c) assistants. As a therapist or coach, the activities of robots are defined and supervised by practitioners to provide a new medium for delivering psychotherapy. In addition to the role of therapists/coaches, social robots can function as mediators that

enable or facilitate the treatment progress by mediating interactions between the therapist and client. As a mediator, the robot can also act as the source of motivation and encouragement, which can make the treatment engaging [115, 333].

Table 3.1: Selected examples of robots that have been used for therapeutic or assistive applications.

Robot	Picture[a]	Description
Kaspar		Kaspar is a humanoid robot developed specifically to support children with ASD. Kaspar can be personalized with different hair and eye colours, clothing, etc [505].
	 	Example setup for studies into robot-mediated interviews. In this study, typically developing children were either interviewed by a human (left) or a robotic interviewer, i.e., the humanoid robot Kaspar, which acted as a mediator, to assist the (hidden) human interviewer (right) [509]. See also applications for children with special needs [507].
IROMEC		IROMEC is a cartoon-like robot used in the European IROMEC project [245]. The robot was designed to support play for children with cognitive, developmental or physical impairments. Other results of the project include the development of different play scenarios for robot-assisted play [394].

Paro	 Credits: AIST, Japan 	Paro is a pet-like robot in the shape of a baby seal with five different sensors, including tactile, light, audition, temperature, and posture sensors, so that it can perceive its environment and interact with people [430]. Paro has been used extensively in long-term care homes, as shown in the picture on the right [431].
Labo-1	 	Labo-1 is a machine-like robot. The image on the right side shows this robot in the first study in 1998, where children with ASD interacted with an interactive robot. Labo-1 operated autonomously and attracted children with ASD [498, 113].

[a] All pictures are used with permission of the authors.

Finally, as assistants or tools, interactive robots can be used for the elicitation and development of primary social skills, or for assessment/diagnoses [115]. Social robots can play these roles singly or in combination, depending on the type of mental health disorders and the associated therapeutic interventions.

Given technological advances in social robots and their growing capabilities, these robots may begin to play an increasing role in enhancing and broadening mental health care interventions and accessibility [228]. Today, interventions employing social robots have been discussed in the context of mental health, such as depression and anxiety disorders. Since it is a relatively new application area of robots, research on social robots for social anxiety disorder is limited. However, the noted benefits of robot-assisted therapy for children with ASD [395, 415, 387, 416, 128, 203] opens up the possibility that social robots could be utilized in other ways, including interventions for mental health challenges, such as social anxiety disorder.

In the following section, we will discuss the possibility of the roles and benefits that social robots can have in delivering interventions for individuals with social anxiety disorder. The potential roles for social robots are outlined with respect to different therapeutic activities that may apply to both adult and child clients, though we recognize that the appropriateness of the roles will differ for the specific population. While the possible roles of robots are not limited to the ones that we are going to describe here, the following sections

can provide an overview that can be informative for further research on the influence of interactions with social robots on treatments of social anxiety disorder.

3.4.1 Robot-Mediated Interviews

As individuals with social anxiety disorder experience excessive worries in anticipation of social scenarios as well as increased avoidance of social contexts [326], initial treatment sessions may be anxiety-provoking. Moreover, many children or adolescents are not comfortable with novel or unfamiliar situations or people, which may lead to anxiety that interferes with the assessment procedures during the clinical interviews [351]. One possibility for mitigating this challenge could be to incorporate the use of social robots in the interview process.

In recent years, several studies have investigated the possibility of interviewing children with a robotic interviewer [53, 51, 507, 508, 510]. These studies focused on applying humanoid robots to facilitate communication and interaction for children, and in particular for children with special needs (e.g., children with ASD) in application areas such as interviewing children about bullying [52], and for evaluating child eyewitness memory [51] as well as in the context of interviews by police or social services [511, 510]. The purpose of these studies is to use robotic interviewers as mediators between professional human interviewers and children to create a comfortable, non-judgemental, and enjoyable setting to engage the children in the interview where the children could more easily express their feelings and experiences [509]. Rather than replacing human interviewers, robotic interviewers are designed to provide human interviewers with a tool that allows them to precisely customize and control the robot's expressions and behaviour. In addition, an interviewer could have this opportunity to observe participants' behaviours and non-verbal cues from a third-person perspective [509].

In the field of robot-mediated interviews, various studies have revealed that children's interaction with robotic interviewers is extremely similar to their interaction with human interviewers, regardless of the difficulty of questions [53, 509]. Results showed that children provided both the human interviewer and the robotic interviewer with equivalent content, i.e., similar amounts and types of information [507, 508, 509]. These results suggest that children responded to robotic interviewers and were engaged in the interviews. According to the results of qualitative analysis, some children with special needs may have been more interested in the robotic interviewers than the human interviewers [507]. The results of a study by Bethel et al. [52] showed that children reported occurrences of bullying significantly more when interviewed by a robot than by a human interviewer. Furthermore,

feedback from potential real-world users such as educational psychologists and health care specialists indicated that robot-mediated interviews could be beneficial in real-world applications if the system was sufficiently flexible [511, 510]. They also stated that such systems could have particularly promising applications for children with conditions such as ASD or anxiety that cause communication difficulties and make it hard for these children to communicate with adults in general, and unfamiliar adults in particular. In these cases, a robot as an interviewer could be a useful tool in the hands of mental health workers or clinical psychologists for providing counselling services [510].

Previous studies suggest that individuals with social anxiety who experience excessive fear of negative evaluations, which is one of the main symptoms of social anxiety, tend to evaluate interactions with a robot positively, with less tension and stress [332, 333]. Moreover, the anxiety symptoms experienced during interaction might be more manageable for the person [333]. Thus, it may be beneficial for individuals and specifically children or adolescents with social anxiety to initially participate in robot-mediated counselling sessions to increase comfort and engagement. If individuals with social anxiety find it more comfortable to communicate with a robotic interviewer than with a human interviewer in counselling sessions, interaction with a robot-mediated interviewing system may be advantageous, particularly within earlier sessions. While a different population group, it has been found that individuals with ASD, based on numerous studies showing that they generally respond very positively to robots [57, 357, 395, 240, 416].

3.4.2 Social Robots as Screening/ Diagnostic Agents

Behavioural assessment can be used to observe and characterize social behaviours directly [166, 45]. Behavioural assessment can be applied in conjunction with traditional diagnostic interviews and self-report inventories for a comprehensive assessment of patients' social difficulties [166]. Based on studies, behavioural assessment tests have discriminative validity in distinguishing between young people with and without social anxiety disorder [45, 439, 372]. This approach can also identify social behavioural differences between children and adolescents who are diagnosed with social anxiety disorder [372]. In a group context, this method may use role-playing as a behavioural observation strategy, during which an individual with social anxiety disorder and a peer may perform role-playing tasks using scripted scenarios. It is also possible to include unstructured peer interaction tasks [44]. However, finding appropriate peers in terms of age, availability for needed training, and interaction is a challenge for conducting valid behavioural assessment tests [44].

Social robots have the potential to assist therapists in studying behaviours associated with social anxiety. As discussed in section 2.1, individuals with social anxiety may exhibit

behavioural symptoms such as avoiding eye contact, rigid body postures, and inappropriate speaking voice due to the tension and fear caused by social anxiety. Social robots are capable of detecting human social cues and behaving accordingly. Besides, advanced sensors used in the design of social robots could be useful to capture and quantify a wide range of verbal and non-verbal behaviours during clinical sessions. For example, in comparison to typical clinical evaluations of eye contact, gaze direction can be recorded and analyzed in greater detail, including mutual or averted gaze, number and duration of fixations and gaze points [92]. Furthermore, machine learning algorithms can be employed to recognize human gaze patterns and behaviours such as head movements and facial expressions associated with anxiety and depression [26, 207]. This quantitative information could be made available to the therapist in real-time to enhance diagnosis and initial and ongoing assessment as treatment progresses.

In the context of ASD, it is proposed that social robots could use two methods of passive observation and structured interactions for quantitative measurements of social responses [415]. Robots can record information on social responses through passive observation of the therapist and the client during standard clinical evaluations without directly engaging in interaction. Whereas in structured interactions, the robot can directly engage in interaction to elicit a specific social behaviour or response. The collected information from the passive and interactive methods could provide reliable quantitative measurements, to not only compare different individuals in a standardized manner but also track the progress of each individual over time [415]. With respect to structuring behavioural assessments, social robots could be used to play the role of a peer. The robot could be programmed to demonstrate a wide range of anthropomorphic characteristics, behavioural repertoires, as well as sensory and interactive capabilities. Moreover, social robots could be programmed for various scenarios to focus on specific or single behaviours. In this context, social robots might be used as clinical decision-support tools to track various social anxiety indicators, including verbal and nonverbal behaviours, as well as physical and cognitive symptoms. This information could be used by therapists to form case conceptualizations and track progress across sessions in certain scenarios or appropriate applications.

3.4.3 Robot-Assisted Therapy

The benefits of applying robots in therapeutic interventions for children with ASD and individuals with dementia reflect a promising development in robot-assisted therapy [395, 323]. Robot-assisted therapy can be applied to improve patients' cognitive, social, emotional, and physical functions. In the context of social anxiety, social robots could be incorporated in traditional therapies for social anxiety disorder, such as CBT, and like any other form of

treatment, they could be tailored to suit each client's needs. Such incorporation of interactive robots could function as a "stepping stone" for individuals with severe social anxiety. For example, they could practice social skills and behaviour before applying them in real-life interactions. Therapeutic sessions could involve facilitating the learning of various social and communication skills. Meanwhile, individuals can practise these skills based on their capabilities to be prepared for real-life scenarios. Confronting feared social situations without the pressures of interacting with another person can add value to existing forms of treatment, such as exposure. Due to this added layer, the anxiety symptoms experienced during exposure might be more manageable, which could potentially encourage the individual to continue treatment and eventually confront social situations, including other people, which is the ultimate goal. Besides, the inclusion of robots in the therapeutic context may introduce the element of comfort and fun into the therapeutic session, which could contribute to emotional support and stress relief during stressful situations within the therapeutic process. The treatment sessions would become more friendly and less threatening, and clients may feel more calm and relaxed when a robot participates in treatment sessions.

Integrating social robots in therapeutic environments could provide support for therapists as well. In a study [521], therapists of an autism therapy center participated in ten focus group sessions to discuss possible roles of robots within the therapy environment that would be beneficial to therapists. Suggested roles are including (a) *"As a helper in critical/dangerous situations"*, for example, a robot could be utilized to distract or ask for help from another therapist, (b) *"As a record keeper and reporting device"* to facilitate preparing reports and help with enhancing therapeutic feedback via activities such as recognizing and analyzing client's actions, monitoring and evaluating the progress, (c) *"As an emotional support/mirror"*, a robot could be used to suggest a break, distract to lighten the mood, or mirror a client's emotions, (d) *"As a team player"* to alleviate therapist's workload and mental load (e.g., by distracting and entertaining a client during break activities, repeating therapists instructions, reminding and managing of schedule). While this article [521] focused on the needs of autism therapists, some of these functionalities and roles can be extended to other areas of psychotherapy. This being said, similar studies need to be conducted to develop a better understanding of therapists' needs and expectations about robots in other psychotherapy domains. Additionally, it is crucial to identify the short and long-term implications, both positive and negative, of using social robots in mental health care interventions.

3.4.4 Social Robots as Interactive Social Companions

Individuals with social phobia report fewer friends and increased difficulty managing their friendships and relationships [292]. Social robots are commonly employed in the role of companions to improve the health and psychological well-being of their users. In some situations, animal-like robots are used, which are designed to function in a way that resembles trained therapy animals. Different studies have investigated the role of animals in mental health care and their advantages in the treatment of mental illness [253]. It has been shown that animal-assisted therapy has a beneficial impact on human anxiety levels and reduces anxiety symptoms [50]. Three separate studies have noted that the presence of a therapy dog in university or college settings significantly decreased students' self-reported anxiety levels [108, 264, 448]. Another study identified the efficacy of equine-assisted therapy and cognitive-behavioural health strategies in alleviating social anxiety symptoms in young women [9]. The completely non-judgmental acceptance of individuals by animals is a characteristic that may be particularly appealing to those who have social anxiety or experience social rejection [88].

Social robots may offer benefits of animal-assisted therapy without the practical concerns and challenges involved in working with live animals such as animal welfare, allergies to animals, safety, and risk of contamination or infection transmission [367]. Currently, numerous pet-like robots are available with the aim of simulating the effects of therapy animals. Several studies have emphasized the positive impact of interacting with robotic pets on mental health, such as enhanced socialization and mood, as well as reduced depression, stress, and anxiety [422, 355, 275, 408]. Many of these studies primarily focused on older adults and persons with dementia.

Aibo and Paro are examples of extensively used pet-like companion robots. Aibo is a non-verbal, dog-shaped robot with various sensors through which it can respond to speech, touch, sight, sound, and it can express emotional responses. In a Randomized Controlled Trial (RCT), 38 participants were randomized to interact with the Aibo robot, a real dog, or no object as a control group. At week seven, participants in the dog and Aibo groups reported significantly lower feelings of loneliness than those in the control group, but no significant differences in loneliness or attachment were observed between the dog and Aibo groups [29]. Paro is another most used interactive companion robot in the shape of a baby seal with five different sensors, including posture sensors, light audition, temperature, and surface tactile. Using these sensors, Paro is able to recognize its environment and people. It is shown that interacting with Paro facilitated and increased positive social interactions among residents of a nursing home [408] and also among users and their caregivers [490]. In laboratory studies, children who interacted with the Paro robot indicated a reduction

in stress levels and a promotion in positive mood [107].

These studies, along with many others, suggest that social companion robots may provide an engaging and interactive tool for individuals with social anxiety through helping with the management of anxiety levels and associated challenges through providing in-home resources and services. Interactive social robots could also be used to teach essential social skills to younger people with social anxiety who might not be readily interested in the treatment. The robots' adaptability and ability to perform repeated tasks would also make social robots suitable for teaching, modelling, and/or practising new social skills [387]. At the University of Washington, researchers are working with an emotional and social robot called Emobie that provides in-home companionship to children with anxiety who might not have access to professional therapists [19]. Emobie teaches children coping skills through a storytelling scenario during which this robot listens to the children and responds to them using expressive facial expressions, arm movements, sounds, and colours displayed on a screen located in the robot's abdominal region. Emobie is designed to assist in the improvement of communication between children and their parents and/or therapists by communicating the child's emotions [19].

Furthermore, social companion robots could improve their users' mental health by engaging them in pleasurable activities. Social anxiety has been shown to be associated with depressive symptoms, and a synergic relationship between scores of social anxiety and depressive symptoms has been observed [277, 437]. Engaging in pleasurable activities and increasing access to positive reinforcers are shown to be effective practices for improving depression and anxiety [272, 200]. Social robots could learn and engage socially and emotionally with users over various sensory inputs such as audio, visual, and tactile. Meanwhile, they may offer education, skills training, mindfulness/relaxation practices, and health tracking to users according to their preferences and physical/mental conditions.

Social robots could also be used as assistive and supportive companions in delivering interventions designed to enhance well-being, particularly positive psychology interventions, which focus on helping people flourish with positive emotions and personal strengths and skills [426]. It is believed that experience of pleasure, engagement, and meaning, emphasized in positive psychology, in an individual's life is associated with relieving negative states and coping with mental health issues, including anxiety [268, 425]. A systematic review into the influence of positive emotions in depression treatment revealed that the different strategies of positive psychology, focused on positive emotions, can contribute to significant improvement in depression signs and symptoms. This study also highlighted the relationship between humour and positive emotions [412]. In the field of social robotics, researchers have investigated the efficacy of providing positive psychology interventions via a robot. In a pre-post study, a social robot companion called Jibo was used to deliver posi-

tive psychology interventions, such as character strengths and gratitude, and build rapport with 35 college students living in on-campus dormitories. Deployed in participants' rooms, the robot guided the participants on the positive psychological intervention and a pictorial survey. After seven sessions of interacting with the robot, participants showed statistically significant improvement in their psychological well-being, mood, and readiness to change health-related behaviours for further improved well-being. During the post-study interview, other than expressing some privacy concerns, students expressed appreciation for the robot's companionship and desire to talk and communicate with the robot [212].

3.4.5 Social Robots as Peer/Interactive Playmates

Interactive robotic playmates have been extensively used in therapy applications, most often for children with ASD [114, 112] and in learning environments to support children's language learning [223, 251, 485]. In the field of autism therapy, social robots are usually involved in fun and engaging activities such as games in which social robots often play the role of therapeutic toys or play partners to encourage basic communication and aid children in practising social interaction skills [498, 497, 367].

Social robots' physical presence and properties, such as communication via natural language, gestures, facial expressions, and eye contact can create a rich interactive environment where a user can practise specific skills with the robot. Furthermore, the repeatability and predictability of social robots' behaviour are great advantages of robots over humans. Robots provide an opportunity to practise and explore social skills without fear of the complexity and multi-modality of human-human interaction. Social robots as a "therapeutic teaching device" can participate in enjoyable dyadic human-robot play activities to teach the necessary social skills and engage users in therapeutically relevant interactions [112, p. 447]. In this type of interaction, the robot will direct all its attention to a single person. Besides, it is possible to design play activities that are personalized to a person's specific needs, preferences, and capabilities. For example, the level of teaching social skills could be adjusted incrementally based on each user's progress.

Individuals with severe social anxiety may benefit from practising communication and social skills via interacting with social robots as peers or interactive playmates. These interactions may help individuals with social anxiety become familiarized and comfortable with basic styles of interaction, such that they are more willing and confident to engage in real-life interaction with humans.

3.4.6 Social Robots as Social Mediators

Individuals with social anxiety tend to find it hard to participate in social situations due to communication burdens and the fear or concerns associated with the scrutiny of others. A social robot as a social mediator is a tool to encourage and facilitate social interaction between two or more persons or between the person and the therapist (e.g., if a highly anxious child is unwilling to interact with a therapist directly).

Social robots have been successfully used as mediators for children with ASD for many therapeutically relevant areas, such as touch, joint attention, eye contact, turn-taking and sharing, robot behaviour imitation, and cooperation [387, 139, 395, 396, 393, 498, 394]. Based on the literature, social robots can facilitate social exchanges between a child with ASD and a partner by incentivizing communication, eliciting and reinforcing social behaviour as well as providing feedback and encouragement [95]. In an observational study, Werry et al. [498] showed that scenarios with a robot as a mediator and pairs of children can create a particularly fascinating social context for observing various social and non-social interaction patterns. Analyzing these behavioural patterns can help to identify specific problems as well as the abilities of children with ASD in social interactions. Giannopulu and Pradel [164] explored the role of a robot as a mediator between a child with autism and a therapist. In this study, the child used the robot as a tool to convey positive emotions to the therapist.

Robins et al. [393] conducted three case studies in which interacting with a minimally expressive robot, Kaspar, encouraged low-functioning autistic children to interact with other children to break their isolation and generalize this behaviour to co-present others. Kaspar is a humanoid robot developed to support children with ASD [505, 459]. This robot has shown the potential to be incorporated into current educational and therapeutic interventions for children with ASD [205]. Recent studies in robot-assisted therapy have indicated how using Kaspar, as a mediator, can help children with ASD to develop and improve skills, such as visual perspective-taking [259]. It is also shown that play sessions with Kaspar have a positive influence on some children's behaviours in particular areas, including communication and interaction, imitation, prompted speech, focus, and attention [224].

In comparison to other social robots' roles, such as companions or coaches, social robots as mediators will mainly focus on enhancing human-human interaction to support social interactions between people. In the research area of robot-assisted therapy for children with ASD, social robots have been shown to be helpful tools for motivating and reinforcing the social engagement of children [395, 416, 240]. This approach could potentially be generalized to other health conditions such as depression or anxiety where individuals'

phobias or social behaviour deficits will affect their social interaction [440].

Designing social robots as social mediators in the particular domain of social anxiety requires the careful study of how social robots can motivate and support individuals with social anxiety to participate in social interactions with one or more partners. For example, social robots could support socially anxious children by prompting and facilitating conversation between youth interacting, moderating social interactions, providing positive reinforcement to increase confidence, promoting conversation inclusiveness and participants' engagement (e.g., [306, 470, 451]) and offering social feedback (e.g., [460]) to develop and practise social skills.

The ultimate goal of interactions with a social mediator robot is to enable individuals with social anxiety to transfer and generalize their learned social skills to their daily social interactions with familiar or unfamiliar people. Thus, as a final stage of such interventions, after a participant has shown sufficient improved interaction skills, the robot will, in fact, no longer be needed, and individuals would instead continue practising learned social skills with a human partner to further enhance and promote communication and social interaction skills. However, it should be noted that the possibility of transferring and generalizing learned skills from human-robot interaction to human-human interaction is an unsolved issue and requires substantial further research. In a recent study, an autonomous social robot, Jibo, was used for a month to provide a home-based intervention to improve the social skills of 12 children with ASD, who were between 6 and 12 years old [417]. The results of the study provide evidence that it may be possible to transfer learned social skills beyond robot-mediated interactions to human-human interactions; however, long-term preservation of improved skills still remains a challenge [417].

3.4.7 Social Robots as Coach or Instructors

There is a growing interest in developing social robots acting as instructors or coaches to monitor and engage users in a number of therapeutic or non-therapeutic tasks in a highly personalized way to improve their social, physical, or cognitive well-being. For example, Kidd and Breazeal [238] developed Autom as a behaviour change coach to facilitate sustained engagement in a diet and exercise program by tracking each participant's weight loss and providing personalized feedback. In a between-subjects and longitudinal study of six weeks, Autom was compared to a standalone computer and a paper log. After six weeks, participants who took part in the weight-loss program with Autom continued participating in this program for significantly more days than participants in the two other conditions. Besides, a significantly closer working alliance with the robot was reported. In another

study, Fasola and Matarić [138] designed and developed Bandit, a robotic coach system, to engage older users in physical exercises. In this study, the robotic coach methodology has been developed based on psychology research on users' intrinsic motivation. Besides, the researchers compared the physically present Bandit robot to its virtual version to explore the role of physical embodiment. The results showed that physical embodiment had a positive effect on participants' evaluations of the robot and the interaction. Enjoyableness, social attraction, helpfulness, social presence, and companionship were identified as factors that influence participants' preferences for the physically embodied robot coach over the virtual coach.

In the context of social anxiety, social robots as coaches or instructors could be incorporated into the treatment of social anxiety for social skills training, cognitive restructuring, mindfulness practices, and relaxation training. A social robot as a social skills training coach could be used to address verbal and non-verbal behavioural deficiencies that may emerge in social situations. This intervention can entail teaching verbal social skills (e.g., how to initiate a conversation and give others positive feedback during a conversation, verbal qualities such as volume, tone, and rate, etc.) and non-verbal social skills (e.g., eye contact, facial expression, body postures, use of gesture, etc.) via behavioural rehearsal, corrective feedback, and positive reinforcement. For instance, public speaking anxiety is one of the prevalent social phobias. A great deal of stress and frustration resulting from excessive public speaking anxiety can negatively affect speech performance and lead individuals to further avoid situations that require public speaking. Good public speaking skills are essential in terms of educational achievement and career success. Those skills can be learned through appropriate training and practice. To facilitate public speaking training, various interactive technologies such as mobile applications, intelligent interfaces, and virtual agents have been developed to promote presenters' learning experience by providing them with automated feedback on their verbal and non-verbal behaviours [256, 462, 287, 110, 420, 77, 463].

The RoboCOP is a robotic coach for public speaking [479] that uses an anthropomorphic robot head called the Furhat robot [7]. This system aims to simulate an interactive rehearsal of real-life presentations to mitigate presenters' public speaking anxiety. This robot can perform the role of an audience as well as a coach and can provide verbal feedback on presenters' speech quality (e.g., speaking rate, pitch variety, and filler rate), content coverage, and eye contact. The design of the feedback strategies was based on an exploratory study with eight professors from different disciplines who had experience in guiding students in their lectures or were teaching public speaking classes. RoboCOP also offers high-level advice on other aspects such as presentation goals, audience benefits, talk organization, and how to present a strong introduction and close a speech. To facilitate the

rehearsal, the authors designed a topic-based note authoring interface that allows presenters to prepare and segment their speaking notes into a series of key topics for each slide. During rehearsal, RoboCOP tracks the presenter's speech using automatic speech recognition to provide feedback on content coverage based on the key topics covered on each slide. The Rehearsal procedure consists of two spoken rehearsal modes: *Slide Walkthrough mode* and *Dry Run mode*. During the Slide Walkthrough mode, the presenter practises verbalizing slides, and the robotic coach, as an audience, provides preliminary feedback after each slide. Then, the presenter performs a complete presentation in Dry Run mode, in which the summative feedback will be provided upon completion of the rehearsal to avoid interrupting the presentation flow. To evaluate the impacts of verbal feedback and physical embodiment of RoboCOP on the presenter's experience, 12 participants with different levels of presentation experience were recruited. Three feedback modalities, including RoboCOP coaching feedback, graph-based visual feedback, as well as voice feedback were compared in a within-subject study. Results indicated that practising the presentation with RoboCOP has significantly improved the presenters' rehearsal experience in comparison with two other feedback modalities. In a second evaluation study, a panel of 12 judges, including students, researchers, and professors with different experience levels in presentation, rated the presenter's rehearsal with and without the RoboCOP. Results showed that RoboCOP-assisted presentations significantly benefited from an interactive, motivating, and natural rehearsal environment, which resulted in significant enhancements in the quality of presentations. Besides, participants who practised the presentation with RoboCOP expressed great satisfaction and desire to use RoboCOP for their future presentation rehearsals.

RoboCOP is an example of applying robots to social skills training to mitigate public speaking anxiety. Numerous participants with a fear of public speech expressed that they were more comfortable practising presentations with RoboCOP compared to human audiences. They also reported that the presence of the robot helped them practise maintaining eye contact during the presentation rather than looking at their notes [479]. It can be argued that the robot's physical embodiment and its eye gaze tracking capability are the advantages of this platform over other media for public speaking training. This platform could also be developed to deliver feedback on a presenter's body language and facial expressions. To improve the effectiveness of the training process, future systems need to include mechanisms that could dynamically set realistic objectives based on each presenter's characteristics, performances, and anxiety level. For example, the coach's frequency and timing of feedback and suggestions could adversely affect certain participants' confidence levels and increase their anxiety, particularly when they do not show any noticeable improvement. Thus, further research is required to adapt the behaviour of the robotic coach dependent on the presenters' level of abilities and anxiety to provide more

personalized feedback and suggestions as well as a non-threatening experience for different users.

In addition, social robots can present a novel approach to address individuals' social anxiety by delivering cognitive restructuring training and practice. As noted earlier, one aspect of CBT is identifying and modifying the maladaptive thoughts associated with anxiety (e.g., negative evaluation or scrutiny from others). As a non-judgmental, stress-reducing, and encouraging agent [54, 239], social robots could be advantageous for applications in cognitive restructuring. As a first step of implementing cognitive restructuring training, the robot could help users identify the negative or irrational self-related thoughts that produce distress before, during, or after the specific social situation, identify corresponding emotional states, and assist individuals in replacing those inaccurate thoughts with more positive and rational statements through providing a series of questions (e.g., what evidence is there? what would you say to a friend? etc.).

In a recent study, a conversational agent, Amazon Alexa, has been used to address public speaking anxiety through cognitive reconstruction exercises. Alexa, as a coach, interacted with participants through structured conversation scripts and instructed them to imagine themselves presenting a speech to identify the participants' negative self-focused statements during public speaking. Next, Alexa taught participants to substitute their negative thoughts, such as *"What I say will probably sound stupid"* with positive and adaptive coping statements, such as *"There's nothing to lose. It's worth a try"*. The results of the study on 53 college students who had moderate to intense fear of public speaking revealed that the interaction with Alexa helped to alleviate pre-speech state anxiety. In addition, Alexa's sociability (e.g., self-introduction, showing empathy, and using conversational fillers) increased students' satisfaction and willingness for future engagement. In this study, participants also discussed Alexa's weaknesses as a public speaking coach, including machine-like interaction and lack of anthropomorphization, lack of flexibility in response time for different participants, lack of personalized advice, and feedback [492].

A social robot as a coach or instructor can also offer an innovative approach to mindfulness practices (e.g., instructing meditation and hatha yoga exercises) and relaxation training for the management of physiological arousal such as rapid heart rate, sweating, blushing, and trembling that often accompany anxiety. Robots could teach individuals how to relax in anxiety-provoking situations, starting with training progressive muscle relaxation. In this intervention for social phobia, users learn how to attend to and control physiological arousal before or during exposure to feared social situations [188, 399].

Incorporating the social robot as a coach or instructor into the treatment of social anxiety could facilitate coaching in real-life settings and allow individuals with social anxiety

to acquire and practise cognitive and behavioural skills for different social situations in which they may experience debilitating fear or anxiety. Social robots can create interactive learning environments for users to practise specific skills and receive timely feedback. By supporting experiential learning, social robots have the potential to improve the effect of coaching interventions and reduce associated costs. Furthermore, these robots can be designed for the means of facilitating a variety of therapeutically relevant functions both inside and outside of therapy sessions with clinicians [367]. Within a therapy session, social robots can provide direct guidance to and monitoring of clients participating in relevant therapy activities defined by a human provider. Outside of the therapy sessions, these robots can be used to engage and encourage users to perform and practise therapy-relevant activities and homework assignments [367]. In this setting, robotic coaches are platforms that could assist users in adhering to treatment by providing education and real-time corrective or motivational feedback, as well as monitoring the treatment progress.

3.5 Technology: Present and Future

To date, most robots used in therapeutic scenarios in the literature involved some level of remote or Wizard-of-Oz control [464, 395, 486, 507], particularly in the context where the robot is a mediator, i.e., interacts with the client and therapist/carer/teacher or parent - a person who knows best of how the robot, in any specific situation, should respond to the individual person. The need for adaptation and personalization of robot behaviour to individuals has been recognized as an important requirement for robot-assisted therapy and it has been suggested that such scenarios might benefit from some level of robot autonomy [471, 518], as well as suitable interfaces for carers/therapists [459]. If some, or many, behaviours of the robot could be autonomous, this might reduce the cognitive and workload of the clinicians involved, so that they, themselves, could focus on the interventions with the clients rather than being distracted by technical details on how to control the robot. As stated in section 3.1, we do not suggest replacing human experts (clinicians, counsellors, etc.) but propose to complement their work using robots as their tools, similar to other digital devices.

Projecting into the future of how robots in therapy could be used in clinical practice, there is a potential for advanced technical robot development, including the ability of a robot to learn and adapt to the individual's needs and the interaction context to provide personalized behaviours for specific interactions and therapies (e.g., [466, 64, 103, 5, 282]). Note, these issues will not be applicable in practice in the near future (at least not in the 'wild', i.e., in real settings and without the repeated involvement and monitoring of

researchers), but it is an avenue for future research. Such robot adaption to users and their needs could also help sustain long-term interactions in robot-assisted therapy where those needs change, e.g., in situations where such systems are being used over a long time period of months or even years.

Future applications might also benefit from a robot's abilities to acquire and analyze data during therapy sessions, although this will have to address significant issues of privacy and confidentiality of data in daily practice. Another avenue for future development of robots to help individuals with social anxiety disorders is the tracking of emotional and physiological states with specialized sensors (e.g., some of the widely available devices such as Fitbits, Polar sensors, etc.) and data that can improve the robot's social response to emotional and attentional states of the client and may allow the robot to intelligently select psychological interventions to provide the proper interaction for the intended therapeutic goal (e.g., [282, 227, 163, 248, 135]). Note, while this is still a very active area of research in the field of robot-assisted therapy, and solutions are not yet ready to be applied in daily practice, if successful in future, algorithms might be able to assess clients' behaviour and predict their reactions which could yield some degree of autonomy in the interaction of the robot with clients. Also, either manually by the clinician or with some level of automation, the robot's behaviour could be adjusted and modified by the therapist to allow changes in the robot's behaviour over multiple sessions, if required. It needs to be seen in future research, but possibly machine learning techniques might in future allow the robot to adapt autonomously to the changing needs of each client over time and perform certain given tasks, such as playing games autonomously, but this is still ongoing and active research. While we insist that it is important that the whole therapeutic process is being led and supervised by therapists, to ensure the appropriateness and achievement of therapeutic goals, in the long term, if successful, interactive robots with some level of autonomy could potentially reduce the burden on therapists [100, 518].

3.6 Scenarios - Integrating Social Robots in Conventional Interventions for Social Anxiety Disorder

In this section, we provide examples of the possible applications of social robots in conventional interventions for social anxiety through four different scenarios. Each scenario has been designed with the aim of illustrating how social robots as complementary tools might be integrated into each conventional therapy available for social anxiety. These scenarios have been proposed to inspire future empirical research; therefore, thorough analyses

are required to identify both possible outcomes as well as challenges associated with the evaluation of these scenarios.

The structure of presenting the outlined scenarios is inspired by Robins et al., who developed robot-assisted play scenarios for children with ASD [392, 394]. Each scenario described below targets children, adolescents, or adults because the problems associated with social anxiety disorder are prevalent in all these populations, and all these groups may benefit from innovative methods of intervention [440]. The scenarios also incorporate the aforementioned behavioural and cognitive interventions and different roles of social robots to facilitate the achievement of relevant therapeutic outcomes for individuals with social anxiety disorder. The proposed scenarios are focused on promoting improvement in the emotional symptoms, physiological symptoms, and behavioural manifestations associated with social anxiety disorder. Furthermore, each scenario suggests the place/setting for the therapeutic activity, the variation in the level of difficulty to accommodate different age groups and the benefits the incorporation of social robots would provide to the participants. The duration and frequency of activity would depend on the nature of the client's presenting issues and would need to be adjusted based on empirical work in this area. For some reference, cognitive behavioural treatments typically last for 12-16 weeks and include 60-90 minute long sessions [423, 183]. Studies including individuals with social anxiety disorder found that clients needed to undergo 6 to 12 weeks of CBT in order to show any improvement [220, 183].

Scenario 1: Game of Social Skills: The goal of this scenario is to teach effective use of verbal and non-verbal communication and social skills to children and adolescents with social anxiety, as well as support interaction between peers. Training sessions could involve practising a wide range of social and communication skills while simultaneously allowing individuals to work according to their own abilities in preparation for real-life scenarios. The robot would play the role of a friendly playmate during one-to-one sessions and a mediator in group sessions. Table 3.2 describes this scenario.

Scenario 2: Simulating Social Situations: This scenario is proposed to provide exposure to various social scenarios (e.g., conflict resolution, starting conversation, small talk, public speaking, job interview, etc.) and help participants develop comfort and appropriate communication and interaction skills within these contexts. Both the robot and the participant would engage in a role-play [399, 188], where the robot would act as a coach/instructor in this scenario and offer an interactive rehearsal of such social situations to improve participants' skills and confidence in similar social situations. Table 3.3 describes this scenario.

Table 3.2: Scenario 1 - Game of Social Skills

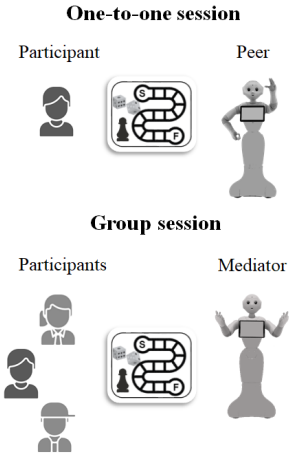
Target Group	Children and adolescents
Role of the Robot	Peer or friendly playmate in one-to-one sessions. In group sessions, the robot would presume the role of a mediator and provide positive reinforcement to the group.
Role of the Participant	Learner
Activity Description 	In individual sessions with a robot and a clinician, the youth could learn different social skills and the most effective way to implement them. In this psychoeducation stage, the social robot could model the social skills for the participant. After psychoeducation, the robot and the participant would engage in a one-to-one game with rules. In the game, the robot and the participant would use a dice to arrive at different locations on a game board that corresponds to particular social skills that the participant needs practice in. Upon arriving at a location on the game board, the party who rolled the dice would perform the social skill specified for that location. Based on the inherent difficulty of each social skill, a score would be allotted to the skill. Higher scores would be allotted for successfully performing more complex social skills. The party with the most points wins the game.
Place/Setting	Home, school or clinic
Level of Difficulty/ Variations	Within a group context, youth would engage in the same board game with peers in a robot-mediated group intervention session. In this context, the robot is no longer an individual playmate, but instead could be a mediator for the group, supporting all members in practising and demonstrating successful interaction skills. This variation would be useful for participants who have completed the individual sessions with the robot as a playmate.
Potential Benefits	With the incorporation of a social robot, youth may be able to learn different social skills in an engaging manner during psychoeducation. Social robots interact in simple and predictable manners, which offer an opportunity to practise social skills without fear of the complexity of human-human interaction and perceived scrutiny of others. With repeated practice, children may develop increased confidence such that they are more willing to engage in social interactions in real life.

Table 3.3: Scenario 2 - Simulating Social Situations

Target Group	Children, adolescents and adults
Role of the Robot	Coach or instructor that would rehearse with a participant simulated versions of feared social situations.
Role of the Participant	Performer
Activity Description	This activity could involve practising complex social skills in simulated social situations. Before the beginning of this activity, participants would be asked to list feared situations in a hierarchy, beginning with least feared to highly difficult. Then, the participant and the robot would engage in a simulation of a feared social situation. The social robot could be programmed to demonstrate specific verbal and nonverbal behaviours associated with the role. For example, if the simulated social situation is a job interview, the robot would presume the role of the interviewer. The robot could also provide verbal positive reinforcement to encourage participants and build their confidence.
Place/Setting	Home, school or clinic
Level of Difficulty/ Variations	Participants would start with contexts seen as easier on their list and move upwards to more difficult contexts once they demonstrate mastery and report comfort. The ultimate aim would be for participants to engage in these scenarios in real life. That is, the work with the social robot would provide lower levels of hierarchy, and as the participant masters these, real-life scenarios would be attempted.
Potential Benefits	Through this activity, participants could learn to tolerate and see themselves engaging successfully within various situations within a controlled setting. They could try out and experience themselves demonstrating social and communicative behaviours within typically anxiety-provoking social situations with the social robot as many times as needed in order to become comfortable and confident, such that they can then practise the learned behaviours in the 'real world'. For younger participants, the social robot could provide a progress report at the end of each session, which the youth could view later to understand areas that need further improvement or those that they are performing well in.



Table 3.4: Scenario 3 - Monitoring Thoughts and Feelings

Target Group	Children, adolescents and adults
Role of the Robot	Coach or instructor that would engage participants in cognitive restructuring activities.
Role of the Participant	Performer
Activity Description	In this activity, after a clinician has provided psychoeducation regarding thought monitoring and cognitive restructuring, the social robot could be used by a participant to support these activities outside of the sessions. That is, through a structured conversation with the social robot, the participant could reflect on challenging social situations that happened during the day and identify aspects associated with the situation (e.g., details on the thoughts, feelings, behaviour). The robot could solicit participants' views on connections between these aspects and provide encouragement throughout. For those participants who did not experience a social situation (due to isolation), the robot and participant could role-play an envisioned social situation during which the participant could be asked to imagine what they might be thinking/feeling and how they might respond. In this way, possible biased ways of thinking could be elucidated in the absence of social activity. Following, the robot could ask questions that prompt the participant to evaluate the certainty of such thoughts, possibility of alternate, balanced, thoughts, and corresponding feelings with the balanced thought. Transcripts of the interactions could be recorded such that the clinician and participant could review them during the session to identify themes as well as challenges with the task.
Place/Setting	Home, school or clinic
Level of Difficulty/ Variations	As participants are more able to engage in identifying and modifying thoughts, the degree of social robot guidance would be minimized (e.g., fewer number of questions). As well, during role-plays, the robot could be programmed to cue the participant to use previously generated balanced thoughts or coping statements.
Potential Benefits	Homework assignments, such as tracking thoughts are common within CBT. A social robot could support and guide clients outside of the therapeutic context. Moreover, for individuals who are socially isolated, there may be limited opportunities to engage with others, so creating additional interactions with a social robot may be advantageous as a starting point for practising cognitive restructuring activities.

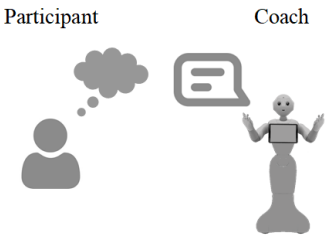
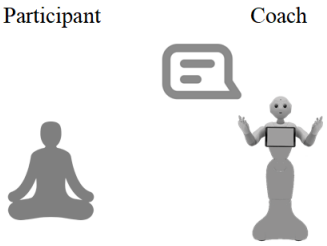


Table 3.5: Scenario 4 - Practising Mindfulness

Target Group	Adolescents and adults
Role of the Robot	Coach or instructor that would model different mindfulness strategies for the participant.
Role of the Participant	Learner
Activity Description	This scenario would begin with a general introduction to stress and social anxiety management. During the psychoeducation stage of this scenario, the participant could learn about different mindfulness exercises, such as regulated breathing. After the psychoeducation stage, the social robot and the participant would engage in a card game. In the card game, the participant would select a card that lists one of the common physiological symptoms experienced by people with social anxiety disorder. The robot would suggest and model a mindfulness exercise based on the selected card, and then the robot and the participant could practise that exercise. In order to track the effectiveness of the exercises, robots could provide feedback on a client's physiological signs using sensory data (e.g., Galvanic Skin Response (GSR), Electrocardiogram (ECG), body temperature, etc.) available from wearable sensors.
Place/Setting	Home, school, clinic or work environments
Level of Difficulty/ Variations	This activity could be performed in a group setting, where all the participants take turns to select a card, and then the robot would model the mindfulness exercises. This variation would allow the participants to practise how to use different mindfulness exercises around other people. Further, the mindfulness exercises could be tailored to specific social situations. For example, the robot could teach the participant about mindfulness exercises that are most suitable when presenting in front of an audience.
Potential Benefits	With a social robot, participants would learn how to manage cognitions and physiological symptoms associated with anxiety through mindfulness exercises in an interactive manner. With the card game, they could practise different mindfulness exercises in a flexible and fun way. They would also have the opportunity to practise the mindfulness exercises in a repetitive manner. As a companion, the social robot could assist the participant with mindfulness exercises during engagement in feared social situations outside the clinical setting.



Scenario 3: Monitoring Thoughts and Feelings: This scenario aims to help participants identify and modify maladaptive or biased thoughts about feared social situations. In this scenario, the robot would act as a coach/instructor to support and guide clients outside of the therapeutic context. Table 3.4 describes this scenario.

Scenario 4: Practising Mindfulness: In this scenario, participants would learn to manage anxiety-provoking physiological symptoms (e.g., increased heart rate). The robot would act as a coach/instructor in this scenario, and would teach different mindfulness exercises. Table 3.5 describes this scenario.

3.7 Risks and Concerns for Social Robots in Clinical Practice

Despite their promising nature, we need to acknowledge several concerns surrounding the implementation of social robots in psychological practice. Here, we mention three crucial issues.

First, social robots lack human-level perception and decision-making skills, which are critical for sensitive practices, such as diagnosis and intervention. Both diagnosis and intervention entail systematically and sensitively collecting and integrating information about the individuals' history, social and cultural environments, and verbal and non-verbal behaviours. Social robots can be beneficial for gathering structured information; however, their utility may be reduced during unstructured sessions, given their limited ability to learn in real-time.

The second concern regarding social robots is related to the nature of the relationship and dependency that can develop between the social robot and the individual undergoing therapy [316]. While social robots might skillfully mimic emotions and affective responses using e.g., facial expressions, speech, body movements and gestures, they lack genuine human-like emotions and empathy [482]. Thus, long-term dependence on social robots may make it even more challenging for individuals to interact with other people, especially for highly vulnerable individuals. For example, in the context of social anxiety, the perceived discrepancy between the familiar social situation (interaction with robots) and the unfamiliar one (interaction with humans) may cause even greater anxiety. Forming relationships with and dependency on social robots raises serious ethical concerns. As Sherry Turkle ([482, p. 514]) put it, "is there a chance that human relationships will just seem too hard?". We have to remember that robots are not people, they are complex mechanical devices. "With robots, people are acting out 'both halves' of complex relationships,

projecting the robot's side as well as their own. Of course, we can also behave this way when interacting with people who refuse to engage with us, but people are at least capable of reciprocation" [482, p. 504-505]). Thus, for some individuals, relationships with robots might be appreciated because it is 'easy', while relationships with humans appear complicated and taxing. Nevertheless, human-robot relationships are *real*, so in the use of social robots in clinical practice, one has to avoid presenting technological solutions (robots or otherwise) as substitutes for human-human interaction and relationships. In fact, socially interactive robots could even emphasize this point during the interaction with individuals, e.g., by stating: "I'm here to help you, but I don't understand human emotions very well, I'm just a robot".

Third, using technology such as social robots raises concerns about psychological privacy due to disclosure of sensitive or intimate information, as well as data privacy and storage given the lack of transparency of complex technologies and data-driven algorithms, and the increasing reliance on cloud-based data processing [289]. Data privacy concerns are further exacerbated by the nonexistent legal landscape around the development and use of social robots [148]. Due to the aforementioned concerns, robust practitioner supervision and ethical guidelines for the development and use of social robots are necessary before social robots can be widely adopted in psychological practices.

3.8 Conclusions

In this work, we proposed social robots as tools to provide support to both children and adults with social anxiety disorders, with the aim to reduce barriers to treatment utilization and enhance effectiveness. Social robots are embodied agents that can interact in a non-judgmental, flexible, predictable, and engaging manner. In comparison to other forms of technological interventions, such as mobile health applications or virtual agents, these characteristics may offer several advantages to integrating social robots in conventional interventions for social anxiety. For example, the social robot's physical presence could create a rich interactive environment for individuals with social anxiety disorders, which may promote better engagement in activities associated with interventions. Furthermore, situations like COVID-19, which has presented new challenges such as maintaining a physical distance from others, may cause interruptions in delivering mental health care and particularly treatments such as exposure therapy [237]. Therefore, although this has to be shown empirically, the physical presence of social robots may fill such gaps, to some extent, and help reduce the negative impact of these situations.

In addition, the incorporation of social robots in conventional interventions has the

potential of functioning as a "stepping stone" for individuals with social anxiety, i.e., they could practise social skills and behaviours with a robot before applying their skills to human-human interaction. Engaging in social behaviours without the pressures of interaction with another person can add a novel (likely introductory) layer to treatments. Particularly, individuals with social anxiety who experience excessive fear of negative evaluations may have less tension and stress when they are interacting with a social robot, and the anxiety symptoms experienced during therapy might be more manageable for the individual [332, 333]. This has the potential to make the overall treatment experience more positive for the client. Social robots could also be personalized and adapted to provide the support most suitable for the individual client. However, considering the limited ability to learn and adapt to individual's needs in presently available, state-of-the-art social robots, significant advances in technology are still needed. Social robots could assume different roles depending on the specific context and user needs. Specifically, social robots could provide clients the benefit of repeated practice and build their confidence through positive feedback. While we have discussed this approach for individuals with social anxiety, certainly, social robots could also be used for individuals who are below the threshold for a diagnosis of social anxiety disorder, but experience some difficulties and distress when participating in social situations.

Incorporating social robots in interventions for social anxiety disorder may not only benefit clients but also clinicians. Social robots can assist clinicians in a variety of therapeutically relevant functions, such as coaching or instructing clients through tasks, providing feedback, assisting with treatment adherence, performing repetitive tasks, and monitoring symptoms and treatment progress. Social robots also offer the advantage of providing interventions in a controlled manner. For example, clinicians, if provided with an easy-to-use interface to program the robot, could control, change, or modify the robots' behaviours and functions for a specific client and scenario.

Social robots may be particularly useful for aspects of the targeted intervention that include many repetitive steps, which would allow clinicians to focus on the overall process of the treatment and concerns specific to the individual. Social robots can be integrated into therapeutic interventions, taking advantage of the strength of social robots (e.g., providing non-judgmental, reliable engagement) with the strength of clinicians who possess deep expert knowledge, as well as the required understanding of human nature in general, and social anxiety in particular. The latter cannot be provided by social robots. Overall, social robots could offer a new way of delivering interventions. They are not meant to be substitutions for human therapists, rather, social robots should be used as tools to extend and enhance the support provided by clinicians.

To the best of our knowledge, this is the first work proposing the incorporation of so-

cial robots in the current conventional CBT approaches for social anxiety. To illustrate the potential applications, we outlined several scenarios and acknowledged possible risks that need to be considered carefully. Note, future research in the application of social robot interventions for social anxiety disorder is needed, and the scenarios we proposed in this chapter, intended as 'food for thought' for the research community and interested researchers, certainly will need to be re-developed and finalized through user-centred and co-design, prototyping, implementation and a series of empirical testing, redevelopment and user feedback, e.g., as it was done in [394]. The goal of this work is to promote exploration and future empirical work and interdisciplinary collaborations to advance the field of robot-assisted mental health interventions in order to benefit clients and clinicians, improving mental health and well-being of those in need.

Chapter 4

Study 1: University Students' Opinions on Using Intelligent Agents to Cope with Stress and Anxiety in Social Situations

4.1 Introduction

Over the past decade, rising rates of mental health problems such as stress, anxiety, and depression have been reported among college and university students [283, 193, 34, 281]. Many students face overwhelming stress and anxiety when participating in different activities and interacting with peers, which can affect their performance and mental well-being. However, many do not seek or receive help [134, 133]. Intelligent agents can offer the possibility of delivering health and mental well-being interventions with the aim of extending and complementing mental health interventions and increasing accessibility. Recognizing that there are many further steps to developing user-centred evidence-based approaches for mental health challenges, as a first step to developing effective interventions using intelligent agents, it is important to identify design elements and functionalities that are perceived as engaging and useful by students.

In this chapter, we present the findings of two online surveys, a pilot study using Amazon Mechanical Turk and a larger study at the University of Waterloo to explore students' perceptions of, and preferences for, using different types of intelligent agents (e.g., virtual agents, social robots, etc.) to support their mental well-being, specifically to

cope with feelings of stress and anxiety in social situations typically encountered within a university context (e.g., engaging in a group discussion, delivering presentations, expressing opinions, etc.). Although these social situations can be considered normal encounters in a student's life, the level of stress and anxiety that individuals experience in such social situations ranges on a continuum. At one end of the continuum is optimal functioning, where an individual feels able to cope with stressors and challenging situations. Moving along the continuum, individuals may experience increased stress and anxiety symptoms, such as nervousness or discomfort in social situations, but can still function relatively well in their daily lives. At the other end of the continuum, an individual may experience severe stress and anxiety in social situations, leading to avoidance of such situations and impairment in their ability to function in various life domains. These individuals may meet the criteria for social anxiety disorder [13], which has been shown to be a rapidly growing condition among young people [210].

Adopting the view that individuals' experiences of stress and anxiety in social situations differ across the continuum, the focus of this study is not solely on those who experience severe symptoms of stress and anxiety in social situations; rather, we want to explore a range of university students' experiences. In this way, the importance of early intervention and prevention strategies to promote mental well-being and prevent the progression of mental health concerns is acknowledged.

The main contribution of this work is to provide insights into how to design intelligent agents as assistive tools to help students manage their stress and anxiety by exploring university students' preferences on different social, technical and design elements that should be taken into account when developing such intelligent agents.

4.2 Research Questions

This work was exploratory in nature, rather than testing specific hypotheses, and was guided by the following research questions (RQs).

RQ2-1 To what extent do students report experiencing stress and anxiety in various social situations within an academic context?

RQ2-2 What do students report as their preferred type of intelligent agent for potentially helping them manage their anxiety related to their most anxiety-provoking social situation?

RQ2-3 What activities do students endorse as being potentially beneficial for managing their anxiety related to their most anxiety-provoking social situation within an academic context, and for which of those activities are they willing to use an intelligent agent?

RQ2-4 What characteristics and factors do students think are important in an intelligent agent for supporting mental well-being?

RQ2-5 What types of data would students allow an intelligent agent to record to help address their most anxiety-provoking social situation? For example, would students allow an intelligent agent to recognize and keep track of their emotional states and/or moods (e.g., using external sensors, wearable sensors, or mobile/smartphones)?

By exploring these research questions, we aim to gain insights into the features and functionalities that should be considered when designing a user-centred intelligent agent for promoting students' mental well-being.

4.3 Methodology

We created the survey questions through an iterative process, where the questions were iteratively reviewed and revised by different team members with different academic backgrounds. This study was approved by the University of Waterloo Human Research Ethics Board (see Appendix A.1). Once participants read the information page and provided consent, they were directed to the online survey implemented on Qualtrics[1], which is a platform commonly used in designing online surveys. This study had three steps, as below:

Step 1 - Demographics questionnaire: Participants were asked to complete a demographic questionnaire asking about their age, identified gender, current academic program (degree), primary faculty, current year in the program, as well as how long they lived in Canada[2], and whether they live alone or with others. All questions were presented as multiple-choice questions, except for age and gender, which participants responded to in text boxes. The participants also had the option of skipping any demographic question that they preferred not to answer.

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

[2] At the time of the survey students could study either remotely or on campus. For participants recruited using Amazon Mechanical Turk, we were limited to recruiting individuals residing in the US. Therefore, the question was modified to ask about US.

Step 2 - Definition of intelligent agents: Participants received a definition of different intelligent agents[3] along with visual examples of various types of intelligent agents (i.e., conversational agents, virtual agents, animal-like robots, humanoid robots, and other types of robots that are not humanoid or animal-like). The presented agents were of different appearances, sizes, etc., to ensure that no specific example would bias participants' choices. For instance, as examples of humanoid robots, we showed pictures of three robots with different appearances, sizes, and degrees of freedom: Pepper[4], NAO[4], and QT[5].

Step 3 - Opinion on intelligent agents questionnaire: Participants were asked to respond to questions regarding (a) their experiences of stress and anxiety in social situations. Social situations were selected to be those commonly experienced in academia. Participants were also asked about (b) their opinion of the important characteristics of an intelligent agent in supporting mental well-being (see Table 4.1 for a list of the characteristics explored in this question). We also asked other questions regarding students' preferences towards the use of intelligent agents, including (c) their preferences for different types of intelligent agents to help them cope with stress and anxiety related to their most anxiety-provoking social situation, (d) design factors and considerations that would make them more inclined to use an intelligent agent for helping with their most anxiety-provoking situation (Table 4.2 shows the examined design factors in this question), (e) the activities they believed would be beneficial for managing stress and anxiety and if they would be willing to use an intelligent agent for the activity/activities they selected, (f) types of data that participants would allow an intelligent agent to record, and (g) how they prefer such data to be gathered. Participants were asked to respond to questions about their preferences towards the use of intelligent agents according to their most anxiety-provoking social situation within a university context.

Participants' responses were in different formats depending on the question asked. We had open-ended questions, multiple-choice questions, and continuous scales.[6] For all survey questions, we provided the option of "prefer not to answer". In addition, we also had

[3]The provided definition of intelligent agents was as follows: "Intelligent agents can be physical robots, software agents (conversational agents such as Alexa), or virtual agents (which have a face and/or body) which can interact and communicate with people. They have some level of intelligence, i.e., have memory and can make decisions on their own."

[4]https://www.softbankrobotics.com

[5]https://luxai.com/

[6]Note, for some of the questions, we used continuous scales as it has been shown to be more beneficial than other methods such as Likert scales [152]. We implemented our own continuous scales using HTML and JavaScript in accordance with recent findings about scale design that reduces bias (e.g., see [303]). To answer these questions, participants were presented with a bar with incremental values, and they slid a point on the bar to indicate their selection.

an option "other (please specify)" along with a text box, allowing participants to provide their own responses or preferences beyond the items specified in the question. We used a modified version of the questionnaire that was introduced in our pilot study (see Appendix A.2 for the demographics questionnaire used in the pilot study). Modifications were made, including reformatting some questions (e.g., demographics questions) to make them appropriate for university students at the University of Waterloo (see Appendix A.3 for the demographics questionnaire used in the study at the University of Waterloo). Survey questions are provided in Appendix A.4

Table 4.1: Characteristics affecting user acceptance related to the adoption of intelligent agents

Characteristics	Source
Learning and adapting its behaviours	Heerink et al. [187]; Rzepka and Berger [407]
Perceive, understand, and express emotions	Bishop et al. [59]; Luxton and Hudlicka [290]; Ghafurian et al. [159]
Recognizing users	Ghafurian et al. [160]
Understanding conversations	Rzepka and Berger [407]
Engaging in conversations	Luxton and Hudlicka [290]; Ling et al. [279]
Telling jokes	Nijholt [331]; Niculescu et al. [329]; Niculescu and Banchs [330]; Olafsson et al. [338]; Oliveira et al. [339]
Playing games	Johnson et al. [218]; Garrido et al. [157]
Making eye contact	Ruhland et al. [403]; Admoni and Scassellati [4]; Kompatsiari et al. [249]

4.4 Study 1.1: Pilot Study

4.4.1 Participants

We recruited 122 participants using the Amazon Mechanical Turk platform. We used the Premium Qualifications options on Mechanical Turk and used "US Bachelor's Degree" as a premium qualification.[7] This qualification is only available in the US, and therefore we could not recruit participants from other countries.

[7]Note that based on the description of this qualification available, it should enable Mechanical Turk "Requesters" to recruit "Workers" who already have a US Bachelor's Degree, and there is currently no qualification (either free or premium) for recruiting students. However, the qualification does not seem to

Table 4.2: Design factors affecting user acceptance related to the adoption of intelligent agents

Factors	Source
Adaptability	Heerink et al. [187]; De Graaf and Allouch [121]
Intelligence	Bartneck et al. [33]
Ease of use	Heerink et al. [187]; De Graaf et al. [120]; Ling et al. [279]
Companionship	Lee et al. [267]; De Graaf and Allouch [121]
Social Intelligence	Luxton and Hudlicka [290]
Users' enjoyment	Heerink et al. [187]; Jin [217]; De Graaf and Allouch [121]; Ling et al. [279]
Effectiveness	Rzepka and Berger [407]; Diederich et al. [127]
Efficiency	Rzepka and Berger [407]; Diederich et al. [127]
Users' engagement	Ke et al. [230]; David et al. [116]
Not requiring much maintenance	Ghafurian et al. [160]
Technical soundness	Ghafurian et al. [160]

Furthermore, to acquire more reliable responses, we limited the availability of our task to those with an approval rate higher than 97%, who had completed at least 100 Amazon Mechanical Turk tasks. After one round of data collection (82 participants) and based on the demographics results that we got (i.e., all non-students whose data should have been removed were over the age of 25 years), we limited participation to those who were younger than 25 years old.[8] The Study took about 10-15 minutes. Participants received $3 USD ($2 base rate plus a bonus of $1) for completing all steps of the study. Participants could stop at any point during the study and were remunerated for the number of questions they answered in addition to the base rate ($2 USD). Their data was removed afterwards.

The data of 11 participants were omitted due to missing data. The data of 26 participants were removed as, according to their self-declarations, they were not students at the time of the study. Our key aim was to gain insights into the experiences and opinions of participants who *currently* are students, so we had to exclude those 26 participants. This left 85 participants (26 female, 59 male; age range: [20,51], mean: 27.6 yrs). This sample included 42 undergraduate students, 34 Master's students, and 9 Ph.D. students.

work as it is intended, and actually, the majority of the participants who met this qualification were students (undergraduate or graduate students). As this was the best option we had for maximizing the chance of recruiting students, we used this qualification and only kept the data from those who self-identified in our questionnaire as students.

[8]Similar to the other premium qualification, this did not work as intended according to the MTurk specifications.

The study received ethics clearance from the University of Waterloo Human Research Ethics Board (see Appendix A.1). Participants were made aware of the minimal risk of getting upset due to some questions referring to anxiety and its effects on personal and professional experiences. All participants were given the option to skip questions or to stop participation at any point. They also received a resource list including the contact information of available mental health services in the US, such as "Ok2Talk". Participants' familiarity with each intelligent agent is presented in Figure 4.1.

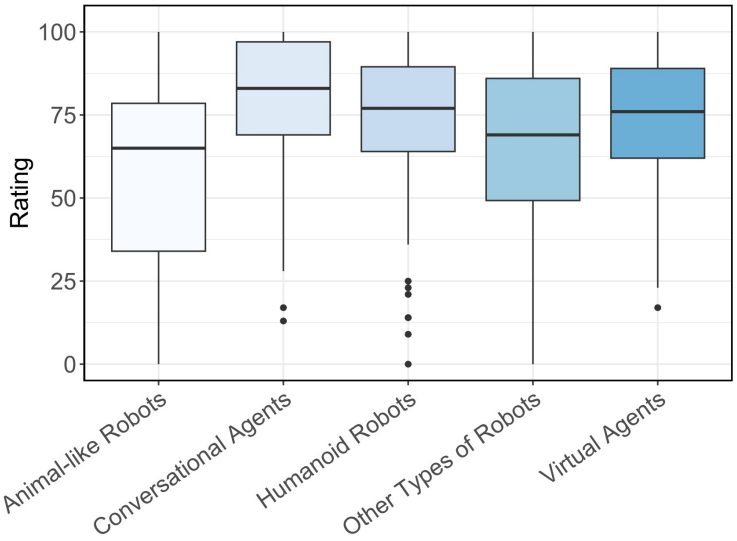


Figure 4.1: Students' familiarity with different intelligent agents

4.4.2 Results

Here, we present the results regarding the above-mentioned research questions.

RQ2-1: Experience of Anxiety or Stress in Social Situations

This study was not intended to diagnose anxiety or stress among students, thus, students were only asked to rate (i.e., self-report) the level of anxiety or stress they experience in social situations on a five-point ordinal scale ranging from "never" to "very often". Results show that 45.9% of participants reported that at least "sometimes" they experience anxiety or stress in social situations (13 female and 26 male), and "sometimes" was selected

significantly more than all other options (significance ranging from $p < .01$ to $p < .0001$, measured through binomial tests). In addition, 8.24% and 11.76% of participants reported "often", and "very often" experiencing anxiety or stress in social situations, respectively. Figure 4.2 shows the results for undergraduate and graduate students, i.e., 42 undergraduate students and 43 graduate students (34 master's students, and 9 Ph.D. students).

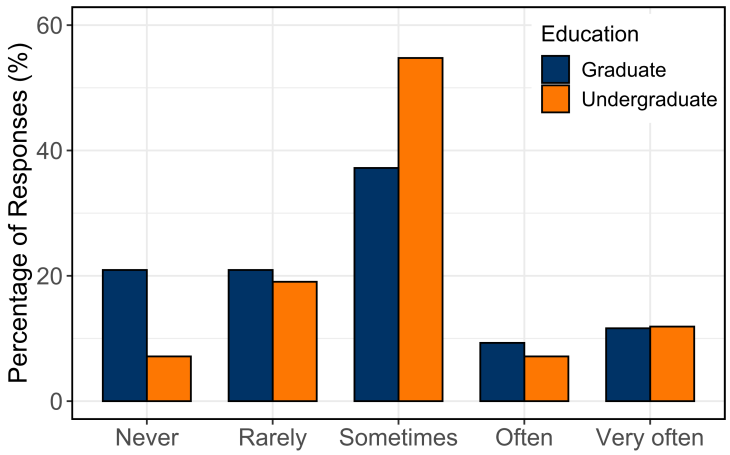


Figure 4.2: Percentage of undergraduate and graduate students experiencing anxiety or stress in social situations

RQ2-1: Most Anxiety-Provoking Situations

To identify students' most anxiety-provoking situations, a multiple-choice question was used. Choices included a variety of anxiety-provoking situations in the university context, such as meeting new people, having an interview, going to social events, taking exams, expressing opinions, public speaking, speaking up in meetings or classes, and performing in front of other people. These choices were inspired by [432, 404, 13] and the participants could select at most three choices to respond to this question. We also provided an "other" option where the participants could input other possible situations (note that none of the participants selected this option). Figure 4.3 shows the most anxiety-provoking situations that the participants indicated to have experienced during their studies. "Participating in meetings or classes", "meeting new people", "communicating at meetings", and "participating in group discussion", were the most frequently selected responses, respectively, with no significant differences between them, and all were selected significantly more than 11

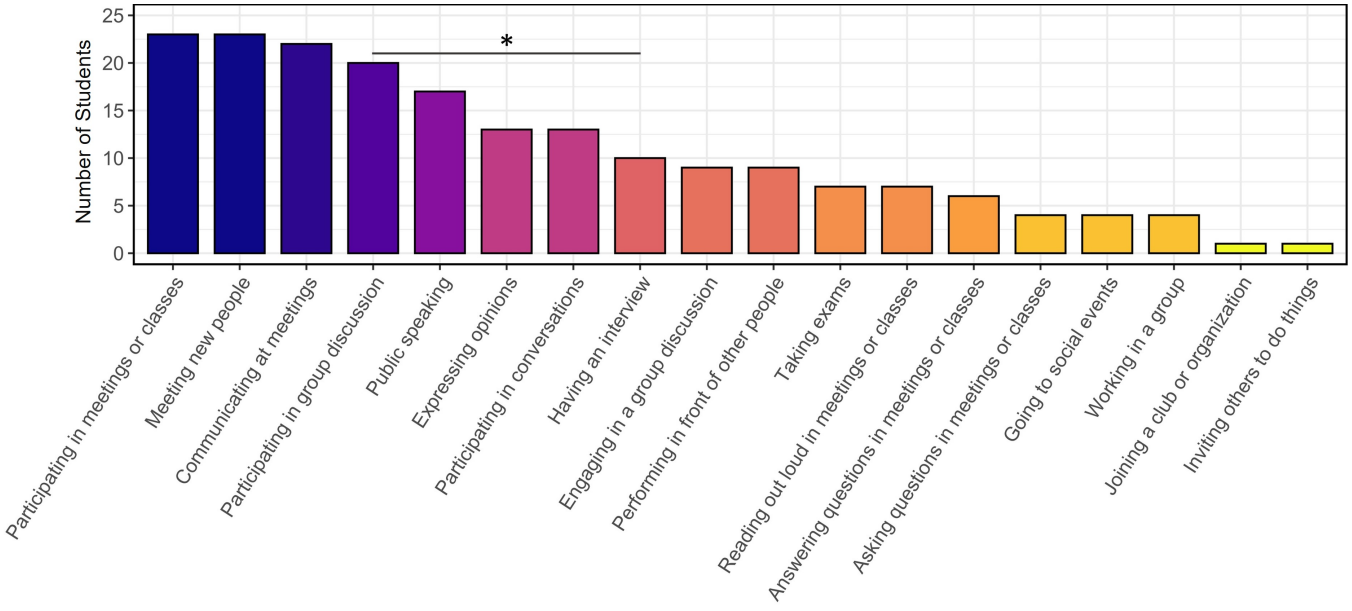


Figure 4.3: Most anxiety-provoking situations. * = $p < .05$ (measured through binomial tests).

other situations (see Figure 4.3) (significance ranging from $p < .05$ to $p < .0001$, measured through binomial tests).

RQ2-2: Preference for Type of the Agent

To answer RQ2, we investigated participants' preferences towards the use of intelligent agents and asked what types of intelligent agents participants preferred to use in order to assist them with their most anxiety-provoking situations. The question was provided as a multiple-choice question and the participants could choose more than one option. Figure 4.4 shows participants' preferences towards the type of agent, categorized based on low levels of anxiety (i.e., rarely, sometimes) versus high levels of anxiety (i.e., often, very often). Both high and low anxiety groups reported preferences for "human-like robots" and "conversational agents", respectively. Collapsed across anxiety groups, the choice "humanoid robots" was selected the most, followed by "conversational agents (e.g., Siri, Bixby, Alexa)" and "animal-like robots"; however, the difference between these three types of agents was not significant. The "humanoid robots" was selected significantly more than the "virtual agents" and "other types of robots that are not humanoid or animal-like" ($p < .05$, measured through binomial tests). The effect sizes, as measured by Cohen's h,

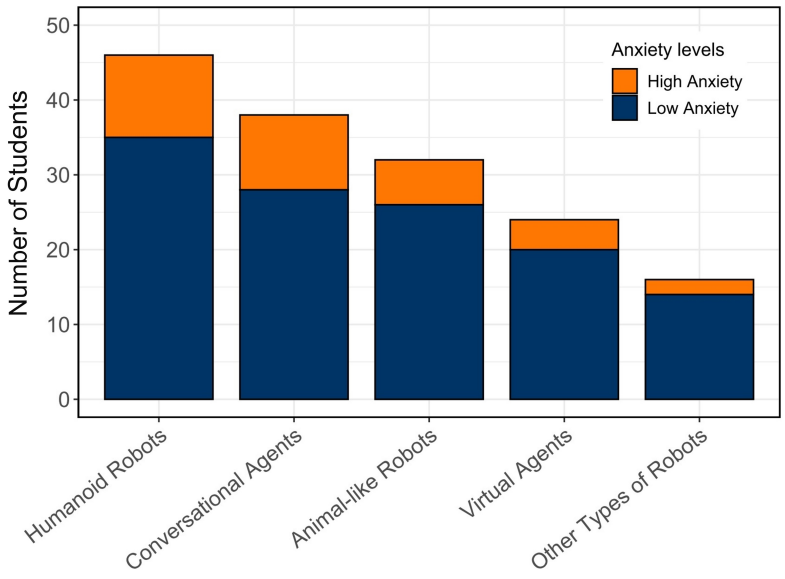


Figure 4.4: Participants' preferences for different types of intelligent agents.

were $h = .64$ and $h = 1.01$, respectively. "Other types of robots that are not humanoid or animal-like" was selected significantly less than "conversational agents" and "animal-like robots" (significance ranging from $p < .05$ to $p < .0001$, measured through binomial tests). "Virtual agents" was also selected significantly less than "humanoid robots" ($p < .01$) and "conversational agents" ($p < .05$, measured through binomial tests).

RQ2-3: Preferred Activities for Managing Anxiety

To inform the decision on the function of intelligent agents in this context, we also asked participants which activities they believed would be beneficial for managing stress and anxiety and they would be willing to use an intelligent agent for. The options were inspired by the activities discussed in [380], and participants were able to choose more than one activity. Types of activities and results are shown in Table 4.3. Options such as "receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation, yoga, journaling, healthy diet, and sleeping behaviours)", "receiving social skills training (e.g., how to communicate and engage with other people)" and "getting help with building confidence (e.g., through positive affirmations)" were selected more often than the other activities. The first two activities were selected significantly more than all

Table 4.3: Activities for which, according to the participants, intelligent agents would be beneficial for managing anxiety

	Activities	**Frequency**
	Receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation, yoga, journaling, healthy diet, and sleeping behaviours).	33
	Receiving social skills training (e.g., how to communicate and engage with other people).	28
	Getting help with building confidence (e.g., through positive affirmations).	25
	Receiving personalized psycho-education (e.g., providing education and information about the condition to those seeking or receiving mental health services for it).	15
	Getting help with thinking calming or positive thoughts.	12
	Monitoring and tracking mood changes and providing feedback on my progress.	11
	Practising social skills via role plays (e.g., practising public speaking).	10
	Receiving daily reminders to keep users on track with activities that support mental well-being.	6
	Receiving companionship (e.g., conversational partner).	3
	Receiving extrinsic motivation to achieve academic success.	3
	None of these activities.	2
	Pleasurable activities to improve mental well-being (e.g., playing games, dancing).	1

other options except for getting help with building confidence (significance ranging from $p < .05$ to $p < .0001$, measured through binomial tests). The difference between these first two activities was not significant. The effect sizes, as measured by Cohen's h, ranged from $h = .77$ (comparing "receiving personalized coaching for activities and tasks that support mental well-being" with "receiving personalized psycho-education") to $h = 2.45$ (comparing "receiving personalized coaching for activities and tasks that support mental well-being" with "pleasurable activities to improve mental well-being").

RQ2-4: Important Characteristics for an Intelligent Agent

Figure 4.5 shows the ratings for the important characteristics of an intelligent agent for supporting mental well-being as rated by the participants. The selection of important characteristics was inspired by previous studies discussed in Table 4.1, and continuous scales were used for the ratings. The agent's ability to "recognize persons (e.g., recognizing the user)", "understand conversations", "engage one in conversations", and "learn and adapt its behaviour according to users' needs/preferences" received higher ratings than the other characteristics ($p < .05$, measured through t-tests). The effect sizes, as measured by

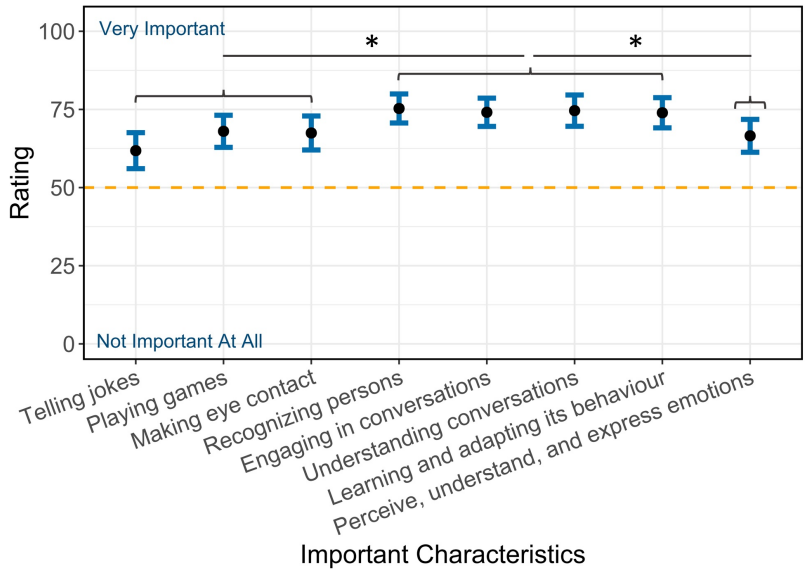


Figure 4.5: Ratings regarding important characteristics for an intelligent agent. Error bars indicate 95% confidence intervals. $^* = p < .05$ (measured through t-tests).

Cohen's d, ranged from $d = .33$ (comparing "ability to recognize persons (e.g., recognizing the user)" with "ability to play games") to $d = .56$ (comparing "ability to recognize persons (e.g., recognizing the user)" with "ability to tell jokes").

We did not find any significant differences between these four characteristics; however, there were significant differences between these four characteristics and the ability to "tell jokes", "play games", "make eye contact", and "perceive, understand, and express emotions" (significance ranging from $p < .05$ to $p < .001$, measured through t-tests).

RQ2-4: Important Factors Motivating the Use of Agents:

Literature suggests a variety of factors that would influence user experience and adaption of intelligent agents (e.g., [136]). Hence, in this study, participants were asked to rate the importance of factors that would make them more inclined to use an intelligent agent for managing anxiety related to their most anxiety-provoking social situations, the selection of which was inspired by previous works (see Table 4.2). The factors were rated on a continuous scale from "not important at all" to "very important".[9] As shown in Table 4.6,

[9]Explanations were presented for each item used in the question to make sure participants understood the meaning of the terms in this context, e.g., "efficiency: how efficient the agent is in helping you in

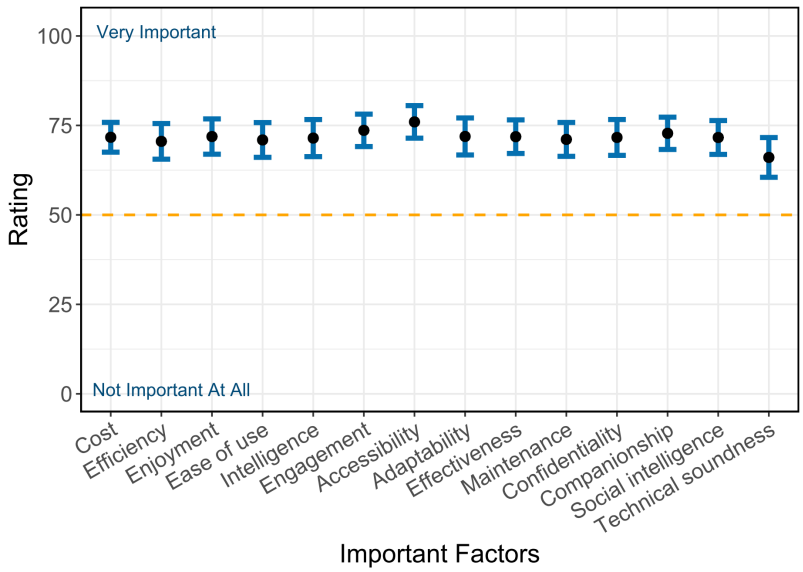


Figure 4.6: Ratings regarding important factors motivating the use of agents. Error bars indicate 95% confidence intervals.

factors including "accessibility: how easy it is for you to access it", "engagement: how well you can engage with it" and "companionship: if it is capable of acting as a companion for you (e.g., generates feelings of support or connection in a social and personalized manner)" received slightly higher ratings than the other factors. However, there were no significant differences among the three factors. Nevertheless, the fact that all factors received an average rating of over 60 (in a range from 0 being 'not important at all' and 100 being 'very important') shows the importance of all of these factors for the potential adoption of an intelligent agent.

RQ2-5: Preferences for Data Collection

We asked participants about the types of data they would allow an intelligent agent to record to help address their most anxiety-provoking social situation (see Figure 4.7). Participants could select multiple choices. While many participants indicated that they would allow their voice and video to be collected even if they are not interacting with the agent, the most preferred type of data to be collected by an agent was "voice, only when interacting with the agent", which was selected significantly more than the last four options shown

designated tasks" or "effectiveness: if there is evidence of effectiveness to improve mental well-being".

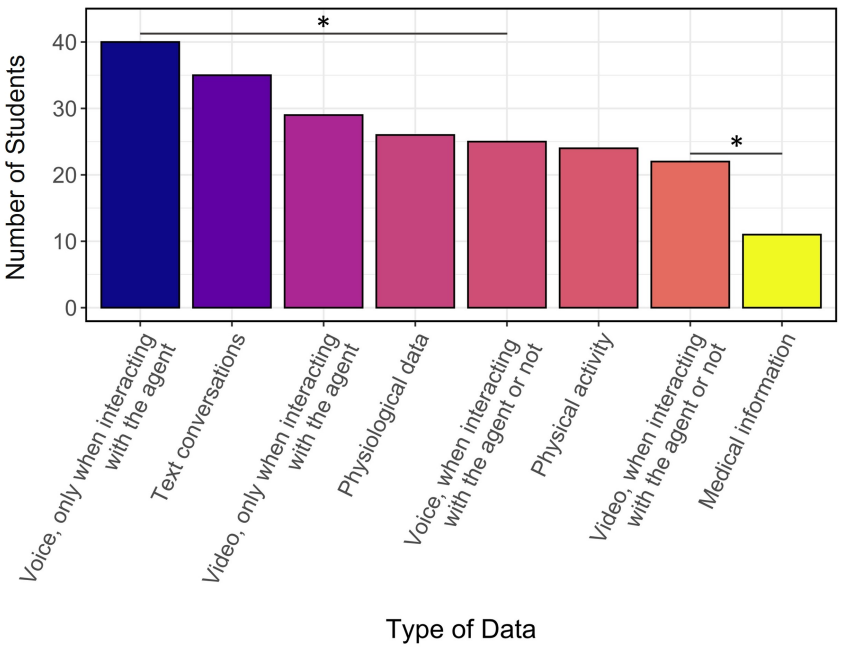


Figure 4.7: Types of data that participants would allow an intelligent agent to record. * = $p < .05$ (measured through binomial tests).

in Figure 4.7 (e.g., "my voice, regardless of whether I am interacting with the intelligent agent or not", "physical activity", "my video, regardless of whether I am interacting with the intelligent agent or not"; $p < .05$ to $p < .0001$; significance was calculated through binomial tests). The effect sizes, as measured by Cohen's h, ranged from $h = .46$ (comparing "voice, only when interacting with the agent" with "my voice, regardless of whether I am interacting with the intelligent agent or not") to $h = 1.01$ (comparing "voice, only when interacting with the agent" with "medical information"). "Medical information" was selected significantly less than all other types of data ($p < .05$ to $p < .0001$).

We also asked whether participants would like an intelligent agent to recognize and keep track of their emotional states and/or moods to help address their most anxiety-provoking social situation (e.g., using external sensors, wearable sensors, or mobile/smartphones). Their responses were as follow: "yes": (48.24%); "no": (28.24%); "maybe (it depends)": (20%); "prefer not to answer": (3.53%). Results showed significant differences between "yes" responses, and "no" or "maybe" responses ($p < .05$, measured through binomial tests), suggesting that it would be accepted and preferred for such intelligent agents to keep track of users' emotional states.

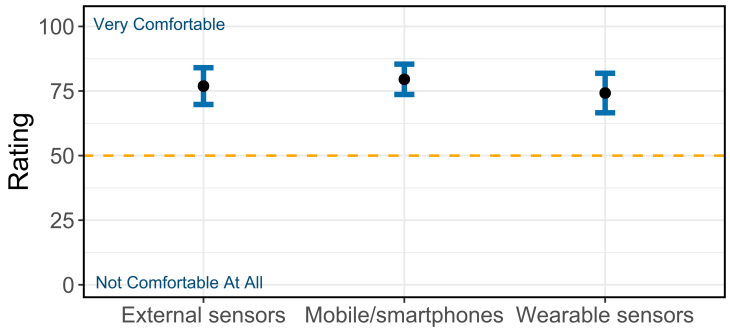


Figure 4.8: Ratings regarding different methods for an intelligent agent to gather data on emotional states and moods. Error bars indicate 95% confidence intervals.

As a follow-up question, we asked participants who responded "yes" to the question above (41 participants), how comfortable or uncomfortable they would be with an intelligent agent monitoring and tracking their emotional states and moods using (a) external sensors (e.g., camera, microphone), (b) wearable sensors, and (c) a mobile/smartphone, in order to identify the best method for an intelligent agent to gather such data. Ratings on continuous scales are shown in Figure 4.8. All methods received an average rating above 70 (ratings ranging from 0 to 100), and we could not detect any significant differences. This suggests that any of these methods have the potential to be considered in this application domain.

4.5 Study 1.2: A Large Scale Study at University of Waterloo

4.5.1 Participants

We recruited 1263 undergraduate students [10] at the University of Waterloo through email. The survey email containing information about the study, the duration of the study, and

[10]This study aimed to recruit graduate and undergraduate students, following the approved protocols at the University of Waterloo. Thus, we followed a different method to recruit graduate students and created a web page with study details. This web page was promoted through Graduate student e-news, which was emailed to about six thousand graduate students weekly for two months. However, only 21 graduate students were recruited, and due to the significant difference between the numbers of graduate and undergraduate participants, the data of 21 graduate students were removed from the analysis.

a link to the survey was emailed twice, one week apart, to undergraduate students on our behalf by the University of Waterloo Registrar's Office, which is responsible for coordinating survey requests to undergraduate students. A total of 209 participants' data were removed due to missing data. This left 1054 participants (579 who identified as woman/trans woman, 413 who identified as man/trans man, 30 who identified as non-binary, and 32 participants who preferred not to indicate a gender; age range: $[17, 36], M = 19.62, SD = 4.92 yrs$). Participants' familiarity with each intelligent agent is presented in Figure 4.9, showing a high level of familiarity with conversational agents and much lower familiarity with other types of intelligent agents. While students showed a preference for animal-like robots followed by conversational agents, it is worth noting that these two options represent opposite ends of the familiarity spectrum. Consequently, it did not appear worthwhile to investigate any correlation in the results.

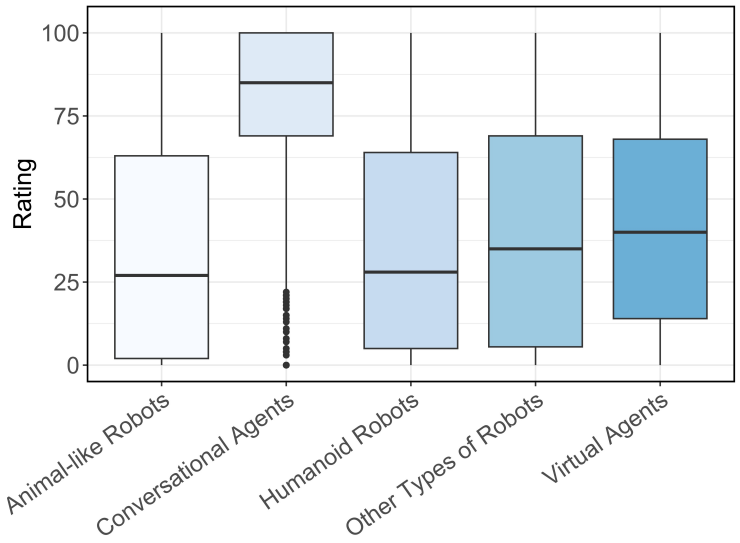


Figure 4.9: Students' familiarity with different intelligent agents

This study was approved by the University of Waterloo Human Research Ethics Board (see Appendix A.1). The study was an anonymous survey, and participation was entirely voluntary. Note we identified a minimal risk that some of the questions about experiences of anxiety and its effects on personal and professional experiences might upset participants. Participants were made aware of this potential risk in the consent form and were provided with a list of available mental health services at the University and via telehealth. Participants were informed that they could decline to answer any questions they did not wish to answer and they could withdraw their participation at any time by not submitting their

responses and closing their web browsers. After receiving ethics clearance, since the survey was going to be administered to more than 500 potential respondents at the University of Waterloo, the Institutional Analysis and Planning (IAP) unit, on behalf of the Survey Advisory Committee (SAC), also reviewed the survey questions and approved them.[11] The study's duration was about 10-15 minutes. We did not provide monetary remuneration, but we included a video bonus for those who completed the study, where they learned about different social robots available in our lab and their functionalities.

4.5.2 Results

Participants' demographic characteristics are provided in Table 4.4. In the following, we present the results regarding our research questions.[12]

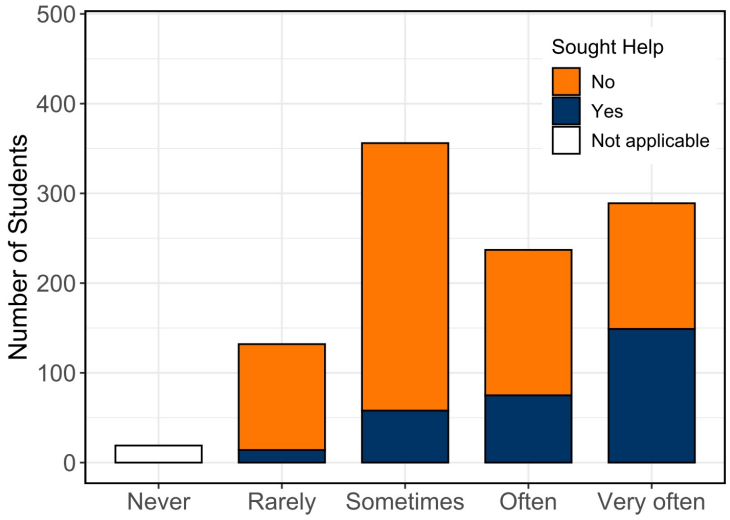


Figure 4.10: Self-reported experience of anxiety or stress in social situations

[11]The University of Waterloo IAP is responsible for the strategic administration, coordination, and use of surveys on campus as part of its commitment to continuous improvement.

[12]With regard to the multiple choice questions asked to explore university students' perceptions of and preferences regarding the use of intelligent agents as assistive tools to address their stress and anxiety in social situations, we focused on the students' most frequently reported preferences.

Table 4.4: Demographic Characteristics

Characteristic	Count n (Percent %)	Experiencing Anxiety (n)(%)*		
		Rarely to Very often	Sometimes to Very often	Very often
Gender				
Woman/Trans woman	579 (54.93)	575 (99.31)	521 (89.98)	196 (33.85)
Man/Trans man	413 (39.18)	398 (96.37)	320 (77.48)	76 (18.40)
Non-binary	30 (2.85)	30 (100)	30 (100)	12 (40)
Prefer not to answer	32 (3.04)	32 (100)	30 (93.75)	10 (31.25)
Primary faculty				
Arts	210 (19.92)	210 (100)	188 (89.52)	65 (30.95)
Engineering	221 (20.97)	217 (98.19)	188 (85.07)	58 (26.24)
Environment	52 (4.93)	51 (98.08)	45 (86.54)	20 (38.46)
Health	76 (7.21)	74 (97.37)	68 (89.47)	24 (31.58)
Mathematics	270 (25.62)	261 (96.67)	213 (78.89)	54 (20)
Science	225 (21.35)	222 (98.67)	199 (88.45)	73 (32.45)
Current year in the program				
Year 1	386 (36.62)	375 (97.15)	332 (86.01)	105 (27.20)
Year 2	271 (25.71)	264 (97.42)	229 (84.50)	75 (27.67)
Year 3	221 (20.97)	220 (99.55)	191 (86.42)	77 (34.84)
Year 4	136 (12.90)	136 (100)	116 (85.29)	29 (21.32)
Year 5 or more	36 (3.42)	36 (100)	29 (80.56)	6 (16.67)
Prefer not to answer	4 (0.37)	4 (100)	4 (100)	2 (50)
Living in Canada				
All my life	669 (63.47)	658 (98.36)	582 (87)	203 (30.34)
Less than 1 year	70 (6.64)	66 (94.29)	57 (81.43)	15 (21.43)
Between 1 and 5 years	111 (10.53)	111 (100)	94 (84.68)	28 (25.23)
Between 6 and 10 years	48 (4.55)	37 (77.08)	31 (64.58)	11 (22.92)
More than 10 years	153 (14.52)	151 (98.69)	126 (82.35)	35 (22.88)
Prefer not to answer	3 (0.28)	3 (100)	3 (100)	1 (33.33)
Living alone				
Yes	179 (16.98)	178 (99.44)	159 (88.83)	122 (68.16)
No	853 (80.93)	836 (98.01)	722 (84.64)	624 (73.15)
Prefer not to answer	22 (2.09)	21 (95.45)	20 (90.91)	14 (63.64)

* The reported levels of anxiety overlap.

RQ2-1: Experience of Anxiety or Stress in Social Situations

Students were asked to rate the level of anxiety or stress they experience in social situations common in academic context on a five-point ordinal scale ranging from "never" to "very often" (see Figure 4.10). The purpose of this question was to ensure that participants had some experience to draw from when reflecting on questions that asked about anxiety. Participants who indicated "never" were not asked the follow-up questions regarding their "most anxiety-provoking" situation. Note that questions regarding experiences of anxiety were not intended to provide any diagnostic information, and the results are solely based on the participants' self-reported experience of stress and anxiety in social situations. As can be seen in Figure 4.10, the survey results revealed that 19 students reported "never" experiencing stress and anxiety in social situations, while 134 mentioned experiencing stress and anxiety "rarely". Furthermore, 361 students stated that they "sometimes" experienced stress and anxiety, while 246 and 294 students reported "often" and "very often" experiencing stress and anxiety in social situations, respectively. Among those who reported "very often" experiencing stress and anxiety, 149 (50.68%) students have sought help from a counsellor, therapist, doctor, or any other healthcare professional to help them deal with the anxiety or stress experienced during social situations.

RQ2-1: Most Anxiety-Provoking Situations

To address this research question, students were asked to answer a multiple-choice question that included a variety of social situations common in academic contexts, such as speaking up in meetings or classes, public speaking (e.g., giving a verbal report or presentation to a group), meeting new people, going to social events, having an interview, expressing opinions, taking exams, and performing in front of other people. The choices of this question were inspired by [432, 404, 13]. Students were able to select at most three social situations in which they experience the most anxiety and stress. Figure 4.11 shows the most anxiety-provoking situations that the students indicated to experience during their studies. Binomial tests were performed to study whether the differences were significant. "Public speaking (e.g., giving a verbal report or presentation to a group)" was selected significantly more than all other options (significance ranging from $p < .01$ to $p < .0001$). The effect sizes, as measured by Cohen's h, ranged from $h = .17$ (comparing "public speaking" with "having an interview") to $h = 2.20$ (comparing "public speaking" with "working in a group"). "Having an interview" was the second selected anxiety-provoking situation, which was selected significantly other than the remaining choices ($p < .0001$). The effect sizes, as measured by Cohen's h, ranged from $h = .27$ (comparing "having an interview"

with "taking exams") to $h = 2.12$ (comparing "having an interview" with "working in a group"). "Taking exams", "meeting new people", "performing in front of other people" and "going to social events" were other situations that were selected significantly more often than the other 12 investigated situations ($p < .001$) with no significant differences between them. The effect sizes, as measured by Cohen's h, ranged from $h = .46$ (comparing "taking exams" with "engaging in a group discussion") to $h = 1.99$ (comparing "taking exams" with "working in a group").

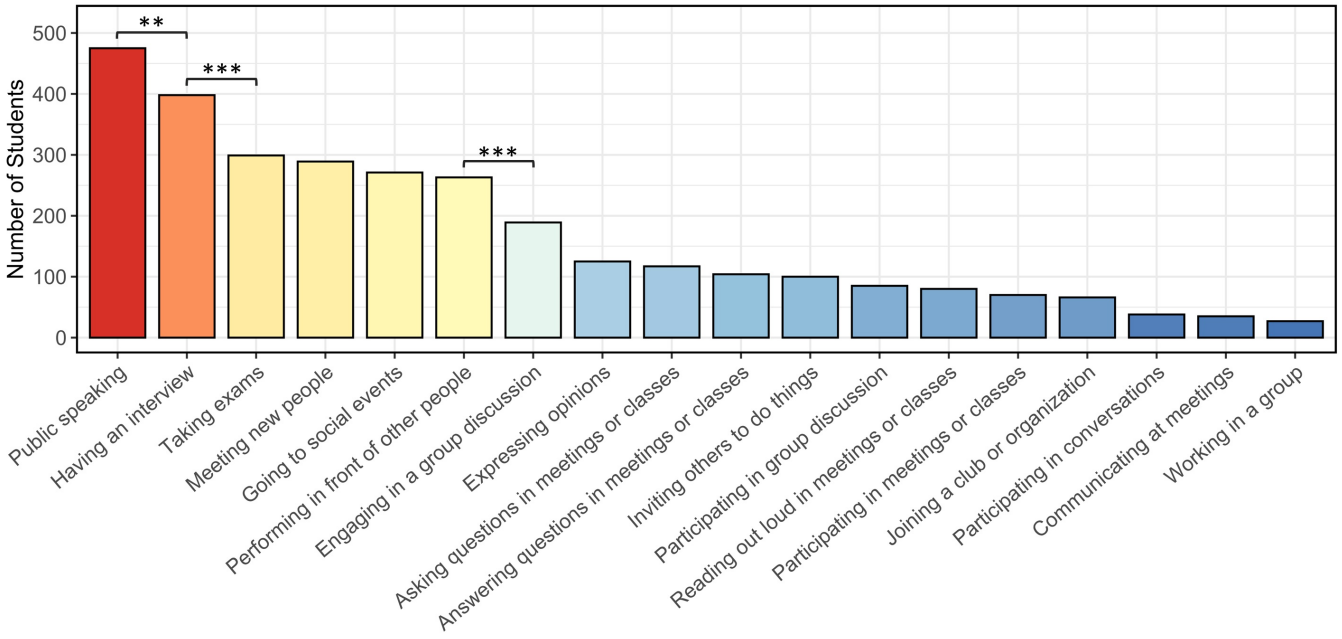


Figure 4.11: Students' most anxiety-provoking situations. The X-axis represents the social situations that participants could select from. $^{**}= p < .01$

We also asked participants if they experience stress and anxiety before being in their most anxiety-provoking situation (e.g., starting to feel anxious before they are scheduled to give a presentation). As can be seen in Figure 4.12, a significant number of participants 522 (50.43%) reported that they "very often" experience stress and anxiety before their most anxiety-provoking situation ($p < .0001$, measured through binomial tests). The effect sizes, as measured by Cohen's h, ranged from $h = .61$ (comparing "very often" with "often") to $h = 2.49$ (comparing "very often" with "never").

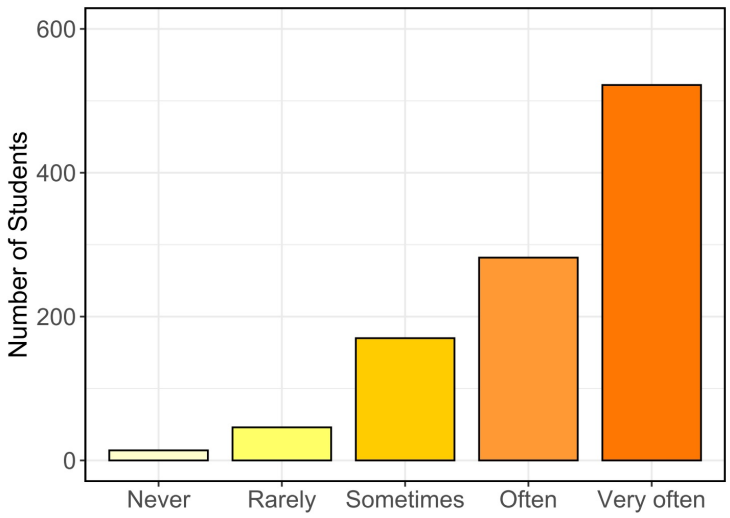


Figure 4.12: Self-reported experience of anxiety or stress before anxiety-provoking situations

RQ2-2: Preference for Type of Agent

To investigate students' preferences towards the use of intelligent agents, we asked participants to select intelligent agent(s) that they would prefer to use for managing anxiety related to their most anxiety-provoking social situation. The question was presented as a multiple-choice question, and the choices included conversational agents (e.g., Siri, Bixby, Alexa), virtual agents, humanoid robots, animal-like robots, and other types of robots that are not humanoid or animal-like. Participants could choose more than one option to answer this question. Figure 4.13 shows students' preferences towards the type of agent, categorized based on low levels of anxiety (i.e., rarely, sometimes) versus high levels of anxiety (i.e., often, very often). Both high and low anxiety groups reported preferences for "animal-like robots" and "conversational agents", with no significant differences between groups in their preferences. Collapsed across anxiety groups, participants preferred "animal-like robots" and "conversational agents (e.g., Siri, Bixby, Alexa)" more than the other types of intelligent agents ($p < .001$, measured through binomial tests). The difference between these two agents was not significant. The effect sizes, as measured by Cohen's h, ranged from $h = .27$ (comparing "animal-like robots" with "humanoid robots") to $h = 1.16$ (comparing "animal-like robots" with "other types of robots that are not humanoid or animal-like"). Moreover, "humanoid robots" was selected significantly more

than "virtual agents" and "other types of robots that are not humanoid or animal-like" ($p < .0001$). As measured by Cohen's h, the effect sizes were $h = .33$ and $h = .92$, respectively. Finally, results showed that "other types of robots that are not humanoid or animal-like" was selected significantly less than all other intelligent agents ($p < .0001$). The effect sizes, as measured by Cohen's h, were $h = .61$ (comparing "other types of robots that are not humanoid or animal-like" with "virtual agents") and $h = 1.16$ (comparing "other types of robots that are not humanoid or animal-like" with "animal-like robots").

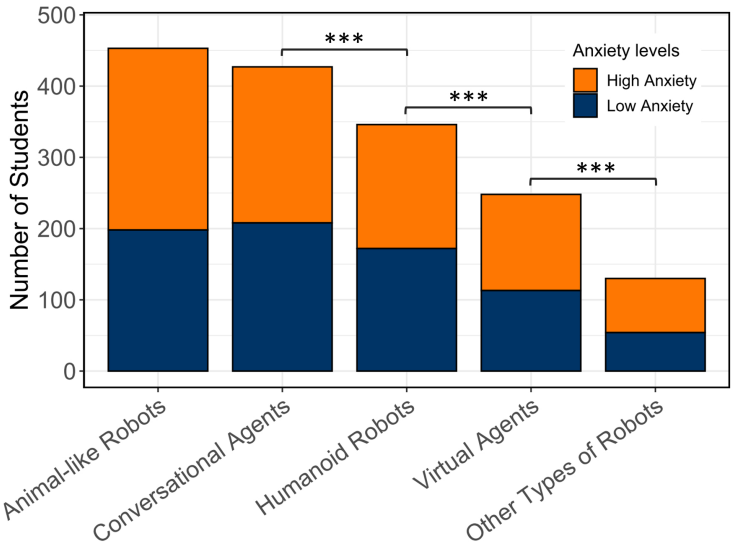


Figure 4.13: Students' preferences for types of intelligent agents. The X-axis represents the types of agents that participants could select from. *** = $p < .001$.

RQ2-3: Preferred activities for Managing Anxiety

To answer RQ3, students were asked to select activities they believed would be beneficial for managing stress and anxiety related to their most anxiety-provoking social situation, and which they would be willing to use an intelligent agent for. The options were inspired by the activities discussed in [189, 400, 380] and participants could choose more than one activity. Table 4.5 shows types of activities and results for this question. Activities including "receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation, yoga, journaling, healthy diet, and sleeping behaviours)" was selected significantly more than all other options except for "getting help with thinking

Table 4.5: Activities for which, according to the participants, intelligent agents would be beneficial for managing anxiety

Activities	**Frequency**
Receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation, yoga, journaling, healthy diet, and sleeping behaviours)	**337**
Getting help with thinking calming or positive thoughts	**335**
Getting help with building confidence (e.g., through positive affirmations)	**299**
Receiving daily reminders to keep me on track with activities that support mental well-being	294
Monitoring and tracking mood changes and providing feedback on my progress	292
Receiving companionship (e.g., conversational partner)	252
Receiving personalized psycho-education (e.g., providing education and information about the condition to those seeking or receiving mental health services for it)	245
Receiving extrinsic motivation to achieve academic success	206
Practising social skills via role plays (e.g., practising public speaking)	205
Pleasurable activities to improve mental well-being (e.g., playing games, dancing)	203
Receiving social skills training (e.g., how to communicate and engage with other people)	194
None of these activities	69

calming or positive thoughts" and "getting help with building confidence (e.g., through positive affirmations)" ($p < .05$, measured through binomial tests). The effect sizes, as measured by Cohen's h, ranged from $h = .14$ (comparing "receiving personalized coaching for activities and tasks that support mental well-being" with "receiving daily reminders to keep me on track with activities that support mental well-being") to $h = 1.44$ (comparing "receiving personalized coaching for activities and tasks that support mental well-being" with "none of these activities").

RQ2-4: Important Characteristics for an Intelligent Agent

To inform the selection of the important characteristics for an intelligent agent in supporting students' mental well-being, we asked participants to rate the importance of each

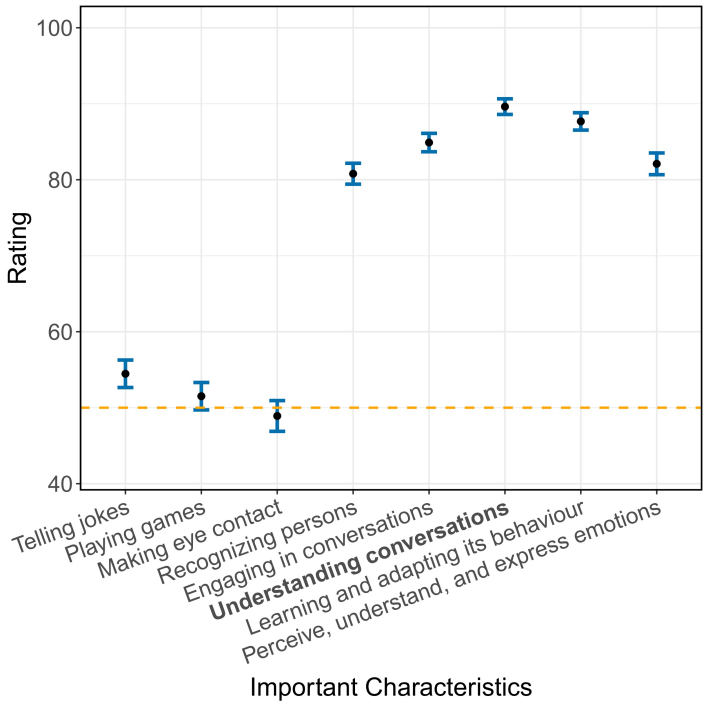


Figure 4.14: Ratings regarding important characteristics for an intelligent agent. The X-axis represents the choices given to the participants. Error bars indicate 95% confidence intervals.

characteristic on a continuous scale from 0 being "not important at all" to 100 being "very important" (see Figure 4.14). The agent's "ability to understand conversations" received higher ratings than all other characteristics (significance ranging from $p < .01$ to $p < .0001$, measured through t-tests). The effect sizes, as measured by Cohen's d, ranged from $d = .12$ (comparing "ability to understand conversations" with "ability to learn and adapt its behaviour according to the user's needs and preferences") to $d = 1.73$ (comparing "ability to understand conversations" with "ability to make eye contact"). "Ability to learn and adapt its behaviour according to the user's needs and preferences" was the second highest rated characteristic ($p < .001$). The effect sizes, as measured by Cohen's d, ranged from $d = .16$ (comparing "ability to learn and adapt its behaviour according to the user's needs and preferences" with "ability to engage in conversations") to $d = 1.61$ (comparing "ability to learn and adapt its behaviour according to the user's needs and preferences" with "ability to make eye contact"). "Ability to make eye contact" received significantly lower ratings than all other characteristics (significance ranging from $p < .05$ to $p < .001$). The

effect sizes, as measured by Cohen's d, ranged from $d = .10$ (comparing "ability to make eye contact" with "ability to play games") to $d = 1.73$ (comparing "ability to make eye contact" with "ability to understand conversations").

In addition, we conducted a comparison between participants with low levels of anxiety (i.e., rarely, sometimes) and high levels of anxiety (i.e., often, very often) in terms of their ratings on agents' ability to make eye contact. The result of the t-test did not reveal a significant difference in ratings of participants with low anxiety levels ($M = 50.32, SD = 29.98; 95\%CI[47.37, 53.26]$) compared to participants with high anxiety levels ($M = 48.29, SD = 29.25; 95\%CI[45.47, 51.12]), p = .33$.

RQ2-4: Important Factors Motivating the Use of Agents

Students were asked to rate the importance of factors that would make them more inclined to use an intelligent agent for managing anxiety related to their most anxiety-provoking social situations (on a continuous scale from 0 being "not important at all" to 100 being "very important").[13] As shown in Figure 4.15, "confidentiality: if it is able to maintain the confidentiality of your data" received significantly higher ratings than all other factors ($p < .0001$, measured through t-tests). The effect sizes, as measured by Cohen's d, ranged from $d = .20$ (comparing "confidentiality" with "accessibility") to $d = .80$ (comparing "confidentiality" with "companionship"). "Accessibility: how easy it is for you to access it" is the second factor that has been rated more than the other factors (significance ranging from $p < .05$ to $p < .0001$), except for "enjoyment: how much you enjoy interacting with it" ($p = .31$). The effect sizes, as measured by Cohen's d, ranged from $d = .10$ (comparing "accessibility" with "engagement") to $d = .67$ (comparing "accessibility" with "companionship").

Nevertheless, the fact that all factors received an average rating of over 68 (ratings ranging from 0 to 100) highlights the importance of all of these factors for the adoption of an intelligent agent.

RQ2-5: Comfort with Data Collection

We asked participants about types of data that they would allow an intelligent agent to record to help address their most anxiety-provoking social situation. The question was

[13] We provided explanations for each item used in the question to ensure participants understood the meaning of the terms in this context, e.g., "effectiveness: if there is evidence of effectiveness to improve mental well-being" or "efficiency: how efficient the agent is in helping you in designated tasks".

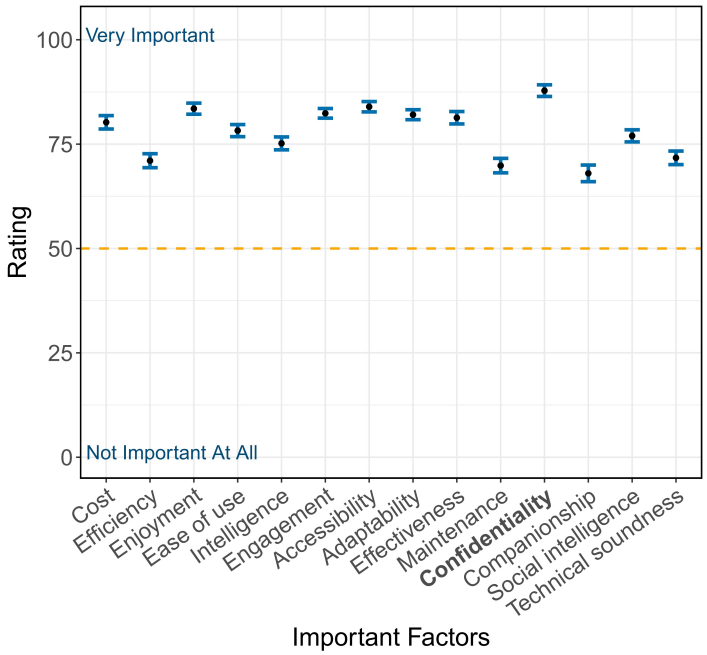


Figure 4.15: Ratings regarding important factors motivating the use of agents. The X-axis represents the choices given to the participants. Error bars indicate 95% confidence intervals.

presented as a multiple-choice question. Figure 4.16 shows types of data that participants could select from and results for this question. Participants could select multiple options (e.g., both audio and video when interacting with the agent). Preferred types of data to collect by intelligent agents were "voice, only when interacting with the agent", and "physiological data (e.g., heart rate, blood pressure)", which were selected significantly more than all other options in Figure 4.16 ($p < .001$; significance was calculated through binomial tests). The difference between these two selected types of data was not significant. The effect sizes, as measured by Cohen's h, ranged from $h = .20$ (comparing "voice, only when interacting with the agent" with "physical activity") to $h = 1.81$ (comparing "voice, only when interacting with the agent" with "video, when interacting with the agent or not"). Besides, "physical activity", "medical information (e.g., allergies, medical conditions, health provider's contact information)", and "text conversations" were selected significantly more than other types of data, including "video, only when interacting with the agent", "voice, when interacting with the agent or not", and "video, when interacting with the agent or not" ($p < .001$), with no significant difference between them. The effect

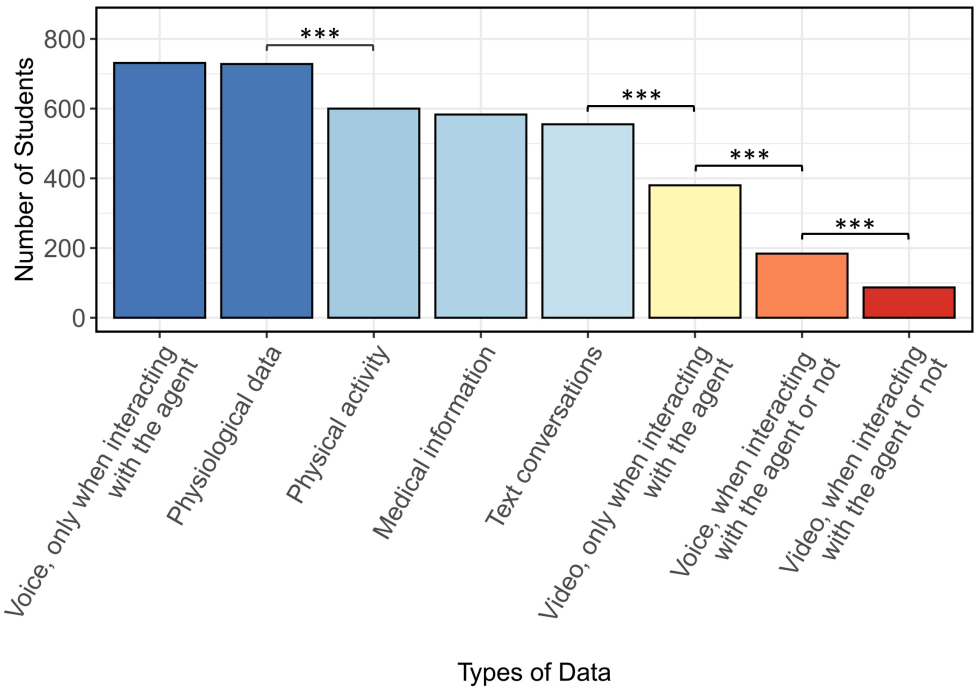


Figure 4.16: Types of data that participants would allow an intelligent agent to record. The X-axis represents the choices that participants could select from (except for "other"), and the Y-axis shows the number of participants who selected each choice. *** = $p < .001$.

sizes, as measured by Cohen's h, ranged from $h = .45$ (comparing "physical activity" with "video, only when interacting with the agent") to $h = 1.69$ (comparing "physical activity" with "video, when interacting with the agent or not"). "Video, when interacting with the agent or not" was selected significantly less than all other options ($p < .001$). The effect sizes, as measured by Cohen's h, ranged from $h = .73$ (comparing "video, when interacting with the agent or not" with "voice, when interacting with the agent or not") to $h = 1.81$ (comparing "video, when interacting with the agent or not" with "voice, only when interacting with the agent").

We also studied if participants would allow an intelligent agent to recognize and keep track of their emotional states and/or moods to help address their most anxiety-provoking social situation (e.g., using external sensors, wearable sensors, or mobile/smartphones). Their responses were as follows: "yes": 381 (36.81%); "maybe (it depends)": 482 (46.57%); "no": 93 (8.99%); "prefer not to answer": 79 (7.63%). Results showed significant differences between the "maybe" responses, and "yes" or "no" responses ($p < .001$; measured

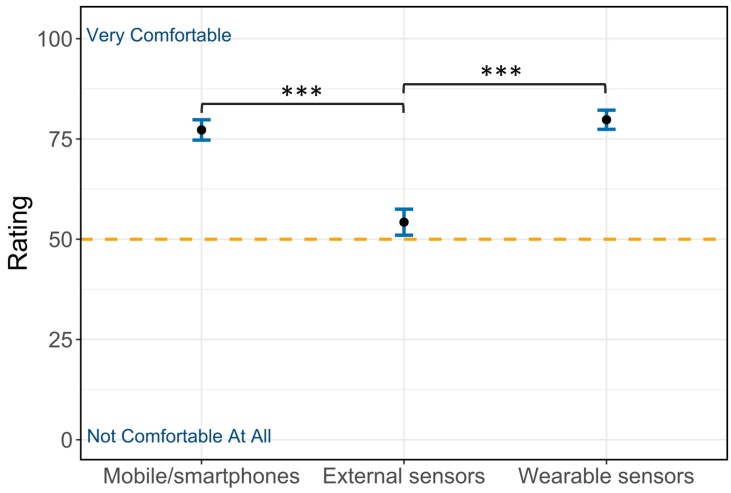


Figure 4.17: Ratings regarding different methods for an intelligent agent to gather data on users' emotional states and moods. Error bars indicate 95% confidence intervals.*** = $p < .001$.

through binomial tests). The effect sizes, as measured by Cohen's h, were $h = .22$ and $h = 1.45$, respectively. However, "yes" responses were selected significantly more than "no" responses ($p < .0001$). The effect size, as measured by Cohen's h, was $h = 1.27$.

As a follow-up question, we asked participants who responded "yes" to the above question (388 participants), how comfortable or uncomfortable they would be with an intelligent agent monitoring and tracking their emotional states and moods using (a) mobile/smartphones, (b) external sensors (e.g., camera, microphone), and (c) wearable sensors to record physiological data (e.g., heart rate), to identify what would be the best method for an intelligent agent to gather such data. Ratings on continuous scales are shown in Figure 4.17. All methods received an average rating above 50 (ratings ranging from 0 being "not comfortable at all" to 100 being "very comfortable"). According to the results of t-tests, "wearable sensors" and "mobile/smartphones" received significantly higher ratings than "external sensors" ($p < .001$). The effect sizes, as measured by Cohen's d, were $d = 1.00$ (comparing "wearable sensors" with "external sensors") and $d = .90$ (comparing "mobile/smartphones" with "external sensors"). No significant difference was observed between the ratings received for "wearable sensors" and "mobile/smartphones".

4.5.3 Discussion

Given the growing prevalence of mental health problems among university students and barriers to accessing mental health service providers, it is important to find and evaluate innovative solutions to improving access to mental health interventions, especially for those who are unlikely to seek support through existing means. The available literature on the applications of intelligent agents such as social robots, conversational agents, and virtual agents in the mental health and well-being domain demonstrates the high potential of these agents as a viable solution to complement and expand the reach of existing mental health interventions (e.g., [422, 334, 317]).

In this study, we explored the preferences and perceptions of 1054 university students towards the use of intelligent agents (i.e., social robots, conversational and virtual agents) for mental health support. Previous research has documented a lack of user-centred design and not addressing the problems that users were concerned about as some of the contributing factors to low user engagement in digital mental health interventions [476]. This lack of user-centred design highlights the importance of considering the opinions and expectations of university students as a key target group in this context. The current study reflects a first step toward the user-centred design of an intelligent agent that could be used to assist university students in dealing with stress and anxiety related to social situations that may typically be encountered within a university context. Therefore, with the future aim of designing an intelligent agent to support university students' mental well-being, we surveyed university students, as prospective users, via an online study to gain insight into their preferences in using intelligent agents as assistive tools to help them manage their stress and anxiety (e.g., through developing coping strategies that are perceived to be helpful to use during anxiety-provoking situations). Our findings have the following practical, ethical and design implications for intelligent agents that aim to support university students' stress and anxiety.

Anxiety or Stress in Social Situations: Students' self-reported experiences of stress and anxiety in common social situations in academic contexts indicated that public speaking is the social situation in which the most stress and anxiety are experienced. These findings are consistent with previous research that has shown public speaking anxiety to be one of the prevalent social phobias among higher education students [30, 405, 131, 297]. As public speaking is a common academic activity and is essential for academic achievement and future career success, it is beneficial to provide university students with support such as education, activities, and practice to help them manage their anxiety in this context.

Type of Agent: Considering the type of agent and its appearance is important when designing AI-based interventions, as these factors can influence people's perceptions, expecta-

tions, experiences, and evaluation of an agent's behaviour and capabilities [401, 273, 461]. A recent systematic review on social robot-based interventions in the psychological domain has shown that several studies targeting anxiety disorders primarily used animal-like robots (e.g., Paro, Aibo) [130], which is grounded in the framework of animal-assisted therapy and its beneficial impact on reducing human anxiety levels and alleviating its symptoms (e.g., see [50]). Our results, with animal-like robots being selected more than other options, support the selection of animal-like robots for delivering interventions for reducing stress and anxiety for university students. Indeed, the presence of therapy dogs in university or college settings has been reported to significantly reduce students' self-reported anxiety levels [264, 448, 108]. The absolute non-judgmental acceptance of people by animals is a characteristic that might be especially appealing to those who experience stress or anxiety in social situations [88]. Likewise, in the mental health and well-being context, animal-like robots are designed to provide similar positive effects to real animals, including psychological comfort, stress and anxiety reduction, and social communication [50] without the challenges and concerns involved in working with live animals, such as the availability of specially trained animals, animal welfare concerns, and possible allergies to animals [367]. Nonetheless, despite the widespread use of animal-like robots in mental healthcare applications, they have limitations when more human-like verbal and non-verbal interactions (e.g., language, facial expressions, gestures etc.) are required.

Intelligent Agent-led Mental Well-being Practices: To fulfill the students' specific needs, it is important to explore their expectations regarding the potential functions that intelligent agents could perform in mental healthcare. Based on the findings of this research, students expressed preferences for receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation and yoga) and getting help with thinking calming or positive thoughts) to help them manage their stress and anxiety in social situations. In recent years, there has been a growing interest in designing and developing intelligent agents (i.e., social robots, virtual assistants, and conversational agents) acting as mental well-being coaches or instructors to monitor and engage users in several therapeutic or non-therapeutic activities to improve individuals' mental health and well-being. In this context, some of the past works have used different types of intelligent agents to deliver training and coaching on different psychological interventions, such as meditation and mindfulness practices (e.g., deep breathing, hatha yoga) [202, 428, 10], cognitive behavioural therapy techniques (e.g., cognitive restructuring training) [492], positive psychology [212] to help alleviate anxiety and depression symptoms and improve individuals' moods. However, further empirical studies are critical in this area to determine the long-term effectiveness of these interventions and how they can be most effectively integrated into existing mental health care systems.

Design Factors and Characteristics: The results pertaining to design factors have illustrated the significance of factors such as confidentiality and accessibility in mental well-being interventions. In the present study, students also indicated capabilities (e.g., "ability to understand conversations" and "ability to learn and adapt its behaviour according to the user's needs") as important characteristics in an intelligent agent for supporting mental well-being, which is also in line with past studies in other contexts [187, 407]. These findings have important implications for the design and implementation of intelligent agents aimed at supporting mental well-being. By understanding conversations and adapting to user needs, intelligent agents can provide a more natural and personalized experience, which could help improve user satisfaction and drive greater adoption of these systems. Nevertheless, ongoing research and development in the field of natural language processing are needed to improve speech recognition and speech output capabilities in intelligent agents for efficient verbal interactions.

It was, however, interesting to see that agents' ability to make eye contact was not considered as important as the other examined characteristics, while past studies have shown the positive impacts of the use of eye contact on human-agent interaction, such as increasing the perceived sociability of the agent, capturing and maintaining users' attention to the agent, and enhancing the users' engagement in the task they are performing with the agent, etc. [4, 249]. This result could have been affected by the nature of our study, namely that participants did not actually interact with the agents. Possibly, participants interpreted the question about eye contact by envisaging particular ways this could be implemented, e.g., that the intelligent agent would 'stare' at them, resulting in an uncomfortable situation. The effectiveness of eye contact in agents developed for this context needs to be evaluated further in future studies involving in-person human-agent interactions.

Data Collection and Privacy: Finally, we explored university students' concerns related to data privacy and data collection by agents that are designed to help address their most anxiety-provoking social situations. Interestingly, we received varying comfort levels related to the preferred data collection approach. For example, collecting data related to physical activity, medical information, and text conversations was found to be acceptable by more than half of the participants, with many students also agreeing to the video recording of interactions while interacting with the agents (36.7% of participants), or even at times without any interactions taking place (8.4% of participants). These results are interesting as generally different types of data can be beneficial in expanding the functionalities of intelligent agents, as well as in personalization of their interactions, and these results suggest that a large portion of intended users might be agreeable with sharing a large range of data.

Presently, there is a growing interest in using sensors in well-being applications to gather personalized data that can not be captured by intelligent agents (e.g., see [428, 10]). Notably, integrating specialized sensors capable of tracking emotional and physiological states presents a potential area for the future development of intelligent agents to support individuals in managing their stress and anxiety. As suggested by our research findings, wearable sensors and mobile/smartphone devices were preferred by students for the purpose of gathering such information. Of course, when data is collected, data privacy is of utmost importance and needs to be considered carefully by researchers and designers.

Connection with the Pilot Study: A related study was conducted on the Amazon Mechanical Turk platform as a pilot study [377], involving 85 graduate and undergraduate students within the USA. Results showed that, similar to the present study, many participants reported that they at least "sometimes" experience anxiety or stress in social situations. Besides, while "animal-like robots" were still among the top three preferred intelligent agents in the pilot study, "humanoid robots" were selected the most followed by "conversational agents", and "animal-like robots". This difference to the study conducted at the University of Waterloo is interesting, and future studies need to better compare preferences for animal-like robots and human-like robots, e.g., by providing in-person experiences and using platforms that can demonstrate both appearances and allow users to select their preferred platform. Similar to the present study, students showed preferences for receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation and yoga) to help them manage their stress and anxiety in social situations. Besides, all the discussed design factors received an average rating of over 60 (in a range from 0 being "not important at all" and 100 being "very important") by students in the USA. Moreover, in line with the findings of the present study on participants' preferences for data collection, "voice, only when interacting with the agent" was selected more often than the other options, however in the pilot study, recording "medical information" was selected significantly less than all the other options. Medical information is another factor that can contribute to the personalization of intelligent agents and, therefore, needs further investigation.

To summarize, the results of this study provide directions on the activities, important considerations, and type of agent to select when designing intelligent agents to deliver interventions for supporting university students. Understanding users' opinions in a user-centred design of technologies can be critical to their success, as they can help better understand users' specific needs and identify potentially engaging and effective features [265, 69, 175]. User-centred design is also suggested to positively influence users' engagement with technology-based mental health interventions and improve users' adherence to these interventions [345, 78]. This study presented a foundational step in the

development of intelligent agents as assistive tools to support university students' mental well-being. Our findings can help researchers in designing intelligent agents to deliver mental health interventions that are based on users' real needs as opposed to researchers' assumptions and help improve the acceptance of intelligent agents.

4.5.4 Implications for Design

In this study, we explored the importance of several characteristics and features when designing intelligent agents to deliver interventions for supporting university students. While we presented students' general priorities and preferences, incorporating the study's findings into the actual design of such agents will depend on several factors, such as the agent's role, the number of interaction sessions, and the context and setting of deployment (e.g., home or university, etc.). Therefore, although this study presented students' general preferences, design decisions (e.g., type of agent) may depend on multiple factors that need to be taken into consideration along with user preferences.

For instance, priorities for the selection of agents, characteristics, and data collection may change based on the selected activity: an agent that is a practice tool at a university to complement the work of a clinician (e.g., by practising relaxation techniques such as mindful meditation and progressive muscle relaxation) may not require recognizing individuals or collecting any data, whereas, an agent that is used to adapt to a user's behaviour, e.g., breathing behaviour when practising mindful meditation to adjust the pace of practices, would require collecting and analyzing the relevant data; however, it may still not need to recognize the user. If the interaction is designed to extend beyond a single session and requires tailored feedback on the individual's performance or progress across multiple interaction sessions, then the agent needs to recognize the user. Yet, IDs can be used instead of users' names or personal information.

Study settings could also influence these choices. For example, individuals may use these agents in their homes to receive personalized coaching on various activities that promote mental well-being (e.g., meditation, yoga, journaling, healthy diet, sleeping behaviours, etc.). In such cases where there is a single user, the agent may not require a formal identification of the user, however, an agent implemented in a setting with multiple users, such as at a university, may require to identify individuals prior to providing the activities.

Similarly, informed by users' preferences, the setting and agent's activity can affect the choice of agent. While animal-like robots were preferred over all other types of agents based on our findings, selection of agent type should also be made based on the agents' capabilities. For example, in the context of a public speaking coach where the agent might

need to demonstrate human-like skills, including verbal and non-verbal communication, animal-like robots may no longer be appropriate, and based on our results, humanoid robots (which were preferred over virtual agents) might be a suitable choice. On the other hand, if only verbal human-like communication is required (e.g., an agent helping with positive thoughts), based on our results, conversational agents could be a suitable choice as they were preferred significantly more than humanoid robots and virtual agents.

4.5.5 Limitations and Challenges

Our study had several limitations. First, we did not provide participants with a definition of stress and anxiety. Instead, we relied on participants' interpretations of these terms. Second, the selection of options for intelligent agents' design elements, characteristics and capabilities, as well as beneficial activities for managing anxiety were informed by previous studies in this field, and while participants were able to provide responses beyond the provided choices in all these questions, it is likely that some design elements or activities might have been missed. Related, the results may have been influenced by the provided choices.

Although the online survey used in this study enabled us to reach out to a large and heterogeneous[14] group of students, they were not able to interact directly with different agents when comparing them and providing opinions about them. This could have affected participants' choices, e.g., the participants relied on their own familiarity with and imagination of each agent's capabilities, appearances, etc., which could have affected the results. Therefore, we believe future research would greatly benefit from the direct interaction of participants with the proposed intelligent agents to obtain more informed feedback. However, it is important to note that administrating online or in-person questionnaire surveys to gather individuals' opinions is a well-established approach in human-agent interactions (e.g., see [410, 325, 31]). Despite their limitations, surveys serve as an initial step in understanding the perspectives and preferences of prospective users and reaching out to a large group of users, which is critical when designing or developing an intervention.

In addition, since participants voluntarily participated in this study, there might have been the risk of a self-selection bias in the recruitment. We hope that this bias, which is inherent in any user studies with participant volunteers, was reduced in our study due to the large and heterogeneous group of participants we recruited.

[14] A heterogeneous group of participants with respect to students' gender identities, ages, years in program, and faculty of study.

Finally, as it was not the focus of the study, we did not ask participants about other (non-intelligent agent) types of intervention delivery (e.g., bibliotherapy, workshops, individual or group counselling, etc.). Thus, we cannot compare perceptions of intelligent agents (and their perceived benefit) relative to other intervention approaches, nor predict if there would indeed be an adoption of these intelligent agents in practice above other approaches. Future work could involve in-person studies with an agent developed according to the results of this study, additional co-design sessions, and comparing preferences for, and reactions towards intelligent agents with other types of support.

4.5.6 Future Work

Although this study presented insights into university students' opinions about important characteristics of intelligent agents for supporting mental well-being, we have to acknowledge that the desirable characteristics of the agent may depend on the actual activity, setting, and context. Thus, in future research, these aspects can be explored in a more nuanced way to understand whether certain agent characteristics would be more or less engaging for specific activities, using in-person studies where the participants can interact with the agents with the opportunity to learn about participants' user experience and acceptance of those agents.

Moreover, there are different factors, such as students' age, gender, personality traits, education, cultural factors, etc., that may influence university students' preferences for using intelligent agents as assistive tools to cope with stress and anxiety in social situations. Through this survey, we ensured the recruitment of a large and heterogeneous group of participants; however, we did not analyze how each of these factors possibly affected the results (as it was beyond the scope of this study). Hence, future work should examine in further detail which of these factors might affect preferences for using intelligent agents and how this information would be beneficial in personalizing the behaviours of these agents to provide a solution for a diverse group of people with different backgrounds, preferences and needs.

Additionally, there is a growing body of literature highlighting the different roles that intelligent agents can serve, such as coach, companion, and mediator in mental health care interventions (e.g., see [367, 492, 317, 380, 23]). This flexibility can encourage employing intelligent agents in a variety of settings (e.g., home, university) and with a wide range of functionalities. However, selecting the right roles and implementing these agents effectively in each role are dependent on context as well as factors such as users' perceptions, preferences, and expectations of agents' design and functionalities, which calls for further empirical research in this area.

To summarize, the application of intelligent agents to support university students who experience stress and anxiety in social situations has received limited attention. Therefore, as a first step to understanding how to effectively implement relevant interventions using intelligent agents to support university students' mental well-being, we investigated students' opinions on intelligent agents as assistive tools for dealing with stress and anxiety in social situations that are common in academic contexts. Building on the findings of this exploratory study, our future work will involve conducting co-design sessions with both prospective users (i.e., university students) as well as experts and other stakeholders in the mental health and well-being domain to actively engage them in the design process of an agent delivering interventions to address stress and anxiety among university students. Subsequent studies then need to investigate the efficacy of such assistive, intelligent agents to support students' mental well-being.

4.6 Conclusions

This study presented a first step toward the user-centred design of intelligent agents for the purpose of supporting university students' mental well-being. We presented the findings of an online survey regarding university students' perceptions of and preferences for using intelligent agents to support their mental well-being, specifically to cope with feelings of stress and anxiety in typical social situations occurring at university. This study highlighted several characteristics (i.e., the ability to understand conversations and the ability to learn and adapt its behaviour according to the user's needs and preferences), factors and considerations (i.e., confidentiality, accessibility, enjoyment) that are important for the development of an intelligent agent to support students' mental well-being. The findings of this survey with students suggested that intelligent agents, such as social robots, might have the potential to support students' mental well-being (e.g., by offering activities and tasks such as meditation, yoga, healthy diet, or getting help with thinking calming or positive thoughts, etc.), as the students who had experienced anxiety showed willingness in using these agents for supporting their anxiety. Besides, a personalized coaching approach can be used to deliver these activities, and if designed appropriately (e.g., through co-design with prospective users and different stakeholders in this domain), these interventions have the potential to assist university students in developing effective coping strategies for managing stress and anxiety in social situations. For instance, mental well-being interventions can be designed to address university students' most anxiety-provoking situations, such as public speaking, having an interview, taking exams, etc., and to make these interventions more accessible to students, e.g., they can be made available on university campuses as a

starting point.

Significant technological advances are still required to effectively implement all the identified characteristics and factors in this study. Therefore, considering the different affordances and limitations of intelligent agents, it is imperative for agent designers and researchers in this context to carefully select intelligent agents based on mental well-being practices and applications, as well as users' specific needs, interests, and priorities in this context. They may also need to consider a trade-off, for example, between an intelligent agent, such as a social robot, that requires a certain level of maintenance but can provide a high level of social presence (e.g., see [267]) and engaging interactions (e.g., see [465]), compared to a conversational or virtual agent with lower social presence but which could be more accessible and affordable.

Chapter 5

Study 2: Co-Design of a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety

5.1 Introduction

In our previous study, we found that public speaking is the social situation in which the most stress and anxiety are experienced among university students, which is consistent with several other studies that identified public speaking anxiety as a prevalent social phobia among higher education students [30, 405, 297]. The results regarding the preferred type of intelligent agents to help university students manage their stress and anxiety in their most anxiety-provoking social situations support the idea that students would be interested in interacting with intelligent agents, such as social robots, in this domain. In addition, the students who reported experiencing stress and anxiety in social situations expressed willingness to use these intelligent agents for activities, including receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation, yoga), getting help with thinking calming or positive thoughts and getting help with building confidence.

Therefore, based on the findings of the first study, we decided to develop a robotic mental well-being coach to help university students manage their public speaking anxiety. To develop an effective solution, it is imperative to adopt an intelligent and user-centred

design approach with iterative evaluations. The co-design approach, involving the collaboration of end-users and stakeholders throughout the design process, has emerged as an effective methodology for developing technology-based interventions that meet users' needs and preferences, creating an opportunity to improve the acceptability and effectiveness of such interventions [411, 445].

5.1.1 Co-Design Methodology:

Co-design is a crucial aspect of technology design, serving as a valuable method to actively engage different stakeholders, including prospective users and subject domain experts, such as mental health professionals, as co-designers [411, 445]. This technique aims to balance the decision-making powers of researchers and stakeholders, ensuring that the resulting products or solutions align with the actual needs of end users [370]. In the mental health and well-being domain, the co-design methodology has been widely employed in developing social robots for different applications. For example, co-design has been used to enhance the mental health of teenagers [61] and to support emotional well-being in school children with autism [328]. These studies employed methods such as conducting interviews and workshops with prospective users and relevant stakeholders to gather information for designing the social robot.

This chapter presents the co-design of a robotic mental well-being coach specifically targeted at helping university students manage public speaking anxiety. Through iterative co-design processes involving multiple stakeholders and end-users (i.e., mental health professionals and university students), we seek to develop a robot-assisted intervention that can meet the university students' needs and preferences in this context. To this end, we first conducted semi-structured interviews and co-design sessions with several mental health professionals as collaborators, actively engaging them in the design process. After designing the robotic coach with professionals, we conducted a participatory study with university students to learn about their experiences and opinions about the robotic coach for further improvements. This work will contribute to the growing body of knowledge on using social robots in mental health care, informing the design of interventions targeting university students' public speaking anxiety. The findings could also facilitate the broader adoption and utilization of social robots to support students' mental health.

5.2 Research Question

This chapter addresses our third research question:

RQ3: How to design and develop robot-based interventions in a user-centred and co-design approach to support students in managing their stress and anxiety in social situations?

5.3 Methodology

5.3.1 Apparatus

In study 1, the results of the pilot study indicated a preference for human-like robots, while the survey with students at the University of Waterloo suggested a preference for using animal-like robots to help them manage their stress and anxiety in their most anxiety-provoking social situations. Given this difference in the results of these two studies, we decided to employ a robotic platform that can display both human-like and animal-like appearances, allowing users to select their preferred appearance. This allowed more flexibility for customizing the robot's appearance based on students' preferences.

Therefore, in this study, we used the Furhat robot[1] [8] to implement a mental well-being coach. Furhat is a robotic head that uses a projection of images to display different faces, e.g., animal-like, human-like, or anime faces. We selected the Furhat robot as it allows customization of the robot's voice (e.g., pitch, rate, volume, prosody) and appearance (e.g., human-like faces of different genders, skin tones, eye colours, a dog character, and an anime character), providing a personalized experience tailored to each user's preferences. Moreover, its conversational interaction capabilities, facial expressions, and eye contact abilities make it suitable for this application. We developed a Graphical User Interface (GUI) on a tablet to be used along with the Furhat robot, using ReactJS and Node.js to assist with getting more accurate input and to display some information to participants (see Figure 5.3).

5.3.2 Co-Design - Stages 1 to 3

Co-designing the robotic mental well-being coach with mental health professionals involved three stages (see Figure 5.2):

Stage 1 - Semi-structured Interviews: We invited five Mental Health Professionals (MHPs) who joined our team as collaborators (rather than study participants) to assist with the co-design of the system. We contacted all MHPs directly (as opposed to having posters, etc.), and we had no prior collaboration with them. Our MHPs collaborators included a licensed psychotherapist, a student wellness coordinator, a community wellness

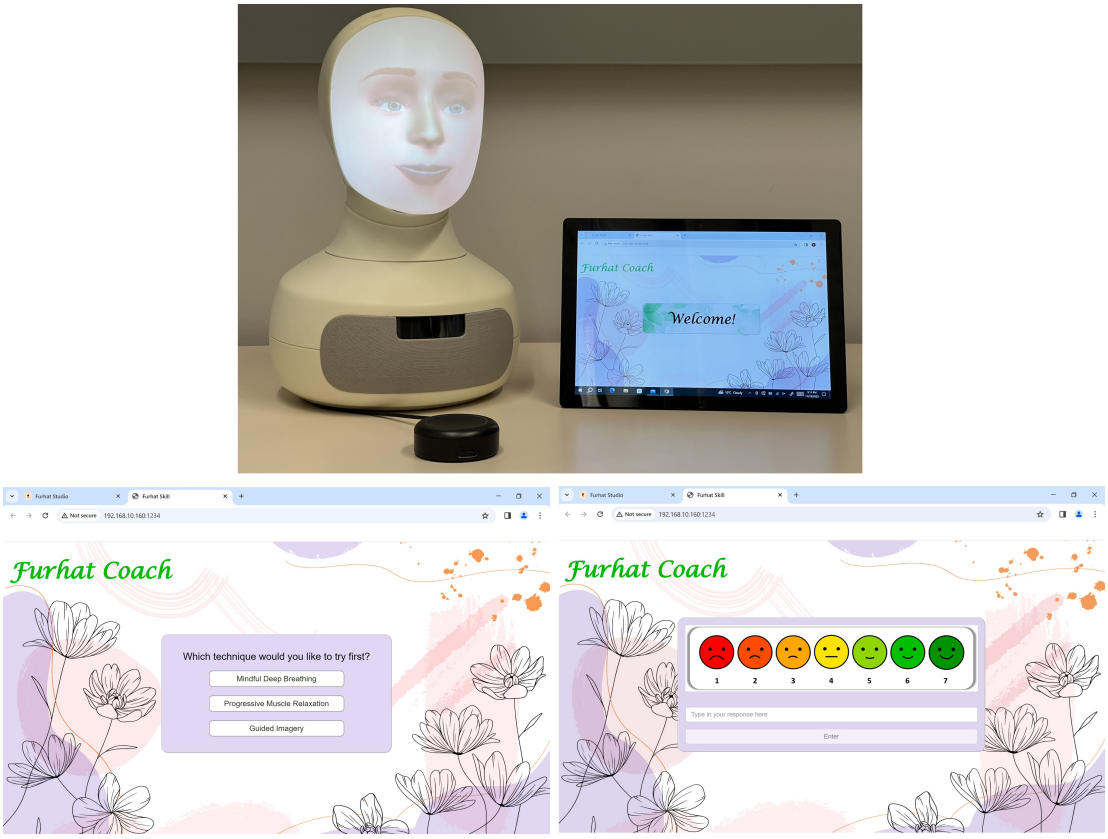


Figure 5.1: Furhat robot and the developed application

officer, a counsellor and a clinical psychologist, with years of experience ranging from 3 - 30+ years in supporting individuals' mental well-being, particularly university students. We conducted semi-structured one-on-one interviews with each of our MHPs collaborators that lasted around 90 minutes and were structured as follows: (i) *warm-up discussion about the project and purpose of conducting co-design sessions*; (ii) *introducing social robots*: as an illustration of social robots, we showed MHPs a video describing different social robots available in our lab, including Furhat[1], Pepper[2], NAO[2], Miro[3], and QT[4]. The video highlighted the distinctive capabilities of different social robots. We also created a short demo of the Furhat robots to interact with MHPs and introduce its different capabilities. The MHPs briefly interacted with the Furhat robot to gain a deeper understanding of its characteristics and capabilities that can be utilized in developing human-robot interaction. The interaction included the robotic coach introducing itself and demonstrating its various capabilities, such as face recognition and tracking, displaying diverse facial ex-

pressions, changing appearance (e.g., human-like faces of different genders, skin tones, and eye colours), speaking in different voices and in multiple languages. It was an interactive session; for instance, the robot asked questions, and there was verbal interaction between the mental health professional and the robot. We also asked MHPs about their opinions on using Furhat as a robotic mental well-being coach to help students manage their public speaking anxiety; (iii) *brainstorming ideas for designing a robotic well-being coach*: we encouraged the professionals to share their ideas and insights on the design of a robotic well-being coach, including various features, functionalities, interaction styles and stress management techniques that could effectively support university students in managing public speaking anxiety. Examples of questions posed during interviews with MHPs are presented in Appendix B.1. The interviews were modified based on the mental health professionals' backgrounds and expertise. All interviews were recorded and transcribed. We did not implement thematic analysis to analyze the collected data due to the small number of mental health professionals who collaborated with us on this project. This stage led to an initial draft of the robot's dialogue script.

Stage 2 - Interaction Design and Implementation: During this stage, three MHPs, including a licensed psychotherapist, a student wellness coordinator, and a clinical psychologist, continued their collaboration with us and reviewed and provided feedback on the robot's dialogue script designed in the previous stage. Two of the mental health professionals were not able to continue their collaboration due to time constraints. This stage was conducted mainly through email communications. We sent an email to our collaborators containing the scripts of the robots' dialogue and asked them to review and provide their comments and feedback. Subsequently, our collaborators shared their edits and comments with us via email. MHPs provided valuable feedback on diverse aspects of the scripts, drawing upon their distinct expertise and backgrounds. For instance, a collaborator specializing in delivering MBSR techniques provided detailed feedback, particularly focusing on MBSR techniques (i.e., guided imagery and mindful deep breathing exercises) in the scripts. Additionally, a clinical psychologist who collaborated with us played a pivotal role in refining and enhancing the section related to reframing negative thoughts. Hence, all the feedback and input from all collaborators was carefully considered and integrated into the final script of the robot's dialogue. After receiving all the comments and edits, and incorporating feedback and making necessary refinements, the script was implemented on the Furhat robot.

Stage 3 - Evaluation and Testing: In this stage, all three MHPs who reviewed the robot's dialogue interacted with the developed robotic mental well-being coach individually and went through the complete process of session explained in Section 5.4.1. Afterwards, we asked MHPs to share their perspectives and feedback. Through multiple sessions,

improvements were made to the behaviour and functionalities of the robotic mental well-being coach. The feedback received primarily focused on enhancing the naturalness of the human-robot interaction and improving the interaction content and flow. The team recorded all the sessions and took note of all the suggestions for system improvement. A final version was created after careful consideration of all the inputs and comments across multiple sessions.

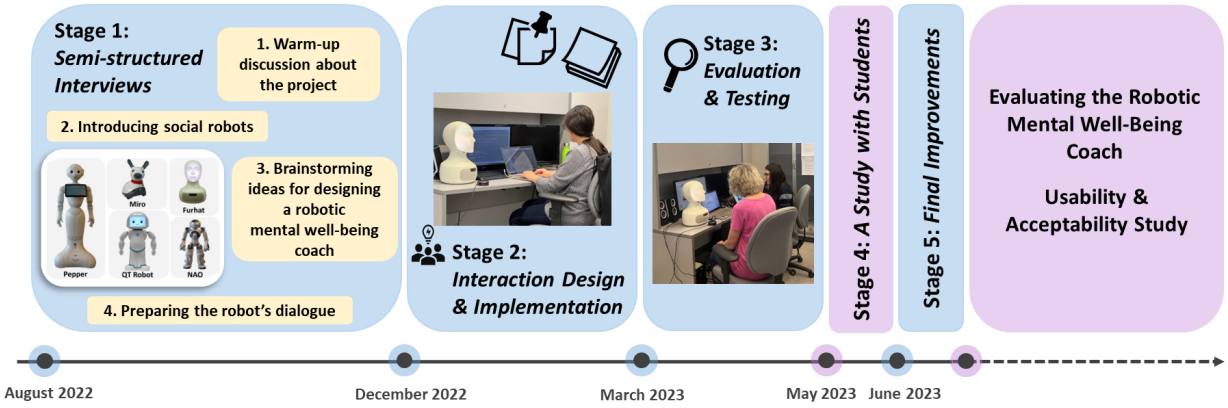


Figure 5.2: Timeline and stages of the co-design process of a robotic mental well-being coach

5.3.3 A Participatory Study with University Students - Stage 4

After designing and creating a script for the interaction scenario, based on feedback provided by the MHPs, we developed the robotic coach with our MHPs collaborators. Then, university students were recruited to share their experiences and provide feedback on the developed robotic coach (as informants in the co-design process). Each participant interacted with the developed robotic coach individually. The study took 45-60 minutes per individual and was approved by the University of Waterloo Human Research Ethics Board (see Appendix B.2). Each participant received $10 CAD remuneration for participating in this study.

Step 1 - Pre-study Questionnaire: Participants were asked to complete a demographic questionnaire about their age, gender, current academic program (degree), primary Faculty, and their past experiences with robots. We also asked participants to complete the Personal Report of Communication Apprehension, Public Speaking Subscale (PRCA-PS) [309] to measure public speaking anxiety. This questionnaire was used because it has been widely

employed for assessing public speaking anxiety in university students, and its validity and reliability are well-documented. The Cronbach's alpha reliability ranges from 0.93 to 0.95 for all items [208]. Participants rated their agreement with the PRCA-PS items on a scale of 1 (strongly agree) to 5 (strongly disagree). Scores on the scale range from 6 to 30. A score of 13.75 to 20.75 indicates moderate anxiety, while a score of 20.75 to 30 represents a high level of anxiety. Lastly, we presented participants with a brief video featuring the Furhat robot in various forms - including human-like faces of different genders, skin tones, eye colours, a dog character, and an anime character (see Figure 5.1). We asked participants to choose the face they preferred to interact with (see Appendix B.3 for pre-study questionnaire).

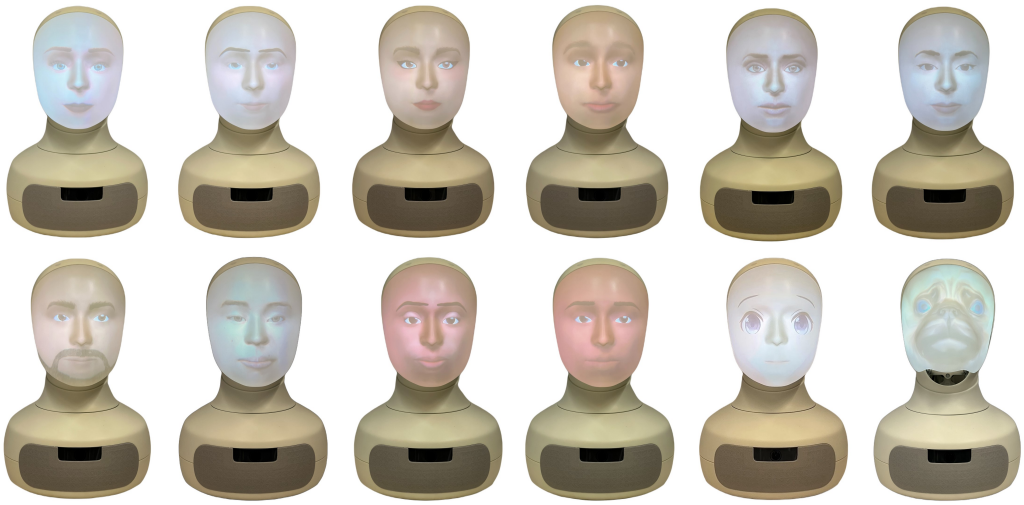


Figure 5.3: Various appearances of the robotic coach that participants could select from

Step 2 - Interacting with the Robotic Coach: The researcher explained the study's stages to each participant and then accompanied them to the experiment room where the Furhat robot was located. After ensuring that the participant had no further questions, the researcher left the room. During the interaction, the participant engaged with the autonomous robotic coach designed in Stages 1-3, with a Furhat face based on their individual selection in Step 1.

Step 3 - Post-study Interview: After interacting with the robot, we conducted a semi-structured interview with each participant to gather qualitative feedback about the robot. We opted for semi-structured interviews to gain a deeper understanding of the

students' perspectives. Semi-structured interviews have also been extensively used in co-design and participatory studies. This approach allowed us to explore nuances, gather detailed insights, and capture the richness of their experiences, which might be challenging to capture solely through predefined scales. During the semi-structured interviews, we asked participants about their experience with the robot, general impressions, and their likes and dislikes about the robot. We also asked their opinions on potentially having such a robotic coach on campus. Post-interview questions are presented in Appendix B.4. All interviews were recorded and transcribed.[1]

Participants: The study was conducted with 6 students at the University of Waterloo (3 female, 3 male), aged 21.67 ± 1.87 years. This sample included 3 undergraduate and 3 Master's students, with 3 from Engineering, 2 from Science, and 1 from the Art Faculties. The majority of the participants (N=5) indicated no prior experience with social robots. According to the PRCA-PS scale, 4 participants reported experiencing high levels of public speaking anxiety, while 2 reported moderate anxiety.

5.3.4 Final Improvements - Stage 5

Following the study with university students, we again collaborated with the MHPs to examine the study findings. Over two sessions (90-120 minutes) with each of our two collaborators, we discussed the comments and feedback received from university students and modified the system according to their feedback. Our aim was to collectively explore strategies to enhance the robot's performance by considering the feedback provided by the students.

5.4 Findings

In this section, we will first provide the findings of stages 1 to 3, where the system was iteratively co-designed and developed by direct involvement of MHPs. Afterwards, we will discuss the results of the participatory study with university students and how it informed the adjustment and improvements of the robotic system.

[1] In the participatory study with university students, we did not perform thematic analysis to analyze the qualitative data due to the small number of participants.

5.4.1 Co-Design with Mental Health Professionals

Stage 1 Findings

The initial co-design stage with MHPs yielded valuable insights that informed the dialogue script and functionality of the robotic coach.

Robot's embodiment: After showing MHPs a video describing different social robots available in our lab and their characteristics and capabilities, MHPs interacted with the Furhat robot. The interaction involved the robotic coach introducing itself, showcasing its various capabilities, and engaging in conversations with each mental health professional. We then asked about their opinions on using Furhat as a robotic mental well-being coach to help students manage their public speaking anxiety. MPHs expressed positive opinions about Furhat due to its interaction capabilities: *"I think Furhat is a better choice than other robots like QT. This one [Furhat] actually feels more like a session with someone."* (S2). *"I do really feel like I'm talking to somebody when talking with a Furhat. It had those mannerisms to be more engaged with it, to pay more attention and to answer the questions, and I liked that"* (S1). (S5) also noted *"I think this has great potential in the way it interacts with individuals. So, I think it's a great choice. It was actually even more amazing than I expected. I like the eye tracking."*

Mental well-being interventions: The team discussed the potential role of a robotic coach in assisting university students with public speaking anxiety, talking about various techniques they typically use to help university students who struggle with public speaking and exploring various well-being practices, stress management, and coping skills that a robot could facilitate in this context. Suggested techniques that emerged from the discussions included employing techniques commonly used in CBT for social anxiety [190, 399], such as relaxation training (e.g., progressive muscle relaxation), and MBSR (e.g., guided imagery and mindful deep breathing exercises) [169]. MHPs recommended offering different relaxation techniques to accommodate diverse preferences.

Strategies for challenging negative thoughts associated with public speaking anxiety and fostering helpful thinking patterns were also mentioned as useful approaches. The MHPs envisioned the robot as a facilitator of these practices, believing that it could deliver and guide students through these well-being activities.

Robot design considerations: Discussions with MHPs highlighted several important points regarding the design of the robotic coach. They pointed out the potential of

[2] https://www.softbankrobotics.com
[3] http://consequentialrobotics.com/
[4] https://luxai.com/

robotic coaches to bridge the gap in available mental health and well-being resources, offer preventive measures, and help with treatment compliance. The potential of social robots to act as a mediator between students and human professionals, offering personalized support and guidance without being as 'intimidating' as a human, was also emphasized. In the context of public speaking anxiety, MHPs suggested that robots can have the potential to teach and practice relaxation techniques and stress management strategies, which is especially beneficial for students who find themselves in a situation where they desire to acquire practical skills but may feel anxious about seeking help from a human professional. They remarked that by utilizing robots, individuals could potentially gradually build their confidence and begin practising these techniques in a non-threatening and non-judgmental environment. The presence of a robotic coach eliminates some of the barriers that might prevent individuals from seeking assistance from a human, such as fear of judgment or discomfort in discussing their anxiety.

MHPs highlighted the importance of helping students understand and recognize anxiety, explaining that anxiety can manifest differently in individuals, having different symptoms such as breathlessness or shallow breathing. MHPs emphasized that many individuals lack awareness of their own anxiety, highlighting the need for raising awareness about anxiety and its various body sensations.

In addition, the MHPs emphasized the importance of considering cultural diversity and individual needs and preferences. They discussed the potential impact of offering different Furhat face masks (i.e., human-like, animal-like, or anime, as well as different skin tones, genders, etc.) and voice options to cater to individual preferences. Students may have unique preferences for the robotic coach's appearance, interaction style, or voice. It was argued that providing customization options could make the robot more relatable and appealing to individual students.

The robot's behaviour and interaction style were also discussed, with a preference for a more friendly and engaging approach. They pointed out the importance of facial expressions and mannerisms in making students feel more comfortable and engaged. For example, they mentioned that friendly smiles and human-like expressions might create a sense of trust and help with building rapport and promoting willingness to interact with the robotic coach.

MHPs also suggested that the robotic coach should introduce students to campus resources and services to enhance support. One of the MHPs mentioned that this is particularly valuable for international students who may face challenges navigating the complex healthcare system in Canada. They noted that by familiarizing students with available resources and normalizing discussions around seeking help, the robotic coach could help

reduce stigma and encourage students to take necessary steps toward treatment when needed.

Final Design of the Mental Well-Being Intervention based on Stages 1-3:

In stage 1, based on the five sessions of discussion with MHPs, and as they suggested, the robot's dialogue script was designed by adopting the CBT model. CBT model suggests that our thoughts, feelings, and behaviours are connected, and if we change how we think and what we do, we can change how we feel [140]. CBT helps individuals to develop coping skills and strategies by understanding each component of the CBT model (i.e., thoughts, behaviours, and emotions) [140].

According to CBT for social anxiety, people's distorted perception of social situations and their physical arousal can result in behaviours that lead to avoidance of anxiety-provoking situations. While these behaviours can reduce anxiety in the short term, in the long term, they can maintain high levels of anxiety in social situations, potentially leading to complete avoidance of such situations [179]. CBT aims to identify and modify unhelpful thoughts and behaviours and teach skills for managing physiological arousal through various techniques such as cognitive restructuring, exposure, social skills training and relaxation training [190, 269]. Taking into account the three components of CBT — thoughts, behaviours, and emotions — the intervention script was designed to enhance students' self-awareness regarding their thoughts, behaviours, and feelings in the context of public speaking anxiety. The robotic mental well-being coach delivers a concise explanation of each CBT component and their interconnections and asks participants to practise associated evidence-based strategies to assist students in developing coping skills and resilience when confronting public speaking anxiety.

MHPs constructively improved the robot's script in Stage 2 in terms of the content and amount of information provided, ensuring that the content was clear, easy to understand, and did contain appropriate language (i.e., suitable and easy to understand language). MHPs eliminated any confusing or uncommon phrases, especially those related to relaxation techniques, while iteratively refining the wordings to maximize clarity. The explanations for the exercises were also enhanced to be understandable for university students with different levels of knowledge in psychology. Based on these co-design sessions with MHPs, the interaction involves the following sections:

Section 1 - Greetings: As a first step, the robotic coach introduces itself and engages in a brief icebreaker conversation. The robot asks participants to rate their current mood on a smiley face Likert Scale, ranging from 1 (*Very poor*) to 7 (*Excellent*), using the GUI

and then thanks them for sharing it. Questions on participants' moods were included because they were meant to be used in a larger-scale evaluation study with university students. For this study, we did not report the results on the participants' moods because our main objective was to gather feedback from university students on the behaviours and functionalities of the developed robotic coach. This feedback would help us improve the robotic coach before conducting the evaluation study with a larger number of university students. Prior to beginning the main content of the session, the robotic coach asks participants to practice a short, deep breathing exercise. The exercise commences with a calming meditation gong sound. The robotic coach then walks participants through a practice of short abdominal breathing, during which they are encouraged to close their eyes and follow the guided steps. The second meditation's gong sound marks the end of the exercise. Following the relaxation exercise, the coach emphasizes the importance of mastering this technique, particularly for moments of heightened anxiety and tension, such as those encountered before or during delivering a speech or presentation. The dialogue transitions to a discussion about speech anxiety, with the robotic coach inquiring about the participants' own experiences, and prompting them to rate their anxiety levels when giving a presentation or speech using Subjective Units of Distress Scale (SUDS) [47] that ranges from 0 (*feeling perfectly relaxed*) to 10 (*the highest anxiety*) on the GUI.

Section 2 - Relaxation and Stress Reduction Techniques: The interaction progresses with the robotic coach's exploration of how anxiety manifests physically. The goal is to promote self-awareness among participants regarding the physical sensations of anxiety they may experience before or during presentations. To facilitate this, participants are presented with a list of common physical sensations associated with anxiety and are asked about their experience of stress and anxiety. The robotic coach explains the physiological response known as the fight, flight, or freeze reaction and its connection to physical sensations. It then introduces three relaxation techniques, including Mindful Deep Breathing, Progressive Muscle Relaxation, and Guided Imagery for alleviating these physical symptoms. Participants are encouraged to choose one technique for practice. Once participants select a technique, the robot briefly explains it and guides them through the selected technique. Practising the third relaxation technique is optional, depending on the participants' preferences.

Section 3 - Reframing Negative Thoughts: In this section of the interaction, the robotic coach focuses on techniques designed to calm the mind. The robot explains the interconnection between thoughts, feelings, and behaviours, emphasizing how altering thought patterns can lead to improved emotional well-being and functioning. Participants are encouraged to reflect on negative thoughts they have encountered before or during presentations, fostering self-awareness. They are presented with three common pat-

terns of negative thinking: fortune telling, mind reading, and labelling and mislabeling. Afterwards, the robotic coach introduces the concept of reframing negative thoughts using positive self-affirmations [101] and offers a practical exercise in which participants are guided to create and repeat positive statements that reframe their negative or unhelpful thoughts. The robot emphasizes the importance of aligning these affirmations with one's genuine beliefs and the notion of gradual self-improvement.

Section 4 - Changing Behaviour and Confronting Fear: Finally, the robotic coach discusses the concept of an "anxiety cycle", emphasizing how thoughts, feelings, and behaviours can perpetuate anxiety in a continuous loop. It then discusses the "behaviour" component of the CBT model and how stress and anxiety can influence behaviour, often resulting in avoidance or withdrawal from anxiety-provoking situations. Following that, it asks participants if they have ever avoided or postponed a presentation or speaking in front of a group of people. The key message conveyed in this section is that confronting anxiety-provoking situations rather than avoiding them is essential for overcoming anxiety. It encourages participants to practice exercises discussed earlier to relax their minds and bodies and take small steps toward facing their fears and advises them to practice their future verbal presentations regularly. The session ends with the robotic coach asking participants to rate their current mood and expressing gratitude for their participation. To make the system interactive, the developed application asks users questions during interactions, and Furhat adjusts parts of its dialogue and behaviours based on users' answers.

In Stage 3, where the implemented design was evaluated and tested by MHPs, we received valuable feedback from MHPs regarding the robot's voice and behaviour. Throughout 10 co-design sessions of 90-120 minutes with the MHPs, we fine-tuned each section's pauses and speech rate to ensure optimal delivery; e.g., relaxation exercises were delivered by the Furhat robot with lower speech rate and volume, along with proper pauses to create a calming and soothing experience. Natural intonation and rhythm were added to the voice to make it more engaging and expressive. It has been shown that the volume, pitch, and speech rate of a therapist's voice can impact the effectiveness of relaxation exercises [247]. On the other hand, for dialogue related to explanations, we maintained a normal speech rate and volume to ensure clarity and engagement. We implemented specific speech rates and pauses for each exercise, taking into consideration the unique nature of each one. We also used a graphical interface with a robotic coach to display information and prompt participants with questions, asking them to provide input, due to limitations of speech interaction in our envisaged application when the robot will interact with a variety of university students.

A Robotic Coach on Campus - MHPs Opinion:

According to MHPs, having a robot available on campus could be beneficial in helping students acquire coping skills for effectively managing stress and anxiety, particularly for mild to moderate cases. However, they emphasized the necessity of seeking counselling with a professional for more severe situations. They also noted the potential for the robot to help reduce the stigma surrounding seeking counselling and promote better mental health, e.g., by offering the option for individuals to book a session with the robot and receive interactive robotic coaching, it could act as a bridge to human counselling services. This approach could encourage more students to seek help, as they may feel more comfortable starting with the robot and gradually transitioning to human counselling if needed. They noted that by providing a safe and supportive space, robots could guide individuals through various relaxation techniques, such as deep breathing exercises, mindfulness practices, guided imagery, and progressive muscle relaxation. They also highlighted the advantage of social robots over apps, emphasizing robots' ability to offer interactive experiences and provide assistance in practising the previously mentioned techniques. They noted that the robotic coach could offer step-by-step instructions and personalized feedback to help students develop their skills and alleviate anxiety associated with public speaking. By utilizing robots as an initial step, individuals could gain exposure to these techniques at their own pace, gradually building their comfort and confidence. As they become more familiar with the strategies, they may be more inclined to seek further treatment or professional counselling, taking that next step towards managing their public speaking anxiety.

MHPs also emphasized the potential of a robotic coach to provide unbiased intervention. Unlike humans, robots are not susceptible to having "bad days" or personal biases that could impact the quality of delivering mental health interventions. They also pointed out that a robotic coach could deliver mental health interventions to a larger number of students in a day without experiencing fatigue.

The discussion highlighted the potential advantages of having a robotic mental well-being coach for different audiences, including graduate and undergraduate students as well as employees, e.g., by tailoring the robot's programming to address the specific requirements and stress levels of each individual or group.

5.4.2 A Participatory Study with University Students

Experience about the Interactions with the Robotic Coach: All participants expressed positive experiences with the robotic coach, as inferred by their quotes (see Table 5.1), finding the robot to be engaging, relaxing, and knowledgeable and providing useful

information. Participants acknowledged the potential of the robotic coach as a valuable tool for relaxation, particularly for those dealing with anxiety. One participant mentioned that the session resembled normal conversations with a person and that they appreciated the way the robotic coach taught relaxation techniques. While three participants suggested increasing verbal interaction with the robot (see Table 5.1), students' opinions were largely positive.

During the sessions, participants were also asked for their opinions on the content provided by the robot. The feedback indicated that the information shared by the robot was found to be useful, especially for those who lacked knowledge in managing anxiety (e.g., *"It is very useful, especially for people who don't know a lot about managing anxiety"* (P1)). However, there were suggestions for improvement, with two students highlighting the need for more concise explanations and a shorter introductory section. They believed that such adjustments would enhance understanding and retention of the information (see Table 5.1).

Opinion about the Robot-let Relaxation Exercises: Overall, student participants had positive opinions on practising relaxation exercises with the guidance of the robotic coach (see Table 5.1). They found the techniques appropriate and helpful in achieving relaxation, and the instructions were clear. Some students had personal preferences for specific exercises, such as progressive muscle relaxation over guided imagery.

Robot's Features: For participants' opinions on the robot's features, such as appearance, behaviour, voice, speech rate, talking style and eye contact, (see Table 5.2). Suggestions for improvement made by some of the students were (1) adding more expressions, e.g., using facial expressions, (2) increasing the speech rate, (3) and making the dialogue more casual/informal.

1. **Robot's appearance:** Overall, participants found the robot's appearance to be good and visually appealing. Only one participant mentioned mouth movement as an area for improvement.

2. **Robot's behaviour:** Furhat's ability to move its face smoothly in a human-like manner and show facial expressions and gestures (e.g., nodding) were mentioned as positive aspects. Only one participant (P3) suggested adding more facial expressions to help better relate with the robot.

3. **Robot's voice and speech rate:** All participants expressed positive opinions about the robot's voice. They found it to be clear, understandable, soothing, and effective

Table 5.1: Participants' (P1, P2, ..., P6) quotes about their interactions with the robotic coach

Users' Experiences	**Participants' Quotes**
Interaction with the robotic coach	P1: "I think it is cool, very relaxing, very knowledgeable, good information, though I would have preferred to do more voice stuff and speaking to it." P2: "It was pretty good. I'm actually surprised at how realistic it is, really great." P3: "It was really great because I think it could be a useful tool for relaxing when someone experiences anxiety [. . .] it was very engaging, like facing the robot. I think a bit of verbal interaction reaction would make it more interactive. [..] It was a very good experience, and it did help me relax quite a bit, so I would definitely like to see more in the future." P4: "I thought it was really cool. It was really helpful to sort of have a face there talking to me through this entire thing. It's just really calming and relaxing.[..] it was really friendly." P5: "It was great. It was like just a normal conversation with a person. [..] It was interesting. I like the way it teaches us how to relax." P6: "It was really relaxing in the sense that I was thinking of some things before I came in here, and throughout the session, I had almost completely forgotten about it, and I could relax myself well [..] verbal conversation with the robot could be increased to some levels. I think it would make the overall experience much more lively."
Interaction content	P1: "It is very useful, especially for people who don't know a lot about managing anxiety." P2: "I think the information provided by the robot was useful." P3: "I think it was pretty good." P4: "Maybe it can be a little more concise with the information. I think it's easier to listen to information when it's concise; other than that, it was good." P5: "I think the first part before starting the exercises could be shorter." P6: "All the techniques the robot went through throughout the session were really helpful."
Practising relaxation techniques	P1: "It was appropriate for practising these techniques. I liked it." P2: "I really like the progressive muscle relaxation; when people are describing visualization to me, I find it difficult. That's a personal thing. I just don't like when people are talking to me, describing something. But I did like the progressive muscle relaxation, and what it actually did really helped." P3: "I think it's a great tool. Just a slight improvement, like in the guided imagery technique, where it guides us to imagine a scene. I would have preferred it with a little bit less comment there. I think that would help more." P4: "It was great for practising these techniques and did a good job of guiding me through the process." P5: "I was able to perform all the things which I was given. I was able to get relaxed during the session." P6: "It was like good at guiding on how to calm down and with controlling your breath and everything. It gave clear instructions."

in guiding them through the process. Regarding the robot's speech rate, four participants felt it was appropriate and well-paced, while (P2 and P4) suggested delivering certain instructions faster.

4. **Robot's talking style:** P1, P3, and P6 felt that the robot could be more casual, while others found the robot's behaviour to be appropriate, resembling the way a therapist speaks.

5. **Robot's ability to make eye contact:** Half of the participants felt comfortable with the robot's eye contact and found it natural. One participant (P4) noted that they initially experienced discomfort but gradually found it more natural and comfortable over time. Two participants were not comfortable with eye contact (P2, P3), one expressed a personal dislike for making eye contact (P2), and the other found it unnatural to make eye contact with a robot (P3).

Table 5.2: Participants' (P1, P2, ..., P6) quotes on robot features

Robot's Features	**Participants' Quotes**
Appearance	P1: "The mouth, the way it was talking, is the only thing I would change." P2: "I think this one looks really nice, [. . .] I actually really did like it because most robots that I've seen don't look so realistic [...]. Its eyebrows move when it talks, so it kind of makes it seem like someone is actually talking to you, so I do appreciate that." P3: "The appearance was really good." P4: "I thought it was really cool. I saw the pupils moving, and it was like moving its eyes, blinking, and I thought it was really cool." P5: "It was good." P6: "It looks really good."
Behaviour	P1: "It was cool that it moved its head kind of like a person[. . .] It moved pretty normally and smoothly [. . .] I feel like it closed its eyes when you closed your eyes [during relaxation exercises]; that was good. It looks human-ish." P2: "I think it has a really good gesture." P3: "It could incorporate more facial expressions; I think it would help the participant relate more." P4: "That was really cool when it was nodding and then shaking its head and looking over at the screen." P5: "It was like a normal person." P6: "The facial expressions and nodding,. . . really added to the overall experience."

Voice	P1: "Very good and understandable." P2: "In terms of clarity, I understood everything very well." P3: "The voice itself was very soothing; it added to the whole relaxation process. It was very clear and easy to follow." P4: "He was sort of talking very nice voice, and he was guiding me through the process." P5: "It was understandable during all interaction." P6: "It was completely understandable."
Speech rate	P1: "It was good to me." P2: "A little on the slower side [..] the instructions were a bit slow because I think one of them was like holding a breath, but then I was holding my breath for too long [. . .] aside from that, it was pretty well paced." P3: "The speech rate was good to me." P4: "I thought that it could be a little faster with the things like I was breathing, and I was holding it in, and it was kind of five seconds, but there was talking in between that." P5: "It was desirable for me." P6: "It was pretty moderate."
Talking style	P1: "It could be more casual." P2: "I kind of felt it is like the way a therapist would talk to you. That was a good balance between casual and formal. I think it wasn't too on either side." P3: "It could be a bit informal, I guess." P4: "I thought it was perfect." P5: "It was like a normal conversation. It was casual." P6: "It was formal to a good extent, and I think in such scenarios this is very much suitable, but a bit more casual would also probably help in those cases."
Making eye contact	P1: "I was comfortable with the robot's making eye contact." P2: "I don't like making eye contact, even for the robot. In general, I don't love making eye contact with people. I like it if it occasionally looked away [..]. I appreciated that it blinked; that was nice." P3: "It was not as natural as I would be comfortable like I'm interacting with you, so it's easier for me to maintain eye contact with the human. So I think it's not that easy for me to maintain eye contact, considering that I know it's a robot." P4: "It was unsettling at first when I was just starting out, but as I sat with him more, it kind of felt more natural, and it got more comfortable." P5: "I was comfortable with it." P6: "It was a comfortable experience with eye contact with it."

Robot vs. Other Resources and Human Coaches: The majority of the participants expressed a clear preference for using the robotic coach over other resources, e.g., books or voice assistants (See Table 5.3). They found the interactive and engaging nature of the robotic coach to be more effective in providing support for managing anxiety and relaxation.

The presence of a visual face and the sense of natural human interaction contributed to their positive opinions. However, P2 (who felt uncomfortable with the robot's eye contact) expressed a preference for voice assistants over social robots despite finding the interaction with the robotic coach more calming and similar to a conversation with an actual person.

The students held varying perspectives for comparisons between a robotic coach and a human coach. Three students favoured the robotic coach, pointing out factors such as "not feeling watched" (P1), "it's not judging you" (P2), and "not liking involvement with a person" (P5). On the other hand, P3, P4, and P6 preferred a human coach because of being more engaging (P3), more comfortable (P4), and being more used to talking with a human (P6). These different opinions may reflect individuals' different preferences and comfort levels with humans and robots. While a comparison with a human was made, this robotic coach is not meant to replace a human coach but rather to complement the existing resources and improve accessibility to mental health services.

A Robotic Coach on Campus - Students' Opinion: As MHPs supported the idea of having a robotic coach on campus, we asked participants about their opinions on having such a robotic coach on campus. The feedback indicates a positive attitude towards this idea. Several advantages in having access to a robotic coach were emphasized by the students, such as the possibility of engaging with the robotic coach in a private space, allowing them to seek support without feeling exposed in a public setting (e.g., *"That would be nice. Just like not in public, be in a private space that would be really good, I could like pop in, pop out."* (P1)). students highlighted the potential value of a robotic coach in supplementing existing counselling services, which may not always be readily available, e.g., *"Actually, counselling services aren't always available, so this would be good to have it on campus"* (P2), and discussed potentials for supporting introverted individuals, e.g., *"That would be great, especially for someone like me, I kind of am an introvert, so it would help people like me to interact with the robotic coach."* (P3), or *"That would be a great option for students like those who are introverts and those who don't like to speak to people a lot. This is the best option for them to get relaxed"* (P5). One student mentioned the potential of using a robotic coach for individuals who fear approaching others and being judged (e.g., *"It would be a great resource for students, I believe there are people that one of their fear is approaching someone and being judged by them."* (P6)). This suggests that the presence of a robotic coach may help bridge the gap for those who may feel hesitant or uncomfortable in traditional face-to-face interactions. Participants suggested having a robotic coach, particularly during high-stress periods such as exams, assisting with practising techniques that help alleviate stress and anxiety, e.g., *"I think that would be really beneficial, especially around exam times, just like stations where people can go and talk to the robot and learn more about deep breathing and just practising with it."* (P4).

Table 5.3: Participants' (P1, P2, ..., P6) quotes comparing using the robot to other resources and human coaches

Robot vs. Other Resources and Human Coaches	**Participants' Quotes**
Comparison to other resources (e.g., book, voice assistant)	P1: "I wouldn't like the book, [...] I do like the robot [I] think I prefer it. It is more interactive than a book. I like that it closed its eyes [during relaxation exercises]; I liked following what it was doing." P2: "Not books [...], in general, I don't love making eye contact with people. I find this one more calming than a voice Assistant like Siri because It's very robotic; this [the robot] felt like an actual person talking to. I would get this voice in a voice assistant; that would be nice." P3: "I think I would prefer the robot because I have tried the guided meditations earlier with kind of like a voice assistant, you could say, and it was not as engaging because I would leave it midway. I have observed that with this robot, I completed the session. So I think this would be more engaging." P4: "Probably the robot, because with the book, it's just more reading, you know, it's not really like telling you what to do. [..] For voice assistants, there's not like a face that you can see, and so I think this combines both." P5: "I would prefer this robot over any other resources because it has a kind of interaction. It's just not like they're saying to me, and I'm doing something. It creates a sense of feeling like a normal interaction with any human or any person." P6: "I would really prefer the robot because it is catering to that one need of mine; if I'm really looking for some support in terms of the anxiety or the fear that I'm feeling about anything, I would definitely prefer the robot."
Comparison to human coaches	P1: "The robot would probably be better than a person, just cause I'm not feeling watched in the same way, and it's just a robot." P2: "I think I would actually prefer this one [the robot] if it does not look at you all the time [..] It's not judging you." P3: "I think a human coach would be more engaging than the robot, of course." P4: "I think probably the human. I guess it's more comfortable to talk to humans. As like when he was telling me to repeat the affirmations, I felt like it was just me in this room talking by myself." P5: "I would prefer a robot because. I don't like that much involvement with a person." P6: "I would prefer a human coach because we have been very much used to talking to human beings as such. But at the moment, I understand that if the robot can also understand me to a similar level that a human being can understand me, it will be at that stage that I would give the first preference to a robot, as you are not judged by it."

5.4.3 Final Improvements to the Robotic Coach

Based on the co-design stages mentioned above, we made final improvements to the behaviour and functionality of the robot based on feedback from students and with the assistance of MHPs. Over two sessions with MHPs, we adjusted the pauses in the breathing technique to ensure its suitability for individuals with varying breathing capabilities. In response to feedback and to create a more engaging experience, we incorporated additional casual conversations into the robot's dialogue. More facial expressions (e.g., smiling) were also added. To enhance information retention, we condensed certain pieces of provided information (e.g., explanations on anxiety) to make them more concise and memorable for students. Besides, as recommended by MHPs, we will, in our future user study, provide university students with a handout (see Appendix B.5) after the study session, summarizing the techniques and topics covered in a session. This will allow students to review the material and improve their ability to recall the concepts discussed. Furthermore, the handout will include a list of mental health and well-being resources, both on and off campus, that students can access.

5.5 Limitations and Future Work

Our study had several limitations. The voluntary sign-up process may have led to a self-selection bias. Therefore, it is possible that those who were involved generally had a more positive opinion. We gathered feedback from only six students as our goal was to recruit them as informants for improving the system and not for a summative evaluation of the system in a user study. Evaluation of the system with a larger group of university students is imperative to study university students' perceptions of the systems, preferences, and intentions to use the robotic system in the future. In addition, at the beginning of the co-design process, five mental health professionals with different backgrounds collaborated on the project. However, due to time constraints, two of them were not able to continue their collaboration until the end of the co-design process. Besides, all the mental health professionals who collaborated with us were female. Also, all were self-selected into the study. Therefore, there is a possibility that our collaborators generally had a more positive opinion, and the perspectives of the mental health professionals who collaborated on this project may not fully represent the opinions of a larger and diverse group of mental health professionals. However, in qualitative research and co-design studies, a small number of participants are common to gain a deeper understanding of a particular topic or situation rather than drawing broad conclusions [299]. In this work, we sought participants' opinions

on using different methods of delivering mental health interventions to manage stress and anxiety related to verbal presentations, including the robotic coach they interacted with, self-help books, voice assistants (e.g., Google Nest) and human coaches. The purpose of this question was not to compare or replace these different resources but to explore the potential for social robots to complement existing resources and enhance access to mental health services for this application area. Note that participants did not have interactions with human coaches or the other mentioned resources. Future studies might compare robotic coaches to human coaches and other resources (e.g., self-help books, voice assistants) to gain a more nuanced understanding of university students' preferences for each of these methods of delivering interventions in this context.

5.6 Conclusions

Excessive anxiety in public speaking can result in considerable stress and anxiety, diminished speech performance, and avoidance of situations that require delivering verbal presentations. Therefore, offering students appropriate support through educational resources, training, and practice is crucial to help them manage and overcome their anxiety in this context. By providing such support, students could potentially enhance their confidence, improve their public speaking abilities, and excel academically and professionally.

However, access to human coaches and human-led well-being interventions can be challenging due to limited resources, excessive wait times, financial constraints, etc. [320], which calls for innovative technological solutions, including social robots, to extend and complement mental health support and increase accessibility. This chapter presented different stages of co-designing a robotic mental well-being coach with the goal of assisting university students in managing public speaking anxiety to address the research question: RQ3: How to design and develop robot-based interventions in a user-centred and co-design approach to support students in managing their stress and anxiety in social situations?

The robotic coach's behaviour and interactions were designed through 17 co-design sessions with five MHPs and modified based on feedback from six university students as informants to improve the system further. To accommodate the diverse needs of individuals, the robotic system we developed offers a wide range of relaxation exercises. These exercises have been widely used by MHPs, indicating their effectiveness. Nevertheless, it is essential to underscore that no single method can universally apply to all individuals, as confirmed by our research findings. Consequently, providing individuals with a variety of options is crucial to enable them to explore and identify the most suitable relaxation technique that aligns with their unique needs and preferences.

University students had different preferences about the robot's speech and gaze behaviours, emphasizing the importance of considering specific user needs and adjusting the robot's roles and talking style accordingly. For our robotic coach, the robot's talking style was designed to align with that of counsellors and therapists, with the verbal interactions being edited by MHPs. A balance between formal and casual elements or personalization based on individual preferences (e.g., based on user personalities) may enhance users' experiences. Also, students' preferences regarding the robot's eye contact varied. Past studies highlighted the importance of the robot's eye contact in creating natural and engaging interactions [4, 249]. However, individuals with social anxiety may find making eye contact uncomfortable [13]. Thus, further investigation is needed to understand the impact of eye contact on different individuals and design strategies that accommodate their preferences.

Overall, our co-design approach, highlighting MHPs' and students' opinions, demonstrates a favourable perception of the idea of having a robotic coach on campus, emphasizing potential benefits in terms of convenience, accessibility, and support for individuals with diverse needs. Despite these valuable insights, further research and considerations of ethical and practical issues are necessary before implementing such a system on a wider scale.

Chapter 6

Study 3: Evaluating a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety

The aim of this chapter is to evaluate the usability, acceptability, feasibility and university students' perception of the robotic mental well-being coach that was developed in the previous chapter through co-design sessions with MHPs and university students to help students manage their public speaking anxiety. The robotic coach was designed to autonomously deliver an intervention by adopting the CBT model (see Section 5.4.1). According to the CBT model, There is a two-way relationship between our thoughts, feelings, and behaviours, and if we change how we think and what we do, we can change how we feel [140]. The CBT model applies to anxiety by addressing the cognitive and behavioural aspects of anxiety. It helps individuals identify and change negative thought patterns, gradually confront anxiety-provoking situations, develop healthier coping mechanisms, and acquire skills for long-term anxiety management. This approach has been shown to be highly effective in treating various anxiety disorders, such as generalized anxiety disorder, social anxiety disorder, and panic disorder [221].

In this research, the purpose of the developed mental well-being intervention is to help university students develop coping skills and strategies to alleviate public speaking anxiety by understanding each component of the CBT model (i.e., thoughts, behaviours, and feelings) and their impact on their stress and anxiety before or during a verbal presentation.

The developed robotic mental well-being coach aimed at assisting university students in managing public speaking anxiety by delivering strategies derived from evidence-based interventions for social anxiety, such as CBT (i.e., relaxation training) [190, 399], and MBSR (i.e., guided imagery and mindful deep breathing exercises) [169]. Moreover, to help participants challenge their negative thoughts related to verbal presentations, the robotic coach introduces a technique, positive self-affirmations [101], to assist them in reframing negative thoughts with positive and supportive self-talk.

Over the past few decades, the use of social robots has gained popularity in various fields such as health care, mental health care, education, etc. (e.g., [175, 478, 46]). Nevertheless, their introduction into these different areas does not necessarily guarantee acceptance by potential users [122]. Thus, the acceptability and usability of these robots play a pivotal role in determining their successful integration within these fields. To this end, fostering a positive user experience proves essential for user acceptance of social robots and should be regarded as an indispensable component of the robot development process [433].

6.1 Research Questions

This study aims to answer the following Research Questions (RQs):

RQ4-1 How do participants evaluate the usability of the robotic mental well-being coach for managing public speaking anxiety?

RQ4-2 What is the user acceptance rate of the robotic mental well-being coach for managing public speaking anxiety?

RQ4-3 How do participants evaluate the social attributes of the robotic mental well-being coach for managing public speaking anxiety?

RQ4-4 Does the use of the robotic mental well-being coach have the potential to impact students' moods?

RQ4-5 Can the robotic mental well-being coach influence students' willingness to make behaviour changes to manage their public speaking anxiety?

RQ4-6 How do participants evaluate their working alliance with the robotic mental well-being coach for managing public speaking anxiety?

RQ4-7 What are the participants' user experiences (e.g., satisfaction, engagement, enjoyment, etc.) of their interaction with the robotic mental well-being coach for managing public speaking anxiety?

RQ4-8 How do participants' personality traits affect their intention to use the robotic mental well-being coach for managing public speaking anxiety?

6.2 Methodology

To address these research questions, we conducted a study at the University of Waterloo and recruited undergraduate and graduate students. For each participant, the study involved one session of interaction with the robotic coach to gather both qualitative and quantitative data on the robot and its interaction with participants to explore its feasibility, usability, and acceptability. This study took about 90 minutes for each participant and was approved by the University of Waterloo Human Research Ethics Board (see Appendix C.1). Each participant received $20 CAD remuneration for participating in this study.

6.2.1 Procedure and Measures

Prior to the session, participants completed an online pre-study questionnaire administered by Qualtrics[1]. The questionnaire started by asking participants to read an information sheet and give consent. Once participants provided their consent, they were directed to the pre-study questions to answer demographic questions and choose the robot's facial appearance from different options, including human-like faces of different genders, skin tones, and eye colours, as well as the option of an animal-like or anime face. In fact, it allows user-controlled personalization [341], also called customization [63, 258]. Research has shown that user-controlled personalization (i.e. customization) increases perceived human agency and enables a sense of identity by allowing users to make choices about personally relevant features [27, 454]. Upon arrival for the session, the researcher explained the study's stages to each participant and then accompanied them to the experiment room where the Furhat robot was located (see Figure 6.1). After ensuring that the participant had no further questions, the researcher left the room. Next, the participant interacted with the autonomous robotic coach. Afterwards, the participants answered an online post-study questionnaire, which was implemented on Qualtrics. This study consisted of three main steps, which are described below.

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

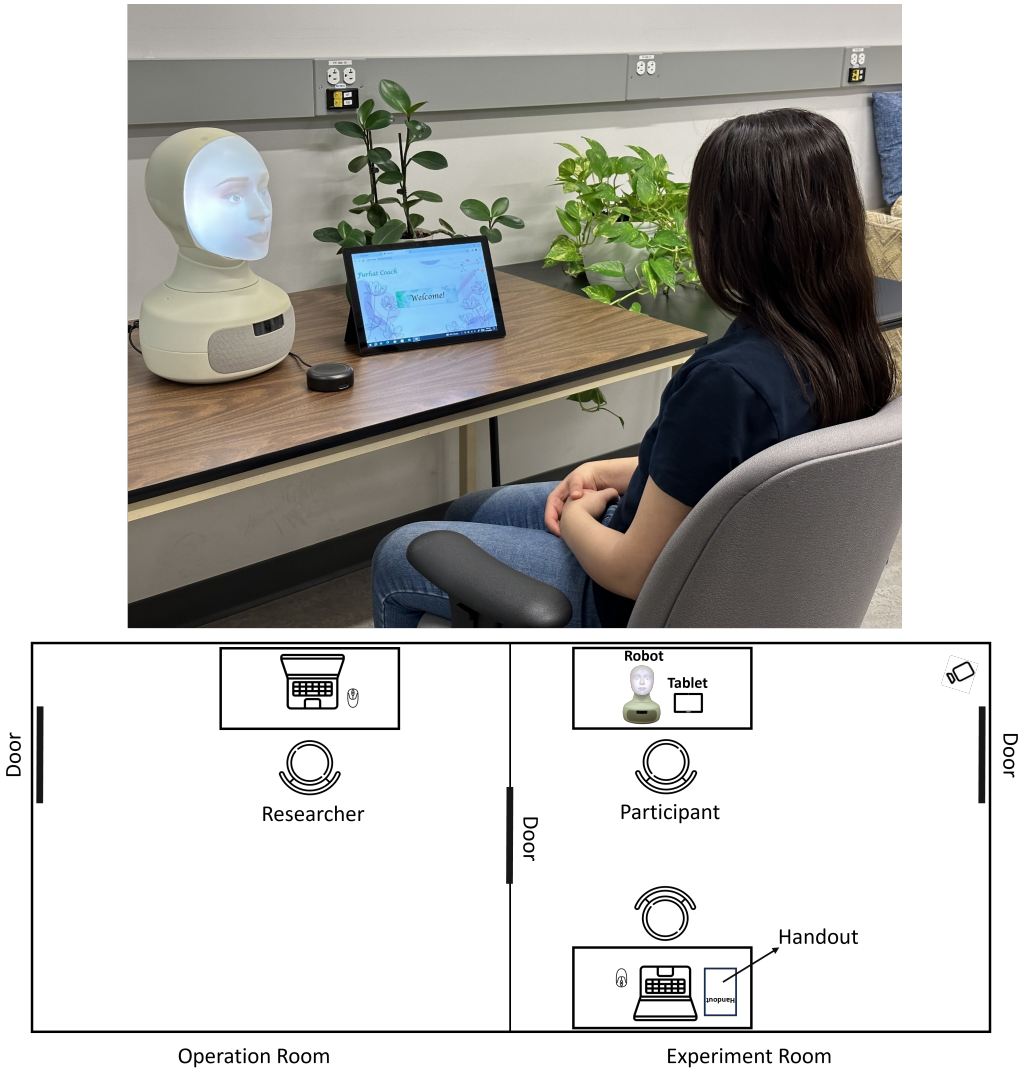


Figure 6.1: An overview of the study setup and experiment room layout

Step 1 - Demographics and Pre-experimental Questionnaire: Participants were asked to complete a demographic questionnaire about their age, identified gender, current academic program (degree), primary faculty, current year in the program, and whether they have ever programmed or interacted with a robot. All questions were presented as multiple-choice questions, except for age and gender, which participants could respond to in text boxes. We also inquired about participants' comfort levels when presenting in

front of others, measured on a continuous scale from 0: *"very uncomfortable"* to 100: *"very comfortable"*. Additionally, we requested information on the number of presentations they had delivered in front of a group of people during the past year to be provided in a text box. The participants had the option of skipping any demographic question that they preferred not to answer. The pre-experimental questionnaire is presented in Appendix C.2.

Public Speaking Anxiety: We also asked participants to complete the Public Speaking Subscale of Personal Report of Communication Apprehension (PRCA) questionnaire [309] to measure their public speaking anxiety. This questionnaire was used because it is commonly used to measure public speaking anxiety in university students and has a well-documented validity and reliability, with a Cronbach's alpha reliability ranging from 0.93 to 0.95 for all items [208]. The subscale comprises six items shown in Table 6.1. Participants rated their agreement with the PRCA-PS items on a scale of 1 (*strongly agree*) to 5 (*strongly disagree*). Scores on the scale range from 6 to 30. A score of 13.75 to 20.75 indicates moderate anxiety, while a score of 20.75 to 30 represents a high level of anxiety.

Big Five Personality Traits: The Ten-Item Personality Inventory (TIPI) [171] was administered to measure potential participants' personality traits. TIPI is a brief self-report questionnaire designed to assess an individual's personality traits based on the Five Factor Model. This model encompasses five key traits: Extroversion, Conscientiousness, Openness to Experience, Agreeableness, and Emotional Stability. The TIPI comprises ten items (see Table 6.1), with two items per trait, and respondents rate each item on a 7-point Likert scale of 1 (*disagree strongly*) to 7 (*agree strongly*). We used this questionnaire to measure participants' personality traits for exploratory purposes, and we did not have a particular hypothesis.

Readiness for Behaviour Change: The Readiness Ruler (RR) questionnaire is a tool commonly used in the field of behaviour change and motivational interviewing [313, 82]. The RR assesses an individual's willingness and motivation to change a specific behaviour related to health, habits, or personal goals for better well-being and mental health (e.g., see [314, 215, 456]). Adapted from RR questionnaire, in this study, we asked participants' perceived importance, readiness and confidence to make behaviour changes for managing stress and anxiety before/during verbal presentations on a continuous scale ranging from 0 (*not at all important/ready/confident*) to 10 (*completely important/ready/confident*). The questions were: (a) At this moment, how important is it for you to make behaviour changes to manage your stress and anxiety before/during verbal presentations? (b) how ready are you to make behaviour changes to manage your stress and anxiety before/during verbal presentations? (c) how confident are you in your ability to make behaviour changes to manage your stress and anxiety before/during verbal presentations? The total score ranges from 0 to 30, with higher scores indicating a greater willingness to change [456]. The RR

questionnaire was administered before and after the study.

Robot's Appearance: Lastly, we presented participants with a video featuring the Furhat robot in various forms - including human-like faces of different genders, skin tones, eye colours, a dog character, and an anime character. We asked participants to choose the face they preferred to interact with (see Figure 6.2 for appearances that participants could select from).

Step 2 - Interacting with the robotic coach: In this step, participants engaged with an autonomous robotic coach designed in Chapter 5, with a Furhat face customized based on their individual preferences given in Step 1.

The script for the intervention was developed through a series of co-design sessions involving MHPs and university students and integrated three components of the CBT model — thoughts, behaviours, and feelings — with the goal of enhancing students' self-awareness concerning these elements within the context of public speaking anxiety, as detailed in Chapter 5.

The interaction consisted of four main sections, each described in detail in Section 5.4.1. To give a brief overview of the interaction, as a first step, the robotic coach introduces itself and engages in a brief icebreaker conversation. The robot asks participants to rate their current mood on a smiley face Likert Scale, ranging from 1 (*very poor*) to 7 (*excellent*), using the GUI and then thanks them for sharing it. Note that the robotic coach asks about participants' moods both before and after delivering mental well-being interventions. The gathered data is then used to measure possible changes in participants' moods before and after the intervention.

Afterwards, participants will engage in a brief deep breathing exercise. The robot then explains how stress and anxiety can affect the body, elucidating various associated body sensations. Furhat also introduces three different relaxation techniques: (1) mindful deep breathing, (2) progressive muscle relaxation, and (3) guided imagery. Each technique is briefly described, and users are encouraged to practice it with the robot. Practising the third exercise is optional. After practising the exercises, the robot explains the impact of stress and anxiety on thoughts, highlighting negative thinking patterns and distorted perceptions. It introduces a technique to reframe negative thoughts using positive self-affirmations: replacing negative thoughts with positive and supportive self-talk. Furhat then emphasizes how stress and anxiety can influence behaviour, often resulting in avoidance or withdrawal from anxiety-provoking situations. Strategies are discussed to overcome avoidance behaviour by gradually exposing oneself to feared situations. The user is encouraged to take small steps towards facing their fears and advised to practice their future verbal presentations regularly. Afterwards, the robotic coach asks participants to rate their

Table 6.1: Items of the pre-experimental questionnaire

Section 1: Personal Report of Communication Apprehension, Public Speaking Subscale PRCA-PS
1. I have no fear of giving a speech.
2. Certain parts of my body feel very tense and rigid while I am giving a speech.
3. I feel relaxed while giving a speech.
4. My thoughts become confused and jumbled when I am giving a speech.
5. I face the prospect of giving a speech with confidence.
6. While giving a speech, I get so nervous I forget facts I really know.
Section 2: Ten Item Personality Inventory TIPI
I see myself as:
1. Extraverted, enthusiastic
2. Critical, quarrelsome.
3. Dependable, self-disciplined
4. Anxious, easily upset
5. Open to new experiences, complex
6. Reserved, quiet
7. Sympathetic, warm
8. Disorganized, careless
9. Calm, emotionally stable
10. Conventional, uncreative
Section 3: Readiness Ruler RR
1. At this moment, how important is it for you to make behaviour changes to manage your stress and anxiety before/during verbal presentations?
2. How ready are you to make behaviour changes to manage your stress and anxiety before/during verbal presentations?
3. How confident are you in your ability to make behaviour changes to manage your stress and anxiety before/during verbal presentations?

current mood and expresses gratitude for their participation. The session ends with the robotic coach mentioning a handout that summarizes the techniques and topics covered in the session. Moreover, it encourages participants to seek help and support when needed using the mental health and well-being resources listed in a handout. Finally, the robotic coach asks participants to complete the post-study questionnaires using the laptop located

on the desk behind them. In addition, it mentions to participants to take the handout that is placed next to the laptop (see Figure 6.1 for the study setup and experiment room layout). This handout (see Appendix B.5) served as a future resource for students to revisit the material and enhance their retention of the discussed concepts. Additionally, the handout included a list of mental health and well-being resources, available both on and off campus, to aid students in accessing the support they may need.

Step 3 - Post-experimental Questionnaire: To evaluate the participants' perceptions of the robotic coach for managing public speaking anxiety, we used multiple questionnaires. The post-experimental questionnaire is presented in Appendix C.3. A detailed description of each of the employed questionnaires is presented below.

- **System Usability Scale:** To measure the usability of the developed robotic coach, we used the System Usability Scale (SUS) [28], which is a reliable and widely adopted usability scale for the assessment of technological systems usability. The scale consists of ten statements that users respond to using a five-point Likert scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). In the System Usability Scale, the odd-numbered questions represent positive statements, while the even-numbered questions represent negative statements. After participants complete the questionnaire, their responses are scored and transformed into a final usability score, typically ranging from 0 to 100. As stated in [28], the calculation of SUS scores involves adjusting the scores based on the type of question. The score for each statement's contribution will be within the range of 0 to 4. Then, for positive statements, 1 is subtracted from the score. For negative statements, the score is subtracted from 5. Following this, all the adjusted scores are summed up, multiplied by 2.5, and, finally, the average of these adjusted scores is calculated [28]. According to to [28], SUS scores are commonly interpreted as follows: 0 to 64 signifies "Not acceptable", 65 to 72 is considered "Marginal/Acceptable", and 73 to 84 indicates "Good" usability, while 85 to 100 represents "Excellent" usability. These score ranges provide a quick and effective way to assess the perceived usability of a product or system.

- **System Acceptability:** In order to evaluate the participant's acceptance of the robotic mental well-being coach, we employed and customized the Almere questionnaire introduced by Heerink et al. [187]. The questionnaire is a theoretical extension and adaptation of the Unified Theory of Acceptance and Use of Technology (UTAUT) developed by Venkatesh et al. [487] and has been extensively used in HRI research. In this study, we used sub-scales of the Almere questionnaire that are relevant to this application, including (a) Anxiety, (b) Attitude Towards Technology, (c) Intention to Use, (d) Perceived Enjoyment, (e) Perceived Sociability, (f) Perceived Usefulness, (g)

Social Presence, and (h) Trust. We also asked participants about the (j) Perceived Ease of Use of the robotic coach, adapted from the Technology Acceptance Model (TAM) [118]. Each utilized construct, its definition and related are presented in Table 6.2. For this work, we made modifications to the "Intention to Use" sub-scale questions, replacing "during the next few days" with "in future". Question items were displayed in a random order, and questions regarding "Anxiety" and "Attitude Towards Technology" were asked at the end of the post-study questions to avoid any potential bias in the results (see Appendix C.3). All questions are rated using a five-point Likert Scale from 1 (*totally disagree*) to 5 (*totally agree*).

- **Perceived Social Attributes of the Robotic Coach:** The Robotic Social Attributes Scale (RoSAS) [84] questionnaire is a psychometric instrument that evaluates the social perception of robots across three dimensions: warmth, competence, and discomfort. The questionnaire is used frequently in HRI research studies. Each of the three dimensions is evaluated through six attributes, using a nine-point Likert scale, ranging from 1 (*definitely not associated*) to 9 (*definitely associated*), resulting in a total of 18 attributes (see Table 6.3). Internal consistency for each subscale of the RoSAS questionnaire was found to be high (Cronbach's alpha above 0.80) [347, 129]. RoSAS holds a substantial advantage in its capacity to assess social perceptions of robots across various contexts and robotic platforms [84]. In this study, we used RoSAS to measure how participants perceived the robotic coach in terms of warmth, competence, and discomfort. The order of the 18 attributes was randomized in the questionnaire.

Table 6.2: Acceptability questionnaire based on the Almere [187] and TAM [118] questionnaires

Construct	**Definition**	**Items**
Anxiety	Evoking anxious or emotional reactions when it comes to using the system	1. If I should use the robot, I would be afraid to make mistakes with it. 2. If I should use the robot, I would be afraid to break. something 3. I find the robot scary. 4. I find the robot intimidating.
Attitude Towards Technology	Positive or negative feelings about the appliance of the technology	5. I think it's a good idea to use the robot. 6. The robot would make life more interesting. 7. It's good to make use of the robot.

Intention to Use	The intention to use the system over a longer period in time	8. I think I'll use the robot in future. 9. I'm certain to use the robot in future. 10. I plan to use the robot in future.
Perceived Enjoyment	Feelings of joy/pleasure associated with the use of the system	11. I enjoy the robot talking to me. 12. I enjoy doing things with the robot. 13. I find the robot enjoyable. 14. I find the robot fascinating. 15. I find the robot boring.
Perceived Sociability	The perceived ability of the system to perform sociable behaviour	16. I consider the robot a pleasant conversational partner. 17. I find the robot pleasant to interact with. 18. I feel the robot understands me. 19. I think the robot is nice
Perceived Usefulness	The degree to which a person believes that the system would be assistive	20. I think the robot is useful to me. 21. It would be convenient for me to have the robot.
Social Presence	The experience of sensing a social entity when interacting with the system	22. When interacting with the robot I felt like I'm talking to a real person. 23. It sometimes felt as if the robot was really looking at me. 24. I can imagine the robot to be a living creature. 25. I often think the robot is not a real person. 26. Sometimes the robot seems to have real feelings.
Trust	Trust	27. I would trust the robot if it gave me advice. 28. I would follow the advice the robot gives me.
Perceived Ease of Use	The degree to which one believes that using the system would be free of effort	29. My interaction with the robot is clear and understandable. 30. Interacting with the robot does not require a lot of mental effort. 31. The robot provides helpful guidance in performing tasks. 32. Overall, I find the robot easy to use.

Table 6.3: RoSAS items [84]

Competence	Warmth	Discomfort
Reliable	Organic	Awkward
Competent	Sociable	Scary
Knowledgeable	Emotional	Strange
Interactive	Compassionate	Awful
Responsive	Happy	Dangerous
Capable	Feeling	Aggressive

- **Perceived Working Alliance - Task:** Participants were asked to complete the Task subscale of the Working Alliance Inventory-Short Revised (WAI-SR) [184], on a seven-point Likert-type scale ranging from 1 (*Never*) to 7 (*Always*). The WAI-SR measures the level of collaboration between a therapist/clinician and a client based on 12 statements in three subscales: bond, goals, and tasks [184]. A higher mean score reflects a stronger perceived working alliance between clients and their therapist/clinician. For this study, we only used the "tasks" subscale that is relevant to our study. We also modified the questions by replacing"therapy" with "session". We asked participants to rate these four questions based on their personal experiences with the robotic mental well-being coach: (a) What I am doing in the session gives me new ways of looking at my problem; (b) I feel that the things I do in the session will help me to accomplish the changes that I want; (c) As a result of this session, I am clearer as to how I might be able to change; (d) I believe the way we are working with my problem is correct.

- **User Experience:** We asked questions to evaluate participants' experience of interaction with a robotic mental well-being coach designed for managing public speaking anxiety. Customized questions were employed to assess various aspects of their interactions with the robotic coach, including perceived satisfaction, engagement, the coach's behaviour, the practice of relaxation exercises, the usefulness of provided information, and more. Participants were instructed to rate these questionnaire items on a continuous scale ranging from 0 to 100, as elaborated in Table 6.4. Furthermore, for three last questions pertaining to participants' willingness to continue practising learned techniques and opinions on the desired availability of a robotic coach at the university to assist them in managing public speaking anxiety, and their intention to use such a robotic coach if it were available at their university, we included text boxes so that participants could share any further comments on these topics.

We also inquired about participants' prior experience with the relaxation techniques introduced to them during the interaction. Those with prior experience were asked to specify which specific techniques they were familiar with, using a multiple-choice question that allowed for the selection of multiple options. Additionally, we assessed the frequency of their practice of these techniques using a four-point ordinal scale, ranging from "rarely" to "very often".

Furthermore, participants were asked to indicate their preferred intervention delivery method for managing stress and anxiety in the context of verbal presentations. They were presented with a multiple-choice question that included several options, including "bibliotherapy (self-help books or resources)", "a robot coach like the one you interacted with", "a robot coach different from the one you interacted with", "an agent different from a robot, for example, a voice assistant agent, such as Google Nest", "other (please specify)", and "none of them". Participants were requested to provide explanations for their choices using a text box. We also incorporated additional branching questions for participants who opted for "a different robotic coach", encouraging them to specify how they would prefer the robotic coach to differ, whether in appearance, behaviour, speech, or any other preferred aspect. Respondents were presented with a multiple-choice format to facilitate their responses. Besides, they were requested to provide further explanation for each chosen option in a text box (see details in Appendix C.3). As a follow-up question, we asked participants whether they preferred human coaching or if they maintained their original choice of intervention method based on their earlier selections.

We included this comparison question since a separate experimental condition with a human coach was beyond the scope and timescale of this thesis. Note, the robotic coach is not meant to replace a human coach but rather to complement the existing resources and improve accessibility to mental health services.

Finally, we administered open-ended questions (see Table 6.5) at the end of the study to gather more qualitative feedback on the interaction. Through these questions, participants could provide feedback on their overall experience with the robotic mental well-being coach, their likes and dislikes about their interactions, as well as their perceptions of the robot's personality and talking style.

6.2.2 Participants

A total of 50 university students (26 female, 23 male and 1 non-binary, age range: [18,33], M = 23.8, SD = 13.33) completed the study. The participants were all University of Wa-

Table 6.4: Questions on evaluating participants' perceptions of the robotic mental well-being coach using continuous scales

Question items	**Range Description**
Please describe your interaction with the robotic coach:	(0: Not satisfying at all - 100: Very satisfying) (0: Not engaging at all - 100: Very engaging) (0: Not relaxing at all - 100: Very relaxing)
I found the behaviour of the robotic coach:	(0: Not natural at all - 100: Very natural)
I found practising relaxation exercises with the robotic coach:	(0: Not comfortable at all - 100: Very comfortable) (0: Not enjoyable at all - 100: Very enjoyable)
I found the information provided by the robotic coach:	(0: Not useful at all - 100: Very useful)
Would you want to continue further sessions with the robotic coach?	(0: Not at all - 100: Very much)
Will you continue to practice techniques you learned from the robotic coach?	(0: Not likely at all - 100: Very likely)
How do you feel about making such a robotic coach available at the university to assist students in managing their stress and anxiety related to verbal presentations?	(0: Not supportive at all - 100: Very supportive)
Would you use the robotic coach if it were available at your university?	(0: Not at all - 100: Definitely)

Table 6.5: List of open-ended questions for qualitative analysis

Item	**Statement**
Q1	Did you encounter any technical problems during the session with the robotic coach?
Q2	Do you have any suggestions to improve the interaction of the robotic coach during the session?
Q3	What did you like about your interactions with the robotic coach?
Q4	What did you dislike about your interactions with the robotic coach? What would you change?
Q5	What did you think of the robot's personality and talking style? (e.g., being too formal or too casual)

terloo students and were recruited through posting recruitment flyers on campus. This sample included 23 undergraduate students, 25 Master's students, and 2 Ph.D. students, with 39 participants from the Faculty of Engineering, five from the Faculty of Mathematics, two from the Faculty of Science, two from the Faculty of Arts, one from the Faculty of Environment, and one from the Faculty of Health. The majority of the participants (N=32) indicated that they previously programmed or interacted with a robot. Within the sample, 15 participants exclusively programmed or interacted with human-like robots, two solely with animal-like robots, and 8 with other types of robots that are not human-like or animal-like. Furthermore, two participants had experience with human-like and other types of robots, four with both animal-like and other types of robots, and one participant had experience with human-like, animal-like, and other robot types. According to the PRCA-PS questionnaire, 6 participants reported low levels of public speaking anxiety, 21 participants reported moderate levels, and 23 participants reported high levels of public speaking anxiety. Moreover, among 50 participants, 33 of them reported previous experience with the relaxation techniques introduced in the session with the robotic coach: 18 with only deep breathing exercises, 8 with both deep breathing and guided imagery, 3 with both deep breathing and progressive muscle relaxation and 4 with all three techniques. In terms of how often participants engaged in relaxation exercises, only seven reported practising breathing techniques often (N = 6) or very often (N = 1). Additionally, 2 participants reported practising progressive muscle relaxation often or very often. As for guided imagery, 9 participants practised it rarely, and 3 practised it sometimes. Out of the various choices available for the Furhat robot's facial appearance, 25 participants opted for a female appearance, 15 preferred a male appearance, 7 chose the anime face, and 3 selected the dog character. Figure 6.2 displays different appearances of the robotic coach in this study, along with the corresponding number of students who selected each appearance.

6.2.3 Statistical Analysis

In this study, to address RQ4-1, we reported the mean and standard deviation for each item of the SUS questionnaire and calculated the average SUS based on the formula mentioned in [28]. Students' average ratings on the items of the acceptability questionnaire were reported with a 95% confidence interval to address RQ4-2. Mean and standard deviation were reported for RQ4-3, RQ4-4, and RQ4-5. Moreover, recognizing the non-normality of the data for RQ4-3 and RQ4-4, we employed the non-parametric Wilcoxon signed-rank test [512] to compare pre and post-study data on participants' self-reported moods and their willingness to change their behaviour. We used Wilcoxon effect size (r) to report the effect size [475]. The interpretation values for (r) are $0.10 < r < 0.3$ (small effect), $0.30 < r < 0.5$

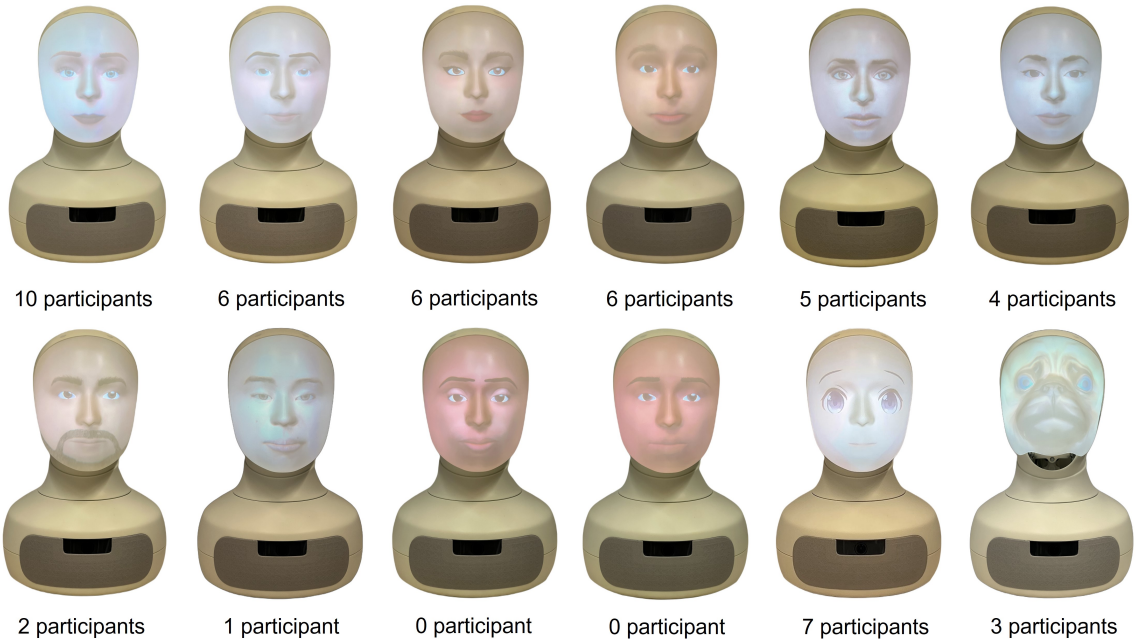


Figure 6.2: Various appearances of the robotic coach that participants could choose from, along with the corresponding number of participants who selected each appearance

(moderate effect), and $r >= 0.5$ (large effect) [475]. Besides, to address RQ4-6, we reported students' average ratings with a 95% confidence interval for each item in the user experience questionnaire. Finally, we employed a multiple linear regression model to analyze the collected data and assess the impact of participants' personality traits (i.e., Extroversion, Conscientiousness, Openness to Experience, Agreeableness, and Emotional stability) on the dependent variable (i.e., intention to use) to address RQ4-8. We also controlled for factors, including age, gender, previous experience with a robot and relaxation techniques, number of presentations, public speaking anxiety, pre-study Readiness Ruler score and Working Alliance Inventory (Task) score, which were initially included in the models. We did not include the data on participants' comfort levels when presenting in front of others in the multiple linear regression model, as it was negatively correlated with the participants' public speaking anxiety. We utilized the Akaike Information Criterion (AIC) [70] as a model selection criterion. A step-back approach is adopted to select a subset of factors and create a model that minimizes AIC. Ultimately, the selected model with the lowest AIC value was considered the best fit for our data, providing insights into the key determinants of the outcome of interest.

6.2.4 Thematic Analysis

We used Thematic Analysis (TA) to analyze qualitative data collected from open-ended questions in the post-study questionnaire. We employed the 6-step TA method developed by Braun and Clarke [72]. The TA six steps are: (1) Familiarization with the Data: e.g., reading and re-reading the data, gaining an overall understanding of the content and noting some initial ideas. (2) Creating Initial Codes: This step involves identifying meaningful pieces of information in the dataset and systematically assigning labels (codes) to them. These codes can be words, phrases, or sentences that capture key concepts or ideas to organize data into meaningful groups. (3) Searching for Themes: In this step, researchers group related codes into potential themes based on patterns and similarities. Themes are broader, more abstract ideas that emerge from the codes. Initially generated codes can either become primary themes or sub-themes, or they may be discarded altogether. (4) Reviewing Themes: The themes identified in the research are reviewed for coherence, relevance, and representation of the data. Adjustments or combinations of themes may also be necessary. (5) Defining and Naming Themes: Researchers provide clear and concise definitions for each theme. Each theme should have a descriptive name that captures its essence. (6) Writing the Report: This involves writing a comprehensive report that presents the analysis with quotations or examples from the data to illustrate each theme. The report should include a detailed analysis of the findings in relation to the research question or objectives. These six steps assist researchers in systematically analyzing qualitative data to uncover significant themes and insights. In this study, two researchers separately coded the data. I conducted the thematic analysis of the entire dataset, and another researcher independently analyzed 25% of the data.

6.3 Results

In this section, we present our research findings obtained through both quantitative and qualitative data analysis.

6.3.1 Quantitative Analysis

The Robotic Coach's Usability

To address RQ4-1, we asked participants to rate the usability of the robotic mental well-being coach for managing public speaking anxiety using SUS. The average scores of each

Table 6.6: Average score for each system usability scale item. Scale ranging from 1 (strongly disagree) to 5 (strongly agree)

Item	Statement	$Mean \pm SD$
Q1	I think that I would like to use this robotic coach frequently.	3.90 ± 0.84
Q2	I found the robotic coach unnecessarily complex.	1.60 ± 0.83
Q3	I thought the robotic coach was easy to use.	4.62 ± 0.53
Q4	I think that I would need the support of a technical person to be able to use this robotic coach.	1.70 ± 0.93
Q5	I found the various functions in this robotic coach were well integrated.	4.24 ± 0.72
Q6	I thought there was too much inconsistency in this robotic coach.	1.34 ± 0.48
Q7	I would imagine that most people would learn to use this robotic coach very quickly.	4.52 ± 0.61
Q8	I found the robotic coach very awkward to use.	1.88 ± 0.92
Q9	I felt very confident using the robotic coach.	4.20 ± 0.61
Q10	I needed to learn a lot of things before I could get going with this robotic coach.	1.34 ± 0.69

SUS statement are shown in Table 6.6. The robotic coach achieved a high usability score of 84.05 on the SUS questionnaire.

The Robotic Coach's Acceptability

To measure the acceptability of the robotic coach for each participant, we computed the average scores of the items that constituted each of the constructs (e.g., Trust, Intention to Use, etc.) of the acceptability questionnaire (Table 6.2). The negatively phrased items were reversed when calculating the average. The results for each acceptability construct are shown in Figure 6.3. In the acceptability questionnaire, higher scores across these constructs generally indicated better performance, with the exception of Anxiety, where a lower score signified lower anxiety levels during interactions with the robotic coach (Mean=1.91, SD=0.7). For all other constructs evaluated in the acceptability questionnaire, scores exceeded the midpoint of 3, indicating positive outcomes in terms of acceptability.

According to the multiple linear regression model (Table 6.7), working alliance (Task subscale) exhibited a significant positive effect ($SE = 0.160, t = 2.343, p < .05$) on intention to use the robotic coach, suggesting that a stronger working alliance with the robotic coach

was associated with higher intention to use it. Conscientiousness personality trait was also positively correlated with the intention to use the robotic coach ($SE = 0.214, t = 2.074, p < .05$), indicating that participants with higher Conscientiousness scores reported higher intention to use the robotic coach.

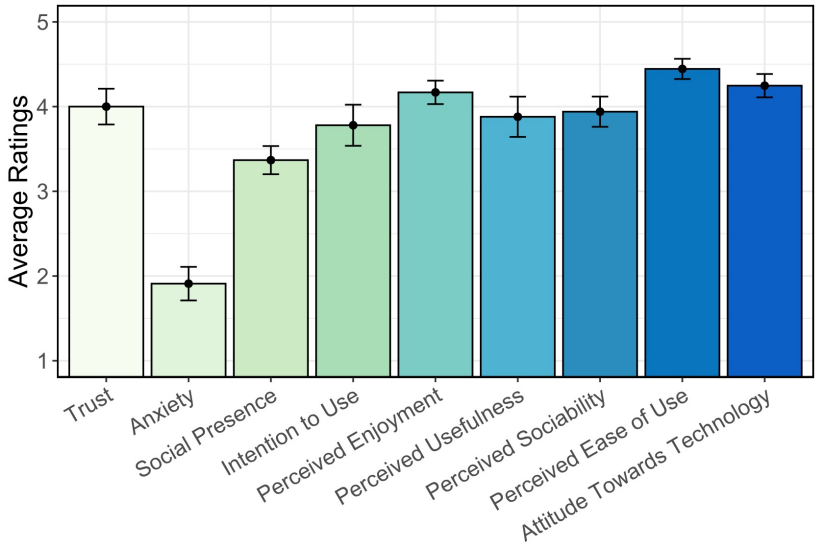


Figure 6.3: Students' ratings of the acceptability questionnaire items. Scale ranging from 1 (totally disagree) to 5 (totally agree). Error bars indicate 95% confidence intervals.

Perceived Social Attributes of the Robotic Coach

Figure 6.4 presents the results of the RoSAS questionnaire, designed to assess participants' social perceptions of the robotic mental well-being coach in terms of three dimensions: warmth, competence, and discomfort. The results highlight that perceived competence ($M = 7.27$, $SD = 0.85$) received the highest rating among the three dimensions, while perceived discomfort ($M = 2.23$, $SD = 0.96$) received the lowest rating, indicating a low level of discomfort experienced by participants. The average rating for perceived warmth was ($M = 6.30$, $SD = 1.36$).

Participants' Moods

While interacting with the robotic mental well-being coach, the robotic coach asked participants to rate their mood on a scale of 1 (*Very poor*) to 7 (*Excellent*) before and after

Table 6.7: Multiple linear regression analysis of potential factors affecting the intention to use the robotic coach (*= $p < .05$)

Covariate	**Intention to Use**			
	Estimate	SE	t	p
Intercept	0.670	1.090	0.611	0.545
WAI (Task)	0.375	0.160	2.343	0.025*
RR_Pre-study	0.026	0.022	1.188	0.243
TIPI: Extraversion	-0.117	0.079	-1.475	0.149
TIPI: Conscientiousness	0.214	0.103	2.074	0.045 *
TIPI: Openness to Experience	0.149	0.117	1.279	0.209
TIPI: Emotional Stability	-0.229	0.114	-2.013	0.052

WAI = Working Alliance Inventory (Task), RR= Readiness Ruler.

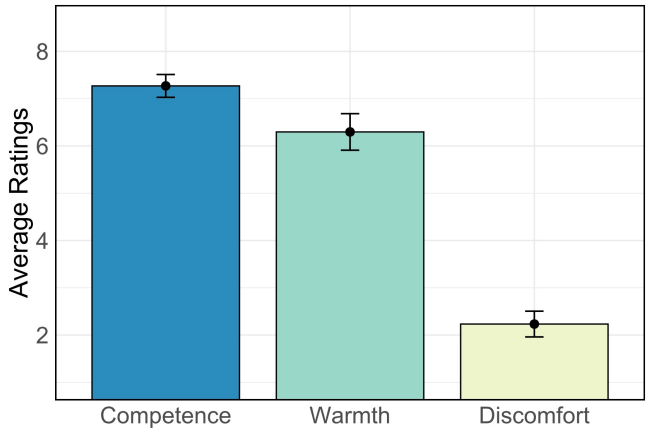


Figure 6.4: RoSAS scores. Scale ranging from 1 (definitely not associated) to 9 (definitely associated). Error bars indicate 95% confidence intervals.

delivering the mental well-being intervention. Comparing pre and post-study results, we found participants' moods improved after the study (see Table 6.8). Since the mood data did not follow a normal distribution, as confirmed by the Shapiro-Wilk test, we utilized the Wilcoxon signed-rank test [512] to determine the significance of the differences. The test indicated a significant difference in the participants' moods before and after the study (V= 749.5, $p < .0001$), with a large Wilcoxon effect size of (r= 0.78), indicating an increase in

participants' mood.

Table 6.8: Mood and Readiness Ruler scores before and after the study, and Working Alliance Inventory (Task sub-scale) score after the study

	Pre-study	Post-study
Measure	Mean (SD)	Mean (SD)
Participants' reported mood	5.22 (0.81)	6.14 (0.72)
Readiness Ruler	22.35 (5.46)	23.7 (4.1)
Working Alliance Inventory		5.58 (0.81)

Readiness for Behaviour Change

The findings demonstrated a rise in the RR questionnaire scores following the study (refer to Table 6.8). Due to the non-normal distribution of the data, as confirmed by the Shapiro-Wilk test, we employed the Wilcoxon signed-rank test [512] to compare the pre and post-RR scores. The test revealed a statistically significant difference in participants' readiness to change behaviour before and after the study ($V = 690.5$, $p < .05$), with a moderate Wilcoxon effect size of ($r = 0.34$), indicating an increase in participants' readiness for behaviour change.

Working Alliance - Task

The results from the questions on the "task" sub-scale of the WAI-SR questionnaire revealed a mean score of 5.58 out of 7 (SD = 0.81), surpassing the neutral point of 4 for this scale. This suggests a positive outcome in establishing a working alliance between participants and the robotic mental well-being coach for managing public speaking anxiety.

User Experience

Participants' evaluations of their interaction with the robotic mental well-being coach for managing public speaking anxiety (addressing RQ4-7) are shown in Figure 6.5. The results show that all the items received an average rating of over 70 (ratings ranging from 0 to 100), with perceived relaxation and usefulness receiving the highest ratings. We also indirectly measured the participants' engagement with or interest in, the robotic coach by recording

whether participants practised the optional third relaxation exercise. We found that 41 out of 50 participants practised all three relaxation techniques.

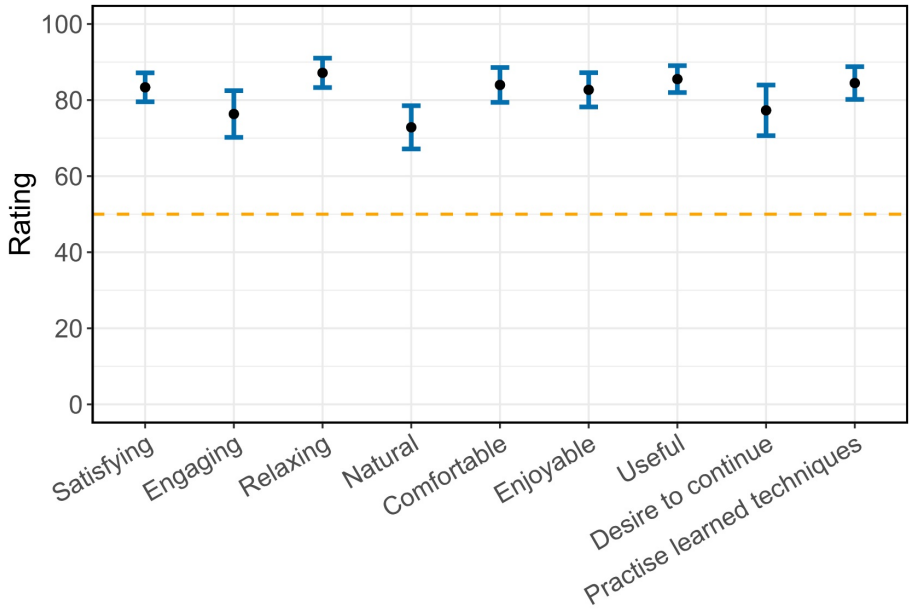


Figure 6.5: Students' ratings regarding their evaluation of the robotic coach. Error bars indicate 95% confidence intervals.

Results on students' preferences for the type of intervention delivery methods that help with managing public speaking anxiety are presented in Figure 6.6. As can be seen, out of the 50 participants, 33 preferred a robot coach similar to the one they interacted with, while seven preferred a voice assistant. Five opted for bibliotherapy (self-help books or resources), and two preferred a different type of robot coach. Three participants selected the "None of them" option and stated their preference for only human coaches or video resources in the provided text boxes.

The two participants who opted for "a different robotic coach" were asked to detail their preferences for differences in appearance, behaviour, speech, or other aspects. They used a multiple-choice format to select their preferences and were also encouraged to provide additional explanations for their choices in a text box. Both students stated that they preferred the robotic coach with a different "appearance" and "speech". One participant who selected a female face mask stated, *"I would like to see complete human-like body features on the robot"*, and in terms of speech, *"the different ranges of tone and speed*

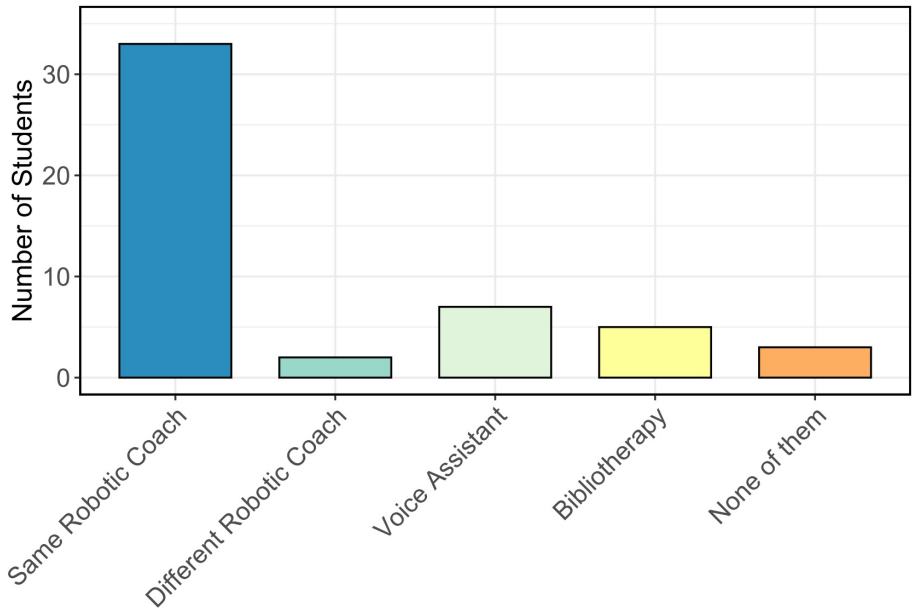


Figure 6.6: Students' preferences for the type of intervention delivery methods that help with managing public speaking anxiety

during guidance, lowering of the volume when speaking during meditation". The other participant who selected the anime face provided insights regarding appearance, noting a desire for it to be *"more realistic. Not make it as human as possible, but the robot looks cold and bare"*. Concerning speech, the need for *"more vocal variety (e.g., volume, depth, tone, speed, etc.)"* was mentioned.

Figure 6.7 shows the results of the follow-up question where we asked participants' preferences for human coaching or their original choice of intervention method.

Results indicated that out of the 33 participants who initially chose a robotic coach similar to the one they interacted with, 24 of them remained with their initial choice. Seven participants opted for a human coach, while two participants chose "other (please specify)". In the related text box, one participant mentioned selecting both options, and another participant indicated, *"It depends on the situation, such as if I feel shy in some cases and don't want to share with a human coach, so I do prefer the robot coach; otherwise, I prefer a human coach"*.

Furthermore, among the seven participants who initially opted for a voice assistant, four participants retained their choice, two participants switched to a human coach, and one

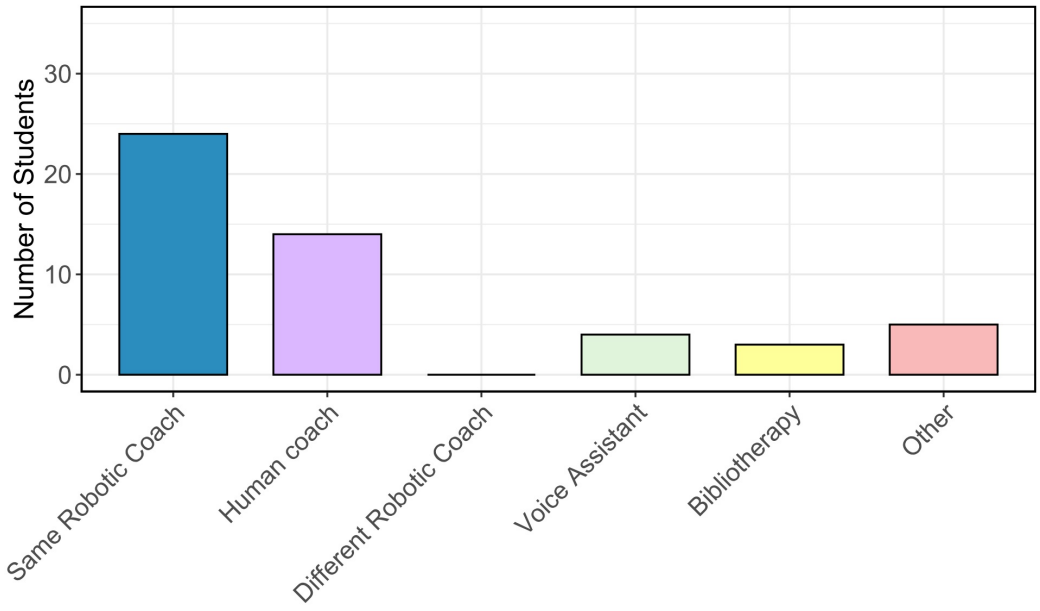


Figure 6.7: Students' preferences for a human coach vs. their initial choice of intervention delivery method to manage public speaking anxiety

participant selected "other (please specify)", expressing a preference for *"guidance video by human"* over these two options. In addition, out of the five participants who originally preferred bibliotherapy (self-help books or resources), three participants maintained their choice, while two participants switched to a human coach. Among the two participants who initially chose a different robot coach from the one they interacted with, one participant opted for a human coach, while the other selected "other (please specify)" and indicated a preference for *"guidance video by human"*. Lastly, of the three participants who first chose "none" of the options, two participants selected human coach, while one participant selected "other (please specify)" and expressed a preference for *"video"* resources.

Figure 6.8 presents the results of the last two questions asking students about how supportive they are towards having such a robotic coach at university and their willingness to use it, as measured on a continuous scale ranging from 0 to 100. As can be seen, both questions received an average rating above 70.

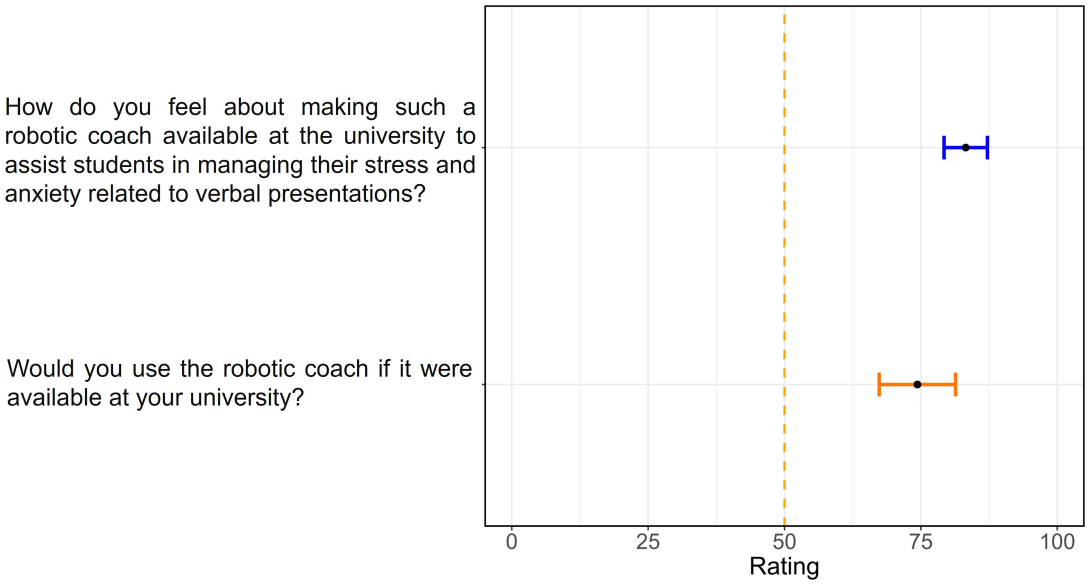


Figure 6.8: Students' ratings on the desired availability and use of a robotic coach at the university to help with public speaking anxiety. Error bars indicate 95% confidence intervals

6.3.2 Qualitative Analysis

Participants' comments were analyzed using the TA method [72] to extract salient themes. In total, eight distinct themes were identified. A theme was accepted if there were a minimum of 15 associated codes or comments related to it. The identified themes were reviewed and revised for coherence and relevance, and sub-themes were created. We performed an inter-rater reliability analysis to measure the agreement between the two researchers, who coded the data, using Cohen's Kappa [260]. The result of calculating weighted Kappa was $(Kappa = 0.924, SE = 0.030, 95\%, CI = [0.865, 0.984])$, showing "almost perfect agreement".

Theme 1: Relaxation Techniques

Participants provided feedback on the learned techniques during the session (see Table 6.9), acknowledging their effectiveness in inducing relaxation and a sense of calm during and after the interaction. Moreover, they expressed a willingness to continue practising these exercises beyond the session.

1. **Experience of Relaxation:** 20 participants stated that techniques provided by the robotic coach helped them to be calm and relaxed. (e.g., *"It was a whole new experience for me, especially the guided imagery task. I kind of forgot where I was for a moment. It was wonderful, and it made me completely relaxed. I had a few upcoming deadlines, about which I was worrying since morning, and I simply forgot about them in that session"* (P3), or *"I liked the Guided Imagery technique; it really worked for me and made me calm and relaxed"* (P27)). P27 refers to participant 27. (See Table 6.9 for more examples).

2. **Willingness to Continue Practising Learned Techniques:** We received 45 comments for the question asking participants about their willingness to continue practising learned techniques. All 45 comments expressed an explicit desire to continue practising the techniques they learned during the session. Their motivation stemmed from various factors such as "feeling relaxed after practising exercises" (e.g., *"I was aware that I need to practice relaxation on my anxiety for presentations or any circumstance that I felt stressed. However, I was not enthusiastic to find methods to relax myself until I faced this robot. The robot was capable of making me very comfortable and relaxed during the session that I trust the methods that were introduced and want to continue practising"* (P7)), "understanding how the suggested methods are useful in tackling stress and anxiety" (e.g., *"I personally suffer from anxiety before public speeches and presentations. After today's session, I intend to use these techniques to calm myself and be less anxious. Knowing the reasons for my body's response to stress and anxiety made me understand how the suggested methods are useful in tackling it. So, I feel ready to incorporate certain behavioural changes and confident to transform myself"* (P4)), and "finding techniques useful/helpful for managing anxiety" (e.g., *"The guided imagery and muscle relaxation were helpful and new to me - I prepare to use these before presentations and in other times of stress. This session will be a helpful reminder!"* (P23)). Examples of the comments are presented in Table 6.9.

3. **Personal Preferences for Specific Techniques:** 11 participants reported varying experiences with the relaxation techniques introduced during the session. For example, *"I felt that the muscle relaxation technique was not very suitable for me as I didn't find it to be relaxing. Rather, it required too much focusing. The breathing technique was the best as it helped me to calm down very fast."* (P8) or *"The very first exercise the robot taught me - deep breathing and holding my breath- would be useful in any scenario, including public speaking. I think as someone who has a tight schedule, incorporating this into my life would be highly beneficial"* (P41). These di-

verse responses underline the importance of offering a range of relaxation techniques to cater to individual preferences and needs.

Theme 2: Interaction Perceptions

38 participants provided valuable feedback regarding their experiences with the robotic coach. Overall, they reported positive experiences with the robotic coach, as indicated by their quotes in Table 6.10.

1. **Robot as a Well-Being Coach:** We received 28 comments about the robotic coach, finding it as knowledgeable, relaxing, engaging, and interactive, e.g., P5 noted *"It is a great combination of being interactive, calm, relaxing and knowledgeable. The robot interacts in a way that the information provided becomes very easy to understand. The exercises were performed at a good pace. It did not feel rushed or too slow"*. They described the sessions as informative and beneficial in relaxing (e.g., P4, P25, P41). The robot's ability to create a safe and unique environment for relaxation practice was noted (e.g., P19). Others highlighted the robot's friendliness and ability to provide clear instructions and useful techniques (e.g., P23, P42, P43). Additionally, P44 marked *"The robot was easy and comfortable to interact with"*. Three participants (P20, P24, P26) also noted the adaptability of the robot during the interaction, e.g., *"I liked that the robot gave me options on what I wanted to do"* (P24).

2. **Human-like Experience:** Ten comments collectively underscore the human-like characteristics exhibited by the robotic coach. Participants remarked on the robot's human-like attributes, including expressions, emotional responses, humour, and gestures (e.g., P8, P9, P39). These human-like characteristics made participants feel as though they were interacting with a person rather than a machine, e.g., P15 stated *"It felt like a person helping me, but it's not a real person, so that was great for me. Because sometimes I do not want a real person to see me having anxiety attacks"*.

Table 6.9: Examples of participants' quotes regarding relaxation exercises

Relaxation Exercises	**Participants' Quotes**
Experience of Relaxation	P9: "I found it really useful as the breathing technique helped me to calm down." p16: "I really find it helpful all the techniques robot taught me and I already feel relaxed after this session." P24: "Before coming to the session I was stressed and the techniques in a way helped me calm down and relax." P34: "Relaxation techniques were really good and made me relaxed during the session." P42: "There were a lot of techniques explained by the robot about how and why they work. When putting them into practice, I seemed to calm down and relax more."
Willingness to Continue Practising Learned Techniques	P2: "The techniques I learned actually made me feel more relaxed. I will probably do them in the future." P5: "I will continue to practice the techniques as these techniques really made me feel relaxed and less anxious. I think these techniques would be great for me in a stressful situation or in a situation involving public speaking." P30: "I felt relaxed doing the breathing exercises, which I will use frequently in the future." P32: "The techniques seem legitimate and worth considering using the next time I feel anxiety related to public speaking or just talking to people." P38: "I would continue with the guided imagery technique mentioned because I felt very relaxed after doing it." P39: "I heard about some of those techniques but I didn't do it before. Doing it with a robot feels good and real to me. I think in future, I will do muscle relaxation and write positive thoughts." P44: "Sometimes I go to panic zone when I have presentations, definitely, I will be using the Mindfulness breathing and Guided Imagery technique that the robot taught me." P45: "The exercises like the affirmations were very helpful to me, and I'll use them again."
Personal Preferences for Specific Techniques	P8: "I felt that the muscle relaxation technique was not very suitable to me as I didn't find it to be relaxing. Rather, it required too much focusing. The breathing technique was the best as it helped me to calm down very fast." P28: "I might use this robotic coach to help me with the anxiety, except for the exercise which made us imagine the mountains and all. The other two were very engaging and relaxing." P41: "The very first exercise the robot taught me - deep breathing and holding my breath- would be useful in any scenario, including public speaking. I think as someone who has a tight schedule, incorporating this into my life would be highly beneficial and I will continue practising this technique to manage stress and anxiety."

Table 6.10: Examples of participants' quotes on their experiences with the robotic coach

Users' Experiences	**Participants' Quotes**
Robot as a Well-being Coach	P1: "Robot found to be knowledgeable and providing much of a helping advice and techniques." P4: "The session was informative and was helpful in relaxing my mind and body. The robot was compassionate in its responses, which put me at ease in interacting with it." P8: "I felt that the robot does its job well of teaching the techniques to calm oneself." P12: "It was nice and engaging, full of vast knowledge." P19: "It felt like a very safe environment where I could close my eyes and follow along with the instructions and learn." P20: "I liked that the robot let me take my time." P23: "Very friendly, personable, interactive; clear instructions; useful techniques & knowledgeable." P25: "I am really satisfied with the interaction I had with the robot. Before coming here, I was really stressed as my project submission is near, and after the interaction, I am feeling relaxed and calm." P26: "It seemed knowledgeable and I could work at my own pace." P33: "The robot guided the interaction in a very professional, unbiased manner. It made me trust its techniques." P38: "I really like this robot to perform relaxation techniques. It's very capable, organic and warm." P41: "I loved how concise and competent the coach seemed despite being a robot. Although I was skeptical at first, the robot was able to guide me through multiple techniques, which were all great to lower my stress." P42: "Very clear commands and very interactive, easy to understand." P43: "The robot's way of explaining was very clear and interactive."
Human-like Experience	P5: "The robot coach felt much more like a human than I had expected it to. Everything was well organized." P8: "Everyone has different experiences and answering questions helps to understand those experiences. The robot feels like a human as it shows expressions and helps to relax with us." P9: "The robot is very human-like and shows its emotional side. It knows how to crack joke and it feels as if it is looking at me." P38: "The robot coach was very interactive and warm. I feel I was guided by a human coach when I had my eyes closed [during relaxation exercises]." P39: "It was friendly and sometimes I thought it is a real person (even with anime face!) and made me smile. Also, sometimes the robot shakes its head, and this makes it more real, and it seems it has feelings or really can see me!."

Theme 3: Robot's Features

There were 31 comments on different robotic coach's features, including appearance, behaviour, voice, speech rate, and eye contact. Additionally, we received 49 comments specifically regarding participants' opinions on the robotic coach's talking style, as we directly asked for their feedback on this aspect (See Table 6.11 for more details).

1. **Robot's Appearance:** There were four comments regarding the robot's appearance, and all appreciated the robotic coach's facial features. Participants found the robot's face to be a positive and engaging aspect of their interactions. They described it as lively and resembling that of a human (P18, P34). Furthermore, one participant mentioned it is nice that the robot has a dog face, which contributed to the sense of fun and relaxation during the sessions (P27).

2. **Robot's Behaviour:** Ten comments on the robotic coach's behaviour collectively highlight the significant impact of the robotic coach's facial expressions and movements in creating a human-like and engaging interaction. They found that the robot's smiling and movements, such as nodding in agreement, closing its eyes during relaxation exercises, moving face, and blinking, created a human-like interaction experience (e.g., P8, P16). P8 and P30 also mentioned that the robot's action of closing its eyes during exercises makes it comfortable to practise exercises. P5 appreciated the robot's movements to establish a connection with the person. One participant suggested that increasing head movements could even further make the interaction realistic (P50). Overall, these comments underscore the importance of facial expressions and movements in creating a realistic and engaging interaction with robotic coaches while also fostering a sense of comfort and a working alliance.

3. **Robot's Voice:** Ten participants provided feedback on the robotic coach's voice. Several participants shared positive remarks, describing the voice as convincing, natural, calm, soothing, clear, and easy to understand (P3, P6, P8, P15, P17, P33, P40, P45). However, two participants had contrasting experiences, with one finding the robotic voice unnatural (P30), and another noting a lack of vocal variety (P46).

4. **Robot's Speech Rate:** In total, we received two comments addressing the robotic coach's speech rate, and both comments recommended increasing the speed of speech, e.g., P42 noted *"I think speaking a little faster would be better to keep the person engaged"*.

5. **Robot's Talking Style:** In our survey, we inquired about participants' perceptions of the robot's conversational style. Out of the 49 respondents who answered this question, 28 participants expressed that the robot's conversational style was natural or struck a good balance – neither too formal nor too casual, fitting their preferences for interaction. Nine participants perceived the style as casual and friendly, while five of them recommended an even more casual tone. Additionally, seven participants identified the robot's talking style as leaning toward formal, although they also noted that it was comfortable and easy to follow. Conversely, four participants felt that the style was overly formal for their preference, and one participant (P18) mentioned that *"it still feels a bit robotic"*.

6. **Robot's Ability to Make Eye Contact:** The robot's ability to make eye contact was mentioned in five comments (P3, P6, P20, P35, P48), where participants expressed their appreciation for the robot's ability to establish and maintain eye contact. Although this aspect can be categorized within the behaviour subtheme, we have chosen to separate it to provide greater clarity on participants' opinions regarding making eye contact with the robotic coach. This separation is due to the mixed results discussed in Chapter 5, allowing for a more focused examination of this feature.

Table 6.11: Participants' quotes on robot's features

Robot's Features	**Participants' Quotes**
Appearance	P6: "I like that it has a face." P18: "I liked the face and the expressions, very lively." P34: "I liked the face. The face really resembles a human." P27: "I like animals, so I feel calm among them. It is nice that the robot has a dog face. It makes me feel fun and relaxed."
Behaviour	P4: "I loved how the robotic coach conversations were compassionate, which made me feel less embarrassed about my weakness. The minor details, such as blinking, smiling, closing it's eyes and even winking at the end, made me feel more comfortable talking to it." P5: "I liked how the robot moves to establish a connection with the person." P8: "It smiles at times, and interacting with a smiling face automatically relaxes you as you also tend to smile. The same happens if you have someone who believes that you will do well [...] The robotic coach nodded in agreement and also closed its eyes while relaxing. It was very human-like. Also, it blinks, and its eyes move, which makes it seem as if it is speaking to the person in front of it."

	P16: "Robot was blinking, moving face which feels like interacting with a human itself." P22: "I enjoyed watching the face of the robot coach track my own." P30: "I like how it moved his head when I moved my head. I also liked how he closed his eyes when doing the exercises, made me feel more comfortable doing them." P31: "I liked facial expressions and reactions." P44: "I liked the robot's face movements and showing her reactions." P50: "More head movement can be made to make it more realistic."
Voice	P3: "The guidance voice was pretty convincing and natural." P6: "The robot's voice was calm." P8: "It has a calm and soothing voice." P15: "Her voice was calming, and it was nice to have step by step slow paced help." P17: "Calm and clear voice!" P30: "Robotic voice felt unnatural to me." P33: "I liked the consistent voice and non-distracting behaviour." P40: "Easy to understand the vocal command with perfect guidance." P45: "The robotic coach was straightforward and had a nice voice." P46: "It lacked vocal variety."
Speech rate	P20: "I would speed up the talking." P42: "I think speaking a little faster would be better to keep the person engaged."
Talking style	P5: "I think it was a perfect mix of being formal and enjoyable at the same time. The robot's way of talking and its expressions made me feel very comfortable throughout the session." P7: "I felt the robot's personality was outgoing, kind, and humorous. The talking style was a bit casual but not discomforting. I actually liked that it tried to make a joke and make me laugh." P15: "I didn't mind the talking style. It was formal but not uncomfortably formal." P13: "It was good; it was quite formal, but since we just met, that's understandable." P22: "The robot was definitely too formal. Needs to be more casual to better simulate talking to a human coach." P26: "A bit formal, but thought it was easy to listen to regardless." P28: "It was great, not too formal but not too casual. I guess it is perfect." P32: "I thought it was fine. It seemed to have a good balance between being casual and formal."
Making eye contact	P3: "I loved the eye contact and face tracking thing." P6: "I like that the robot's gaze actually follows my gaze." P20: "I liked that the robot maintained eye contact." P35: "It was my first experience to interact with a robot so it was a good experience for me. The main thing which I like about the robot is the way she was talking and making eye contact." P48: "The nodes and eye contact make you feel engaged completely with the process."

Theme 4: Robotic Coach vs. Other Resources and Robots

37 comments were about using different intervention delivery methods (e.g., the robotic coach, bibliotherapy, voice assistant, etc) to help students manage stress and anxiety related to verbal presentations. Among these comments, 25 participants provided comments on their preferences for using the robotic coach over other resources, e.g. books or voice assistants (see Table 6.12 for examples of the comments). Overall, participants found the interactive and engaging nature of the robotic coach to be more effective in providing support for managing anxiety and relaxation in comparison to other resources. Their positive opinions were shaped by the presence of a visual face, personalization, social elements, sense of presence, and the sense of realistic and natural human interaction.

1. **Interactive:** Ten participants mentioned the interactivity of the robotic coach over other resources, e.g., P3 noted *"I've used some relaxation instruction audiobooks but they are not interactive. Like I frequently lose my focus on what it was saying. On the other hand, this robot coach felt like some kind of personal trainer/therapist which is kind of monitoring what I'm doing. Due to this kind of feeling, it felt interactive and I didn't lose my focus at all. And as I was feeling more and more relaxed, I was kind of increasing trust and focus on the words of the robot".*

   Likewise, P5 mentioned *"I would prefer this robot as it is a great combination of being interactive, calm, relaxing and knowledgeable. I think the robots like this can have the same information found in self-help books and other resources. Additionally, the robot interacts in a way that the information provided becomes very easy to understand".*

2. **Sense of Presence:** Two participants (P13 and P25) highlighted the effectiveness of a robot coach in promoting active engagement and support for maintaining concentration, especially when compared to self-help methods or voice assistants, e.g., P25 marked, *"Self-help books or just voice assistants can not make me concentrate. My mind will always be wandering. But in the case of the robot, I felt that the robot is watching me, understands the problem I am facing and guiding me through the whole process".*

3. **Personal Experience:** Three participants (P7, P19, P21) cited the personalization and interactivity they experienced with the robot coach as the key reasons for their preference over other resources (e.g., *" I felt comfortable with the robot coach that I interacted which had the same gender and similar ethnicity with a warm voice. I may try a different coach, but not preferably, as I already had a good experience with the current one"* (P7)).

4. **Social:** Social aspects of the robotic coach in comparison to other resources noted by three participants (i.e., P6, P16, P49). For instance, participant P16 preferred the robot coach option, citing the lack of a social element in reading books. It was also mentioned that robots similar to the one they interacted with offered a sense of companionship and relatability, creating the feeling of being surrounded by someone like themselves who offers assistance, or as P6 commented *"The robot has social features (face, eyes, behaviours, etc.), which is a strong advantage over the audio apps"*.

5. **Realistic Interaction:** Five participants also underscored the advantages of the robot coach, including its ability to offer a more genuine and human-like interaction, which contributes to its appeal as a preferred choice in comparison to other methods and resources, e.g., *P35: "You will feel the real experience as compared to voice assistant agents and books that won't give you feedback and not feel real"* or *P45: "This robot coach made it feel like a therapist! That was super impressive"*.

6. **Comparison to Other Robots:** Two participants (P38 and P41) expressed positive impressions of the robot used for relaxation techniques in comparison to other robots they have interacted with. For instance, P38 noted *" I tried another robot to do relaxation techniques, but I feel the robot used for this research is more warm and suitable for this task"*. P41 also described the robot as friendly, personable, and notably more expressive and human-like than other robots they had interacted with in the past.

7. **Preference for Other Resources than the Robotic Coach:** Seven participants favoured voice assistants for reasons such as ease of interaction, accessibility, manageability and capability in verbal interaction and expressing feelings emotionally, e.g., P1 noted *"To me, voice assistants seem to be more likely to interact with and also more manageable. In terms of expressing feelings verbally, they are skillful and also capable of interacting well"*. Similarly, P22 stated *"I find voice assistant agents easier to interact with since I don't have to stare at a robotic face (which I found to be awkward). In addition, I think voice assistants like Siri have more emotional voices"*. P6 also pointed out the portability of the voice assistants and that they do not personally find the physical presence of a robot to be crucial for this interaction: *"Because the voice assistants are small, more compact and portable than a robot that I used in this session. The social and interactive appearance (eyes, face, gaze, etc.) of the Furhat is nice, but that is not a crucial feature for me personally"*. Similarly, three other participants mentioned that they found the presence of a physical robot somewhat redundant and only vice would be enough, (e.g., *"I think because only*

the voice matters to provide instructions, and a physical robot is somehow redundant" (P27), or *"I don't necessarily find the need of physical being present important. Having a voice coach is enough for me"* (P20)).

Five participants expressed a preference for bibliotherapy (self-help books or resources) over other resources. They cited several reasons for this preference, such as feeling more comfortable with this approach, being able to focus better, working at their own pace, and not feeling comfortable discussing their anxiety with others, not even a robot. For example, P2 said *"I feel more comfortable in managing my stress on my own. It feels a little bit weird to talk to a robot. Also, I can focus better when I am reading the resources"*. Similarly, P24 commented *"I feel when the instructions come to me at my own pace (i.e. when you read, you choose the pace), I feel more comfortable with the ideas or activities. I've done this in the past, and it has worked well for me"*. P39 also mentioned that *"I think when I read a book or watch a video, I have enough time to think about that technique and if I want, I can do it later. also, I'm not comfortable expressing my anxiety and asking others to help me or give me some advice, even if it is a robot!:D I prefer to overcome this problem by myself"*.

Table 6.12: Example of participants' quotes comparing using the robot to other resources

Robotic Coach vs. Other Resources	**Participants' Quotes**
Interactive	P3: "I've used some relaxation instruction audio books but they are not interactive. Like I frequently lose my focus from what it was saying. On the other hand, this robot coach felt like some kind of personal trainer/therapist which is kind of monitoring what I'm doing. Due to this kind of feeling, it felt interactive and I didn't lose my focus at all. And as I was feeling more and more relaxed, I was kind of increasing trust and focus on the words of the robot." P4: "In my opinion, talking and saying how a person feels is better than just reading about it. I feel better results can be achieved by interacting with another person or a robot coach like in this session. I feel this robot coach serves its purpose, and its better to focus on something that's visible instead of a voice assistant agent." P5: "I would prefer this robot as it is a great combination of being interactive, calm, relaxing and knowledgeable. I think the robots like this can have the same information found in self-help books and other resources. Additionally, the robot interacts in a way that the information provided becomes very easy to understand."

	P15: "It feels like my meditation guide app but more interactive/personal because of the face." P32: "It seems like it would be more enjoyable than the other options. I think more interactivity with such a robot would be fun though."
Sense of Presence	P13: "It's fun and engaging to have a visible face associated with the instructions. Especially to start out, this would help keep me focused and interested." P25: "Self-help books or just voice assistants can not make me concentrate. My mind will always be wandering. But in the case of the robot, I felt that the robot is watching me, understands the problem I am facing and guiding me through the whole process."
Personal Experience	P7: "I felt comfortable with the robot coach that I interacted which had the same gender and similar ethnicity with a warm voice. I may try a different coach, but not preferably, as I already had good experience with the current one." P19: "It felt more realistic and personal than a voice assistant agent." P21: "Books and resources tend to have a lot of information which can be overwhelming to consume. The robot, even though not a real person, allowed a degree of interaction that helped manage stress and anxiety. The guided tutorials made it easy to follow, almost like watching one of those 5-minute meditation videos online, but made it a little more interactive and personal."
Social	P6: "The robot has social features (face, eyes, behaviours, etc.), which is a strong advantage over the audio apps." P16: "I chose this option as I recently used it and feeling relaxed. Moreover, books are boring and one does not feel social when reading books. Robots like this make you feel like you are surrounded by a person like you to help." P49: "It's an interactive and sociable way to relax."
Realistic Interaction	P19: "It felt more realistic and personal than a voice assistant agent." P40: "It will be really interesting if people are practising with robots. Its guided system is perfect, on the other hand, it can provide any information from Internet, and sometimes you will be thinking that a real coach is guiding you. Based on that, I recommend using this robot coach." P35: "You will feel the real experience as compared to voice assistant agents and books that won't give you feedback and not feel real." P41: "Although having self-help books or resources are more efficient, I find that a robot coach like the one I interacted with gives me a sense of familiarity, as if I am in front of an actual person properly guiding me through an activity to lower my anxiety." P45: "This robot coach made it feel like a therapist! That was super impressive."
Comparison to Other Robots	P38: "I tried another robot to do relaxation techniques, but I feel the robot used for this research is more warm and suitable for this task." P41: "This robot was friendly, personable and was more expressive and human-like compared to other robots I have interacted with before."

Theme 5: Robotic Coach and Other Resources vs. Human Coach

38 participants expressed their opinions regarding the preference between using a robotic coach and other resources in comparison to human coaches.

The students had different viewpoints on comparing a robotic coach with a human coach (see Table 6.13 for examples of the comments). 19 students who preferred the robotic coach identified certain factors, such as "availability" (e.g., P9, P14), "non-judgmental" (e.g., P3, P16, P25), "enhanced privacy" (P3), "personalization as per the comfort level of user" (e.g., P3) and "not comfortable with a person" (e.g., P4, P15), "feel less awkward doing the exercises" (e.g., P32), and "easy and comfortable" (e.g., P44).

On the other hand, 12 participants preferred a human coach because of being "more understanding" (e.g., P5, P26), "the ability to identify problems specific to the person" (e.g., P6), "interacting on a more personal level" (e.g., P6), "being more interactive (e.g., communicating verbally)" (e.g., P7, P30), "being more social" (e.g., P13), and "being more responsive" (e.g., P21).

Four students expressed their preference for a voice assistant over a human coach. They cited reasons, such as the need for only a voice to guide them through instructions (P17), the compactness of Google Nest, which can be placed anywhere (P18), their confidence in Google Nest to walk them through relaxation techniques without any issues (P20), and the ease of interaction (P22).

Three students preferred bibliotherapy (self-help books or resources) over human coaching due to discomfort with human coaches and face-to-face treatment (P2, P39), as well as the non-judgmental and cost-effective nature of books (P24).

Table 6.13: Examples of the participants' quotes comparing using the robot to human coaches

Robot and other resources vs. Human Coach	**Participants' Quotes**
Quotes on Preferences for a Robotic Coach	P3: "I guess because the experience I got was similar to a human coach, and at the back of my mind, I know that no matter what or how many times I tell/ask the robot something, it will not judge or get annoyed with me. Plus, enhanced privacy between the robot and the user is also a thing. Moreover, it's personalized as per the comfort level of the user."

	P4: "One of the main reasons for my anxiety before presentations is my thoughts like the audience judging my appearance, my knowledge and my ability to convey the material. When I'm scared to present general topics in front of other humans, I am most certainly not comfortable discussing my weaknesses. Thus, I would prefer a robotic coach rather than a human if it serves the same purpose efficiently." P9: "The robot is available and doesn't get tired even if it has to teach relaxation techniques to several people." P16: "Robots are best as I feel they won't have judging thoughts like humans and they will help you with all the techniques to manage stress and not just one that works for them." Q25: "With a robot I have a feeling that it won't judge me. That is the reason I would prefer robot." P32: "Since I know the robot coach isn't a person, I feel less awkward doing the exercises." P44: "The robot was easy and comfortable to interact with." P14: "Robot is more flexible with timing." P15: "Because I would like some help but I do not like the idea of a stranger human coach. I get shy and do not want to talk to a person I don't know, especially when I am feeling vulnerable."
Quotes on Preferences for a Human Coach	P5: "Even though the robot was much different than what I pictured, I think that it's difficult to have a great connection with a robot as compared to a human coach. For instance, in one of the exercises, I could not focus enough on the exercise and I struggled to keep my mind focused on my body. I think I could have conveyed this problem to the coach if I was talking to the human instead." P6: "I think a human coach would be better at identifying problems specific to me, and working with me on a more personal level to target the specific problems." P7: "Although the robot coach that I interacted with was chosen among the non-human delivery methods, I still prefer to interact with a human coach as I can have the most interaction where I can explain my situation and communicate. The robot was a good delivery method, but sometimes I felt I was facing a wall as I could not really talk to it." P13: "I think a human coach would still be more effective for verbal presentations specifically because the knowledge that you are speaking to a real human being adds an element of social consequence, which is an essential part of social anxiety. If you can learn to manage social anxiety in the presence of a real human, it better prepares you to do so in front of many humans, as in a presentation." P21: "The robot coach was great but nothing beats interacting with a human. They are responsive and you truly feel seen and heard." P26: "Bit more personable, and relatable. Most people can understand the anxieties humans feel about presenting and performance, and the lived experience helps me understand that the person I am speaking to is competent. A human can gauge what humans feel better than robots." P30: "I like how a human coach is dynamic and I can ask them questions."

Quotes on Preferences for a Voice Assistant	P17: "As mentioned before, only a source of voice to guide me through the instructions is needed; everything else, appears to me to be redundant." P18: "Google nest is more compact and I can put it anywhere." P20: "I feel Google nest can walk me through the relaxing technique without an issue." P22: "I find it easier to interact with."
Quotes on Preferences for Bibliotherapy	P2: "I wouldn't feel comfortable talking with a human coach." P24: "I think I would still choose books because the association of judgement is gone (no one to look at you, its just the book) but it would also be a cheaper option." Q39: "As I said before, I'm not comfortable to express my weakness to others. I want to do it on my way and find the best way by reading different books or any other resources. Maybe one day I want to go for a seminar or workshop to tackle this problem but I never go for a personal coach and ask for a face to face treatment."

Theme 6: Attitudes Towards Availability of a Robotic Coach at University

30 participants stated their opinions about making the robotic coach available at the university. They generally had a positive attitude towards a robotic coach being available at the university, along with current resources to assist students in managing their stress and anxiety related to verbal presentations. They pointed out various benefits of having access to a robotic coach at the University, which are elaborated on below.

1. **Enhance availability and accessibility to mental health care:** Ten participants noted the potential of the robotic coach to increase the availability and accessibility to mental health care. Among these, 4 participants noted the possibility of 24/7 support through robotic coaches, e.g., *"It will definitely assist students 24/7. Just I'm not sure how a different person will take it. May be very effective in the next ten years when people become comfortable around robots"* (P3).

   The comment made by P7 highlights the potential of robotic coaches as a viable alternative to improve students' access to assistance and enhance the overall support system within the university. *"I actually tried to seek help from our university. Although the university always says they are open with resources, when I actually wanted to talk to someone or needed help, there was a waitlist and not very supportive. If we have a robot as an alternative, I think it would definitely help students to have more access and help"* (P7). Similarly, P19 stated that *"I think it would be easier to access a robot coach than a human, so this is a great tool for students, since accessing human support from the university takes a really long time"*.

Besides, participants remarked on the robot coach's potential to aid students in coping with academic and daily life stress, e.g., *"Students are always under pressure with studies and many more things. They are suffering from stress and anxiety, so if this robot coach is available at the university, students can easily book an appointment, take a session whenever they want and remove their stress and anxiety easily"* (P40), and *"We go through a lot of academic pressure and having a social robot would not only help us manage anxiety related to verbal presentations but daily life stress as well"* (P48).

2. **Useful for people who are not comfortable with a human**: Six participants also noted that introducing robotic coaches at universities could provide support for students who are reluctant to seek assistance from humans, e.g., *"I said it is supportive because people who do not want to seek help to a person having access to help from the robot will be great"* (P15), or *"It would be very helpful for the students to interact with the robot if they don't want to meet a real person for support"* (P50).

3. **Useful for people who fear of being judged**: Five participants pointed out one of the common barriers to seeking assistance among students: the fear of judgment. Robotic coaches, as suggested, could mitigate this issue by offering a non-judgmental and accessible resource. *"I believe that there are some people who do not seek assistance because they are afraid of being judged. Using robotic coaches might solve this issue"* (P2). Likewise, P25 commented, *"I think there are students like who will feel more comfortable with the robot compared to human coach as there will be no thought of judgment"*.

4. **Useful for introverted/shy people:** Three students mentioned the potential of using a robotic coach for introverted or shy individuals, e.g., *"Verbal presentations are a huge part of university courses, and I am aware that many students suffer from expressing themselves even though they know the topic well. Introverts like me would find this as an asset to help manage stress and anxiety"* (P4), and *"People sometimes prefer one-to-one meetings (mostly introvert people), with social robot they can have daily conversations and share their feelings more openly"* (P34). Besides, P22 mentioned *"I think it would be good to have the option for those who are shy"*.

5. **Can help calm down students before exams or presentations or interviews:** Four participants highlight the potential for robotic coaches to be effective in reducing student anxiety before anxiety-provoking academic events, such as exams, presentations, or interviews. P20 specifically mentioned, *"I think it could really help calm down students before exams or presentations or interviews"*. Similarly, P33 stated

that "*I think this would be very helpful before midterms/finals*". P25 also pointed out the versatility of the techniques provided by the robot, noting their usefulness not only for verbal presentations but also during moments of anxiety and stress, such as exams or heavy workloads: *"I feel that the techniques which were explained by the robot are very useful not only for the verbal speech or presentation but also for the times when I feel anxious and stressed, for example, during exams and when I feel that there is a lot of workload"*.

6. **Novelty:** Two comments by P26 and P38 highlight the novelty factor associated with the introduction of robotic coaches in a university context, suggesting that this novelty could positively influence individuals' engagement in relaxation techniques, e.g., P38 noted that *"I think it will catch the attention of people, so they will be more willing to do relaxation techniques before presenting. The robot was capable and novel"*. Similarly, P26 pointed out *"I think since usually counsellors are swamped, using a robotic coach like this could help students. To many, it would be novel as well, which is cool"*.

Theme 7: Use of the Robotic Coach at University

In addition to collecting participants' opinions on a continuous scale regarding their willingness to use a robotic coach if it were available at their university, we also offered a text box to allow for additional comments and insights on the matter.

In total 44 participants provided feedback regarding the use of a robotic coach at the university. 25 participants expressed interest in using the robotic coach due to reasons such as perceived usefulness (e.g., *"I found it pretty useful as it was relaxing and told me three ways to calm"* (P9)), a preference for assistance from the robotic coach rather than relying on human interaction (e.g., *"Because I do not want help from other people. I think if I feel like I need some help, I would use it"* (P15)), and a desire to practice relaxation techniques (e.g., *"I would like to use it again to feel relaxed and practice new relaxing techniques"* (P16)). The availability and the non-judgmental nature of the robotic coach were also highlighted (e.g., *"It has no time boundary. Besides, the guiding session is like almost human"* (P40), or *"It is the best way to open up and talk about my emotions without feeling being judged"* (P48)).

12 participants indicated their interest in using the robotic coach, subject to certain conditions, particularly if it offers features such as personalized advice and customization, e.g., (*"Yes. If I get time in between my work and the robot is nearby. I'll definitely use it. But I don't think I'll be using it multiple times if it's not giving me anything new.*

On the other hand, if it's giving me advice or guidance by detecting my current mood or situation, then I'll definitely be using it" (P3)). Accessibility and privacy are important factors influencing their decision to use the robotic coach, e.g., *"I'd use it if there is a quiet and private environment and the robot is easy to get to and use"* (P6) or *"It depends how easy it would be to access. It's definitely a valuable tool, but unless it were very convenient, I would likely not make it a priority to use the robotic coach"* (P13). Similarly, P19 mentioned *"If it was easily accessible and private, I definitely would"*. However, there are also four participants who expressed reservations about using a robotic coach, citing concerns about repetitiveness (e.g., *"Maybe. I am not sure. I feel like if it gave me the same advice/exercises each time, it might get old"* (P26)). Three participants were not interested in using the robotic coach due to personal preferences for human interaction or other resources (e.g., *"I prefer looking at resources and getting to a conclusion myself (figure out what I have to do)"* (P2)).

Theme 8: Suggestions to Improve the Interaction of the Robotic Coach

1. **More Verbal Interaction:** The feedback from 10 participants indicates a common desire for increased verbal interaction with the robotic coach, e.g., P13 suggested, *"If possible, it would probably be more natural to interact completely verbally with the robot"*, P8 stated *"The GUI seems to take away the human touch of the robot. It would work better if the robot could work completely on speech recognition as it can also detect the tone and understand the participant better. But, it is good to have a robot coach to relax"*. Similarly, P2 mentioned *"I felt the interaction was more one-sided. Most of the time it was the robot talking. I wish there could be more human inputs and voice activated (instead of choosing options on a screen)"*. They found the sessions to be more one-sided, with the robot predominantly delivering instructions verbally while relying on a graphical user interface for input. Participants suggested that a more engaging and interactive experience could be achieved through greater verbal interaction, where the robot prompts responses from the participant, leading to a more enjoyable experience.

2. **Personalization and Adaptability:** The feedback provided by two participants emphasizes the potential for enhancing the robot's effectiveness through personalization and adaptability. P3 suggested that incorporating data from EEG or EMG sensors could enable the robot to adapt and provide more personalized guidance. This adaptability could allow the robot to evaluate the user's relaxation level and adjust its approach accordingly, leading to a more tailored experience: *"If by any way we can make it adaptive by training it on data from EEG or EMG sensors, I*

think it can become more personalized to the user and give better guidance. By this, it can know whether the user is actually getting relaxed or not and at what level". Likewise, P5 emphasized the importance of personalization, particularly in exercises, believing that exercises could be more effective if tailored to individual user reactions: *"I struggled in some of the exercises to keep my mind focused. Even though the robot did everything in a great manner, I think it would have been better if the exercises were more personalized according to how I reacted to them".*

3. **Visual examples or images of the exercises:** The feedback from two participants underscores the potential benefits of incorporating visual aids and explanations within the robotic coaching sessions. P7 pointed out *"For some exercises using muscles [progressive muscle relaxation], I felt it would be nice to have some images/visual explanation"*, P40 also mentioned *"It would be better if it has movement visual picture with it. As a beginner, sometimes it is confusing to understand where I should put my hand or how to do that technique".*

4. **Robot's Appearance:** Four participants noted the importance of visual details and humanization in enhancing the realism and engagement of the robotic coach experience. Participants raised suggestions regarding the appearance of the robot, whether it be a dog or a human-like figure. These suggestions include adding hairstyles, e.g., *"Maybe a hairstyle would be nice to have"* (P15), or *"Have the robot wear a wig looks more real"* (P29), ears for the dog, e.g., *"It would be nice if the dog had ears"* (P27), and reducing the brightness of the robot's face when participants close their eyes, e.g., *"The surrounding and robot's face feels a bit bright when we close our eyes. A suggestion would be when we start the exercise after we close our eyes, the robot face light brightness can be reduced as I felt the light in my closed eye also"* (P28).

5. **Interface:** Three participants' suggestions included having subtitles to the graphical user interface, e.g., *"Having subtitles on the iPad in case you missed what the robot was saying"* (P22), *"adding a progress bar"* (P23), and *"ability to turn up the volume"* (P6).

6.4 Discussion

In this chapter, we presented an evaluation study of a robotic mental well-being coach specifically designed to assist university students in managing their public speaking anxiety by delivering strategies derived from mindfulness-based stress reduction and cognitive behavioural therapy interventions.

The robotic coach's usability and utility were assessed using SUS, resulting in a score of 84.05, falling within the good range and close to excellent. The SUS score confirms that the robotic mental well-being coach is both usable and easy to use for the participants in this study **(RQ4-1)**.

The results from the study indicate a generally high level of acceptance of the robotic mental well-being coach among university students, indicating its potential to positively impact university students' mental health by aiding them in managing their public speaking anxiety**(RQ4-2)**. Notably, perceived "Anxiety" during interactions with the robotic coach received the lowest rating, while all other constructs received higher ratings, surpassing the neutral point 3. Specifically, "Perceived Ease of Use", "Attitude Towards Technology", "Perceived Enjoyment", and "Trust" received the highest average scores, respectively, all exceeding 4. In contrast, the construct of social presence received a slightly lower rating. This discrepancy may be attributed to participants' preferences for more verbal interaction with the robotic coach, as also reflected in the qualitative analysis findings. Regarding the social acceptability of the robotic coach, findings from the RoSAS questionnaire across three dimensions —competence, warmth, and discomfort— reveal that participants generally perceived the robotic coach as competent, warm, and inducing minimal discomfort, with competence receiving the highest rating across three dimensions **(RQ4-3)**.

The study revealed a significant improvement in participants' reported moods after the study **(RQ4-4)**, which could be attributed to the calming nature of the exercises. This observation is also in line with the feedback received from several students who reported feeling notably calmer and more relaxed after engaging in the exercises. Participants in the study also showed an increased willingness to make behavioural changes to manage verbal presentation stress and anxiety, as reflected in their RR scores before and after the study **(RQ4-5)**. The possibility of different outcomes in long-term interactions with multiple sessions is worth considering, reflecting the multi-session approach commonly used in real-world treatment scenarios.

Results from the WAI-SR and the qualitative analysis also suggest that students built a positive working alliance (Task subscale) with the robot **(RQ4-6)**. Given the pivotal role of therapeutic alliance in determining intervention effectiveness, it becomes imperative to explore the possibility of establishing a robust therapeutic alliance within a single session [456]. Our study yielded promising results in this regard, aligning with existing research that suggests establishing a working alliance, focused on the Task subscale, which we identified as most relevant for the present study, is achievable within a single interaction [456].

We also investigated the university students' perception of social robots, examining

factors such as satisfaction, engagement, perceived relaxation, natural behaviour, usefulness of the information, desire to continue further sessions with the robotic coach, and practising learned techniques. All these factors received an average rating exceeding 70, highlighting the positive experience participants had with the robotic coach **(RQ4-7)**.

Finally, we found a statistically significant association between students' intention to Use the robotic coach and their Working Alliance (Task subscale). In addition, we found that students' intention to use the robotic coach has a positive correlation with conscientiousness but no correlation with the other four traits **(RQ4-8)**. Conscientiousness is characterized by diligence, self-discipline, responsibility, and self-aware of their actions [468]. Previous research suggests that there is a correlation between agreeableness and conscientiousness and higher levels of trust in robots and automation technologies [93, 307]. It is regarded as a reliable trait in health predictions, as it can be employed to forecast longevity and the onset of health-related behaviours and certain health issues [67]. Note that we asked participants' personality traits for exploratory purposes and to control for potential confounding factors in our data analysis, and we did not have a particular hypothesis. Thus, there is a need for further research to explore the impact of the user's personality traits on their intention to use the robotic coach. This information would be informative for the development of social robots designed to assist university students in managing their public speaking anxiety by offering adaptive and personalized interventions.

In addition, we asked students several questions about their opinions on their interaction with the robotic mental well-being coach. The TA resulted in 8 distinct themes **(RQ4-7)**.

Relaxation Techniques: Participants found the practised techniques effective for inducing relaxation and expressed a desire to continue practising them beyond the sessions. Findings showed that participants might have different preferences for relaxation techniques. To accommodate the diverse needs of individuals, the robotic coach we developed offers a wide range of relaxation exercises. These exercises have been widely used by MHPs, indicating their effectiveness. Nevertheless, it is essential to underscore that no single method can universally apply to all individuals, as confirmed by our research findings. Consequently, providing individuals with a variety of options is crucial to enable them to explore and identify the most suitable relaxation technique that aligns with their unique needs and preferences.

Interaction Perceptions: Overall, the participants gave positive feedback on their interaction with the robot as a well-being coach. Students shared their thoughts on the system and found the robot engaging, relaxing, knowledgeable, and beneficial to learning relaxation exercises. They also highlighted the human-like experience with the robotic coach, fostering a sense of working alliance and comfort that made them feel like they were

interacting with a person, not a machine.

Robot's Features: The robot's appearance and behaviour received mostly positive feedback, with a suggestion for more head movement to make it more natural. Regarding the robot's voice, opinions were mixed; some found it natural, calm, clear, and easy to understand, while others perceived it as robotic with a lack of vocal variety. Participants had varied opinions on the robotic coach's talking style; while several participants found it balanced and not too formal, or too casual, other participants had different opinions. These findings emphasize the importance of designing robot-based interventions to enable users to customize their interactions with robots according to individual needs and preferences. In general, we observed positive feedback regarding the concept of making eye contact. We separated this aspect from the behaviour subtheme to better understand participants' views on making eye contact with the robotic coach. This separation helps us focus on this particular aspect due to the mixed results discussed earlier. However, this aspect of the robot's behaviour needs to be investigated in more detail in future studies focusing on delivering mental health interventions for individuals experiencing stress and anxiety in social situations. The robot's ability to make eye contact is a feature that can be designed in social robots in such a way as to be customized based on the individual needs of users, e.g., frequency and duration of eye contact.

Robotic Coach vs. Other Resources and Human Coaches: In this study, most of the participants showed preferences for the robotic mental well-being coach over the other resources due to reasons such as being more interactive, personal, social and realistic. Participants who selected the voice assistant acknowledged the ease of use, accessibility, portability, manageability and capabilities of the voice assistants in verbal interaction, especially in expressing feelings and emotions. They also noted that voice is enough for them for this type of interaction, and physical robots would be redundant. Similarly, participants who opted for bibliotherapy mentioned reasons such as increased comfort, enhanced focus, the ability to work at their own pace, and a reluctance to discuss their feelings with others, including a robot. While the findings on comparing the preferences for robotic mental well-being coaches to other resources suggest the potential use of social robots as mental well-being coaches to support individuals' public speaking anxiety, it is essential to note that unavailability, price of the social robots and maintenance expenses are possible barriers to adopting this technology in comparison to other technology-based mental health interventions. Therefore, there is a need for further research and development to address these challenges and enhance the feasibility of integrating social robots into mental health interventions. Specifically, future efforts should focus on optimizing the affordability, accessibility, and maintenance of social robots for a broader population. For instance, in this research, we suggest providing access to these robotic coaches on campus,

alongside other resources, to expand their outreach to a greater number of university students and enhance accessibility to mental health services. However, further empirical research in this area is crucial to determine the long-term effectiveness of these interventions and to identify the most effective ways to integrate them into existing mental health care systems.

It is important to note that the primary focus of this study was not to directly compare human coaches to robotic coaches, as we consistently emphasize the assistive role that robots can play in this context to complement existing interventions. Rather, the study aimed to identify areas where a robotic coach has the potential to address specific needs to enhance access to mental health care. For example, students who favoured the robotic coach over human coaches pointed out specific factors, including availability, non-judgmental interaction, enhanced privacy, personalization based on the user's comfort level, discomfort with human interaction, reduced awkwardness during exercises, and ease and comfort. Conversely, participants who preferred human coaches cited reasons such as greater understanding, the ability to identify individualized issues, interacting on a more personal level, enhanced interactivity (e.g., verbal communication), increased social interaction, and greater responsiveness.

Attitudes Towards Availability of a Robotic Coach at University and Intention to Use It: The participants in the study have expressed strong support for introducing a robotic coach alongside the current university resources to assist university students in managing the stress and anxiety they experience when giving verbal presentations. They have identified several advantages to having a robotic coach in this context. Firstly, it is seen as a way to make mental health care more available and accessible, potentially reaching students who may not typically seek help from human counsellors. For example, the robotic coach might be beneficial for students who are not comfortable with human interaction and those who worry about being judged, as well as introverted or shy individuals. Furthermore, participants believe the presence of a robotic coach can help students relax before important events such as exams, presentations, or interviews. Lastly, the novelty factor associated with introducing a robotic coach at the university is expected to positively influence students' engagement in relaxation techniques. Overall, these findings underscore the potential benefits of incorporating a robotic coach into university resources to help university students cope with stress and anxiety in social situations.

We also inquired whether students would be open to interacting with a robot if it were made available at the University, and this question generated diverse opinions and responses. While several participants expressed a keen interest in utilizing the robotic coach. Others noted the importance of features such as personalized advice and customization, with accessibility and privacy being key factors influencing their decision. For example,

they expressed a preference for using it if it were easily accessible and private. Concerns about the potential repetitiveness of interactions were also mentioned by a few participants who had reservations about using the robotic coach at university. Overall, the feedback suggests that the acceptance and usage of a robotic coach for relaxation and stress management can be high if it takes into account individual preferences, addresses accessibility concerns, and offers various interventions that support mental well-being.

Enhancing the Robotic Coach Interaction: Participants offered valuable suggestions for enhancing the interaction with the robotic coach. A prevalent theme centred around their strong preference for increased verbal interaction during sessions. They perceived the sessions as somewhat one-sided, with the robot primarily delivering verbal instructions while relying on a GUI for input. Participants recommended fostering a more engaging and interactive experience by encouraging increased verbal interaction, where the robot actively prompts responses from participants. However, it's important to note that creating efficient and effective dialogues in human-robot interaction is still an ongoing challenge. In interactions that require user input, different individuals may need varying amounts of time to think and respond. Yet, robots lack the necessary flexibility to accommodate these pauses, resulting in timing issues such as short or long response times (e.g., see [22]). Furthermore, participants emphasized the significance of personalizing the robot's behaviour, especially for long-term interactions. Additional suggestions encompassed the inclusion of visual aids, exercise imagery, and adjustments to both the robot's appearance and interface.

To the best of our knowledge, this is the first study exploring the use of a fully autonomous social robot as a mental well-being coach to help university students manage public speaking anxiety by delivering strategies derived from evidence-based interventions for social anxiety, such as mindfulness-based stress reduction (e.g., guided imagery, mindful deep breathing) [169] and cognitive-behavioural therapy (e.g., relaxation techniques) [190, 399]. Moreover, the robotic coach introduces the self-affirmation technique [101] to assist university students in reframing negative thoughts related to public speaking with positive and supportive self-talk. The techniques delivered by the robotic coach are shown to be useful for modifying negative thoughts and managing physiological responses of stress and anxiety linked to public speaking, and they could possibly be extended to manage anxiety in other anxiety-provoking situations (e.g., having an interview, taking exams, etc.). In fact, employing social robots in the mental health domain and specifically as mental well-being coaches is a relatively new area of research, and there is still much to learn about their potential and limitations. Further empirical studies are critical in this area to determine the long-term effectiveness of these interventions and how they can be most effectively integrated into existing mental health care systems. The

findings of this study are particularly encouraging for continuing the research and development of social robots that can be successfully adopted by users and complement the work of human experts (clinicians, counsellors, etc.) in supporting university students' mental well-being.

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6.5 Limitations and Future Work

The primary objective of this study was to assess the usability and acceptability of the robotic coach as an assistive to help university students manage their public speaking anxiety. Thus, the focus of this work was to understand the human-robot interaction and how the users perceive a social robot as a coach for managing public speaking anxiety, rather than determining its actual effectiveness in achieving specific outcomes such as alleviating public speaking anxiety. Nonetheless, improvements in participants' moods and the findings of qualitative analysis yielded promising results regarding their experiences of relaxation during the session. While this study didn't directly investigate the effectiveness of the robotic coach in addressing particular objectives, it serves as a foundational step for future research endeavours that may explore its efficacy and impact in more depth. Furthermore, evaluating effectiveness in this context requires long-term interaction, which was beyond the scope of this study.

Besides, we used only one scale (i.e., task) from the Working Alliance Inventory, as it was the only subscale that we deemed relevant to our study. In future research, it is recommended to assess all three subscales of the WAI-SR questionnaire. Another limitation is that most participants were from the Engineering Faculty, although we posted study flyers across campus. Therefore, while results might not be entirely generalizable to students in non-engineering departments, we would like to note that university students across campus are exposed to and typically own digital technology and devices (computers, smartphones, or laptops) in classrooms, and at home. However, there is a potential that students from more technology-oriented departments might be more familiar with and open to this type of intervention. Future studies should consider a more diverse student sample to provide a more comprehensive understanding of the impact of such an intervention on university students. It is also possible that the voluntary sign-up process resulted in a self-selection bias, which is inherent in any user study with participant volunteers. In addition, given the short-term nature of this study, it is possible that the observed results may have been influenced by the novelty effect, which is common in HRI studies [436]. Nevertheless, several participants in this study had prior experience with robots, potentially mitigating the

impact of novelty to some extent. Future research should explore long-term interactions to achieve a more comprehensive understanding of users' perceptions of robotic coaches while avoiding potential biases introduced by the novelty effect.

In our research, we asked participants for their opinions on various approaches to providing mental health support for managing stress and anxiety related to verbal presentations. Specifically, we sought their views on intervention delivery methods, including the same robotic coach they interacted with, different robotic coaches, bibliotherapy (self-help books or resources), voice assistants such as Google Nest, and human coaches. Importantly, our goal was not to compare or replace these resources but to investigate the potential for social robots to complement existing resources, thereby expanding access to mental health services for this application area. It is worth noting that participants in our study did not interact with human coaches or the other resources mentioned. For future studies comparing robotic coaches to human coaches and other methods, such as self-help books and voice assistants, it is crucial to include controlled comparisons to better understand university students' preferences for each intervention method.

Our findings also suggest participants' preferences for more verbal interaction with the robotic coach (see Section 6.3.2), The ability to understand conversations and engage in them is another avenue to explore to provide a more natural and personalized experience. Verbal interaction can enhance users' satisfaction and adoption of these systems. However, continual research and development in natural language processing are imperative to enhance the efficiency of verbal interactions. In addition, as proposed by participants, incorporating visual demonstrations of the exercises during the interaction can enhance engagement, particularly benefiting individuals who are new to these techniques. Furthermore, implementing a progress bar, including subtitles, and allowing users to adjust the volume are additional suggestions that can enhance the overall user experience.

Moreover, feedback from participants regarding their interactions with the robotic coach emphasizes the crucial role of customization in the robot's behaviour and interventions, particularly in long-term interactions. Therefore, we recommend that future research focus on the development of robot-based mental health interventions to enable users to customize their interactions with the robot to align with their individual needs and preferences. This customization can encompass various aspects, including the duration of interaction, amount of eye gaze, the selection of relaxation exercises, adjusting speech rate, and offering a broader range of voice choices. Even more advanced robots could use real-time adaptation (personalization), which might be particularly beneficial in long-term and/or repeated interactions with a robotic well-being coach (cf. [341], [455] for the distinction between customization and personalization).

Chapter 7

Conclusions and Future Work

7.1 Summary of Research

- **Potential Applications of Social Robots in Robot-Assisted Interventions for Social Anxiety**

  Social anxiety is a condition characterized by debilitating fear and avoidance of different social situations and is among the most prevalent mental health disorders. Although non-robotic, evidence-based interventions for social anxiety are already available, factors such as fear of negative evaluation and judgment, embarrassment, and anticipatory anxiety have led to treatment delay and avoidance among individuals with social anxiety, which calls for innovative approaches, including computer-based interventions, that could minimize barriers to accessing treatment and enhance effectiveness. Hence, we started our research in this context by exploring how social robots can be integrated into conventional behavioural and cognitive therapies for both children and adults who struggle with social anxiety to address our first research question: RQ1: What are the potential applications of social robots for social anxiety?

  We propose the application of social robots as tools that could complement the support provided by clinicians in the context of intervention for social anxiety disorder. The purpose of applying social robots in social anxiety treatment interventions is not only to get people into therapy but also to maximize the effectiveness of therapy through increased engagement and continued support outside the therapy sessions. That is, while the ultimate goal of therapy would be to decrease individuals' anxiety

within human interactions, there may be roles a social robot could adopt to assist in the process of getting to that point.

Social robots are physically present and can exhibit various verbal and nonverbal behaviours or affective modalities to create high levels of social interaction. These features could make social robots an effective component in robot-assisted interventions for social anxiety. In addition, We discussed the benefits of social robots and argued that the incorporation of social robots in conventional interventions has the potential to function as a "stepping stone" for individuals with social anxiety, i.e., they could practise social skills and behaviours with a robot before applying their skills to human-human interaction. Engaging in social behaviours without the pressures of interaction with another person can add a novel (likely introductory) layer to treatments. Particularly, individuals with social anxiety who experience excessive fear of negative evaluations — a common cause of stress and anxiety in social situations— may have less tension and stress when they are interacting with a social robot, and the anxiety symptoms experienced during therapy might be more manageable for the individual [333].

In Chapter 3, we discussed incorporating social robots in conventional interventions for social anxiety and outlined different therapeutic roles and applications (e.g., social robots as screening/diagnostic agents, social mediators, peer/interactive playmates, interactive social companion, coach or instructor, robot-mediated interviews with children, robot-assisted therapy, etc.) that social robots can potentially play in activities rooted in conventional therapies for social anxiety. The potential advantages, as well as limitations of integrating social robots in conventional interventions, were also discussed. Finally, we further explained the possible applications of social robots in conventional interventions for social anxiety through several scenarios. Each scenario has been designed to illustrate how social robots as assistive tools might be integrated into each conventional therapy available for social anxiety.

- **University Students' Opinions on Using Intelligent Agents to Cope with Stress and Anxiety in Social Situations**

  Our initial research provided encouraging insights into the potential applications of social robots for alleviating social anxiety. Thus, with a focus on enhancing the mental well-being of university students, particularly in managing stress and anxiety in social situations, we decided to develop a mental well-being intervention through user-centred design methods. This method helps to ensure that the intervention is rooted in the genuine needs and expectations of the end user rather than relying on assumptions made by researchers regarding gaps and needs. Therefore, as a first

step to identifying needs and preferences, we conducted our first study, an MTurk study with 85 participants and a large-scale study with 1054 participants, to address our second research question: RQ2: What are the university students' opinions and preferences for using intelligent agents to cope with stress and anxiety in social situations? The purpose of this study was to investigate students' perceptions of, and preferences for, using different types of intelligent agents (e.g., virtual agents, social robots, etc.) to support their mental well-being, specifically to cope with feelings of stress and anxiety in social situations typically encountered within a university context (e.g., engaging in a group discussion, delivering presentations, expressing opinions, etc.).

Our first study presented an initial step toward the user-centred design of intelligent agents for the purpose of supporting university students' mental well-being. We found that the majority of participants at least occasionally experienced stress or anxiety in social situations as students. Among those who reported "very often" experiencing stress or anxiety, only 149 (50.68%) students have sought help. Students' self-reported experiences of stress and anxiety in common social situations in academic contexts indicated that public speaking is the social situation in which the most stress and anxiety are experienced **(RQ2-1)**. The results also supported that students would be interested in interacting with intelligent agents in this domain. "Animal-like robots" and "conversational agents (e.g., Siri, Bixby, Alexa)" were the most preferred among the given choices of types of intelligent agents **(RQ2-2)**. Furthermore, the results indicated that participants foresee a variety of activities as beneficial for managing anxiety, for which they would be willing to use an intelligent agent such as "receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation, yoga)", "getting help with thinking calming or positive thoughts" and "getting help with building confidence (e.g., through positive affirmations)" **(RQ2-3)**. This study also highlighted several characteristics (i.e., the ability to understand conversations and the ability to learn and adapt its behaviour according to the user's needs and preferences), factors and considerations (i.e., confidentiality, accessibility, enjoyment) that are important for the development of an intelligent agent to support students' mental well-being **(RQ2-4)**. Preferred types of data to be collected by intelligent agents to help students manage their anxiety were "voice, only when interacting with the agent", and "physiological data (e.g., heart rate, blood pressure)". Results also indicated that many participants would allow an intelligent agent to recognize and keep track of their emotional states and/or moods to help address their most anxiety-provoking social situation, and "wearable sensors" and "mobile/smartphones" received significantly higher ratings than "external

sensors (e.g., camera, microphone) to collect such data **(RQ2-5)**.

- **Co-Design of a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety**

  Public speaking anxiety is one of the most common subtypes of social anxiety, and as also confirmed by the results of our first study, public speaking anxiety is prevalent among university students and can negatively impact their academic success and mental well-being. The challenge of limited access to human coaches and interventions necessitates the exploration of innovative technological solutions, such as social robots, to expand and complement mental health support while improving its accessibility. Thus, we conducted our second study to address our third research question: RQ3: How to design and develop robot-based interventions in a user-centred and co-design approach to support students in managing their stress and anxiety in social situations?

  In this study, we employed a co-design approach to design a robotic mental well-being coach aimed at assisting university students in managing public speaking anxiety. The study involved iterative co-design sessions with mental health professionals and engaging university students as end users to gather their insights and perspectives. We implemented a co-design approach to actively involve subject domain experts, including mental health professionals and prospective users, i.e., university students (as informants), in the design process of the robotic coach. This was done to ensure that the functionality of the robotic coach is built upon evidence-based psychological practices relevant to this context and aligns with the needs and expectations of the end users.

  To this end, we first conducted semi-structured interviews and co-design sessions with five mental health professionals as collaborators, actively engaging them in the design process. The mental health professionals emphasized the potential of robots in addressing the gap in mental health resources and provided detailed suggestions for the development of the robot's behaviour, verbal instructions, and mental well-being interventions. Finally, the robotic coach was designed to deliver an intervention by adopting the CBT model. The interaction involves helping individuals identify and understand physiological anxiety responses during or before giving presentations and addressing them through practising three different relaxation exercises to meet the diverse needs of users. The robotic coach also guides students through a technique to challenge negative thoughts common before or during giving presentations and finally encourages individuals to gradually expose themselves to speaking situations to overcome avoidance behaviours. After co-designing the robotic coach's behaviour

and functionality with MHPs, six university students were invited to test the system and share their experiences and provide feedback on the developed robotic coach (as informants in the co-design process). They found the robotic mental well-being coach engaging, relaxing, and knowledgeable and provided suggestions for improving its interaction and behaviours (e.g., robot's facial expression, talking style and speech rate).

- **Evaluating a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety**

  After revising the robotic mental well-being through multiple iterations based on feedback from MHPs and students, in our third study, we evaluated the usability, acceptability, and user perceptions of the robotic mental well-being coach designed through co-design sessions with MHPs and university students to assist students in managing public speaking anxiety. Graduate and undergraduate students (N=50) were recruited at the University of Waterloo to interact with the robotic mental well-being coach. The purpose of this study is to address our fourth research question: RQ4: What are the usability and acceptability of the robot-based intervention, developed through the co-design process, to support students in managing their stress and anxiety in social situations?

  The robotic coach achieved a high usability score of 84.05 on the SUS questionnaire, demonstrating the high usability of the robotic mental well-being coach for managing public speaking anxiety **(RQ4-1)**. The results of the acceptability of the robotic mental well-being coach using the constructs from the Almere and TAM questionnaire were presented in Section 6.3.1, indicating participants' acceptance of the robotic coach **(RQ4-2)**. Results on the perceived social attributes of the robotic coach, using RoSAS questionnaire across three dimensions of competence, warmth, and discomfort indicated that participants generally perceived the robotic coach as competent, warm, and inducing low discomfort, with competence receiving the highest rating across three dimensions **(RQ4-3)**. Notably, the study revealed that participants' self-reported moods improved significantly after the study **(RQ4-4)**. Additionally, there was an observed increase in participants' willingness to make behavioural changes to manage verbal presentation stress and anxiety **(RQ4-5)**. Findings also suggested the potential of the robotic coach to establish a working alliance over one session, which is a pivotal factor in the health and mental health field for achieving positive treatment and intervention outcomes **(RQ4-6)**. We also explored the users' experiences by investigating factors such as satisfaction, engagement, relaxation, the robot's natural behaviour, the usefulness of information, desire

for more sessions, and practising learned techniques. Achieving high ratings in all factors indicates that participants had a positive experience with the robotic coach. Overall, participants' qualitative feedback suggested that they perceived the robotic coach as engaging, calming, knowledgeable, and advantageous for learning relaxation techniques. Furthermore, the findings point to the potential for integrating social robots into the university's existing resources for supporting students' mental health while also highlighting areas for improvement in the design and interaction of the robotic coach **(RQ4-7)**. Finally, our analyses suggested that the students' conscientiousness personality trait and working alliance between students and robotic mental well-being could impact the intention to use the robotic coach **(RQ4-8)**.

In summary, the comprehensive steps undertaken in this thesis enabled us to employ user-centred design methods in the development of a novel robotic mental well-being coach for addressing public speaking anxiety among university students. In addition, the evaluation procedure outlined in this thesis, with our participant sample, suggested positive outcomes in terms of the perceived usability, acceptance, and intention to use the robotic coach and presented a proof of concept for the potential of social robots as mental well-being coaches to support university students' public speaking anxiety.

7.2 Contributions to Original Knowledge

The goal of this thesis was to explore the potential applications of social robots in promoting university students' mental well-being. The research specifically focuses on social anxiety and developing robot-assisted interventions aimed at helping university students effectively cope with stress and anxiety in social contexts. Applying social robots to help individuals with social anxiety has seen relatively limited attention. To the best of our knowledge, this research is the first work toward understanding how social robots could be integrated into conventional behavioural and cognitive therapies for individuals with social anxiety. While we have discussed this approach for individuals with social anxiety, certainly, social robots could also be used for individuals who are below the threshold for a diagnosis of social anxiety disorder but experience some difficulties and distress when participating in social situations.

The primary original contributions to knowledge are explained in more detail in their respective chapters. In this section, we provide a concise overview of how this interdisciplinary research has contributed to the fields of mental health and well-being, assistive robotics, HRI and HAI by addressing a critical gap in research.

Chapter 2 of this thesis provides an overview of social anxiety and evidence-based behavioural and cognitive treatment approaches for this condition, as well as a review of existing assistive technologies for mental health interventions and specifically social anxiety. Research in Chapter 3 presents the first original contribution. Research on potential applications of social robots in robot-assisted interventions for social anxiety is a relatively novel area of research with limited existing studies. In this chapter, we provided a detailed discussion on potential applications of social robots as assistive tools in interventions for social anxiety by proposing the incorporation of social robots in the current conventional CBT approaches for both children and adults who struggle with social anxiety. We categorized the different therapeutic roles that social robots can potentially play in activities rooted in conventional therapies for social anxiety and oriented towards symptom reduction, social skills development, and improvement in overall quality of life. To illustrate the potential applications, we outlined several scenarios. These proposed scenarios are meant as 'food for thought' for the research community, which we hope will inspire future research. This chapter concludes by highlighting the potential advantages as well as limitations of integrating social robots in conventional interventions to improve accessibility and standard of care, as well as outlining future steps in relation to this research direction. In a nutshell, the goal of this chapter is to promote exploration and future empirical work and interdisciplinary collaborations to advance the field of robot-assisted mental health interventions in order to benefit clients and clinicians, improving the mental health and well-being of those in need. Researchers in the field of HRI and psychologists working with individuals experiencing social anxiety may find these knowledge contributions to be of interest.

Outcomes:

Samira Rasouli, Garima Gupta, Elizabeth Nilsen, and Kerstin Dautenhahn. Potential Applications of Social Robots in Robot-Assisted Interventions for Social Anxiety. *International Journal of Social Robotics*, 14(5):1–32, 2022.
https://doi.org/10.1007/s12369-021-00851-0

Samira Rasouli, Garima Gupta, Moojan Ghafurian, and Kerstin Dautenhahn. Proposed Applications of Social Robots in Interventions for Children and Adolescents with Social Anxiety. Proceedings *Sixteenth International Conference on Tangible, Embedded, and Embodied Interaction*, TEI '22, New York, NY, USA, 2022. Association for Computing Machinery. https://doi.org/10.1145/3490149.3505575

The work in Chapter 4 was a first step toward the user-centred design of intelligent agents aimed at assisting university students in effectively managing stress and anxiety

within social situations. Earlier studies have pointed out a lack of user-centred design and the failure to address users' specific concerns as some of the contributing factors to diminished user engagement in digital mental health interventions. Chapter 4 presents findings of an online survey with 1054 undergraduate students, aiming to identify (i) whether students experience stress or anxiety in social situations common at university, (ii) the most anxiety-provoking situations students experience at university, and (iii) students' perceptions of, and preferences for, using different types of intelligent agents (e.g., virtual agents, social robots, conversational agents) to support their mental well-being, (iv) activities that students believed would be beneficial for managing stress and anxiety, and they would be willing to use an intelligent agent for them, (v) students' opinions of the important characteristics of an intelligent agent in supporting mental well-being, (vi) design factors and considerations that would make students more inclined to use an intelligent agent for helping with their most anxiety-provoking situation, and (vii) types of data that participants would allow an intelligent agent to record to support their mental well-being.

In this work, we provided an overview of various design factors and characteristics affecting user acceptance and adoption of intelligent agents. We created the survey questions through an iterative process where the questions were reviewed and revised by different team members with different academic backgrounds. Moreover, we discussed design implications for intelligent agents supporting students' anxiety. To summarize, the main contributions of this work is to provide researchers and designers with valuable insight into designing intelligent agents as assistive tools to help students manage their stress and anxiety by emphasizing university students' needs, opinions and preferences on different social, technical and design elements that should be taken into account when developing such intelligent agents. This contribution to knowledge is likely to be of interest to psychologists, roboticists, as well as HRI and HAI researchers who are interested in developing technology-based interventions to support university students' mental well-being.

Outcomes:

Samira Rasouli, Moojan Ghafurian, and Kerstin Dautenhahn. Students' Views on Intelligent Agents as Assistive Tools for Dealing with Stress and Anxiety in Social Situations. Proceedings *10th International Conference on Human-Agent Interaction*, HAI '22, pp. 23–31, New York, NY, USA, 2022. Association for Computing Machinery. https://doi.org/10.1145/3527188.3561932

Samira Rasouli, Moojan Ghafurian, Elizabeth Nilsen, Kerstin Dautenhahn. University Students' Opinions on Using Intelligent Agents to Cope with Stress and Anxiety in Social Situations. Accepted for journal publication and published online in *Computers in Human Behavior*, doi:10.1016/j.chb.2023.108072 2023.

Chapter 5 introduces another contribution of this research, involving the collaborative design of a robotic mental well-being coach aimed at assisting university students in managing public speaking anxiety. Collaborative co-design sessions with five mental health professionals (the envisioned secondary users) were conducted to identify the design-related needs (i.e., robot behaviour and interactions) for developing a robotic coach that can effectively assist students experiencing public speaking anxiety. The co-design process involved conducting 17 sessions with these professionals over ten months to design the robot's behaviours and functionalities to meet the university students' specific needs. Although co-design studies demanded a considerable amount of time and effort, by involving mental health professionals in the design of the robotic mental well-being coach, we ensured that the robot's functionalities design was grounded in evidence-based practices and aligned with the best practices of psychological support in this application area that can be delivered by a robotic coach. Besides, given the sensitive application area of mental health and well-being, it was essential for us that the robotic coach's behaviour and functionalities be carefully designed with the help of experts in the field of mental health and tested by them before conducting empirical experiments with the university students at the University of Waterloo. Furthermore, a study involving university students (the envisioned primary users) was conducted to gather their opinions for further improvements to the robotic coach. The findings and discussions in this chapter contribute to the growing body of knowledge on using social robots in mental health care and will provide valuable insights for developing a user-centred robotic mental well-being coach for supporting university students' mental well-being. This contribution to knowledge might be of interest to HRI researchers and roboticists.

Outcome:
Samira Rasouli, Linda Johnston, Jennifer Yuen, Moojan Ghafurian, Leah Foster, and Kerstin Dautenhahn. Co-design of a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety. Proceedings *International Conference on Human-Agent Interaction* (HAI '23), December 4–7 2023, Gothenburg, Sweden, pp. 200-208. ACM, New York, NY, USA. https://doi.org/10.1145/3623809.3623872

In Chapter 6, the designed robotic mental well-being coach was evaluated by conducting a usability and acceptability study with university students. This study contributes significantly to our understanding of the acceptability, usability, and user experience of a robotic coach designed to assist university students in managing public speaking anxiety. The study's findings strongly suggest that this intervention holds promise as a useful and engaging tool for university students, with the potential to enhance their mental health and

overall well-being. While research on the use of robotic coaches for mental health remains relatively limited, the results of this study also offer a promising step in this direction. In particular, given the growing mental health challenges faced by university students, this study could pave the way for the broader application of social robots as robotic mental well-being coaches to address other well-being and mental health concerns and increase access to mental health interventions. As the participants' comments in this study also highlight, social robots have the potential to reduce barriers to accessing mental health interventions by increasing accessibility and providing support for individuals who may not feel entirely comfortable with human interaction. This approach is likely to motivate a greater number of students to seek assistance, as they might feel more comfortable initiating their support journey with a robot and, if necessary, transitioning gradually to human counselling. Hence, the outcomes of this study provide strong motivation for further research and future empirical work to determine the short and long-term effectiveness of using social robots to support university students' mental well-being in this area. The findings of this work offer valuable insights for designers, HRI researchers and roboticists in the creation of robotic well-being coaches and have the potential to enhance the wider adoption and utilization of social robots for supporting university students' mental health and well-being.

Outcome:
Samira Rasouli, Moojan Ghafurian, Kerstin Dautenhahn. User Evaluation of a Robotic Mental Well-Being Coach to Help University Students Manage Public Speaking Anxiety. (Manuscript in Preparation)

In summary, our key contributions to the fields of mental health and well-being, assistive robotics, HRI and HAI are outlined below:

- To the best of our knowledge, this thesis is the first work to introduce the application of social robots in robot-assisted interventions for social anxiety by discussing the potential roles of social robots in conventional therapies and CBT approaches for both children and adults with social anxiety.
- This research presents the first exploration of students' opinions regarding the use of different types of intelligent agents as assistive tools for managing stress and anxiety in social situations.
- This research contributes valuable insights into the design of intelligent agents as assistive tools to aid university students in managing stress and anxiety in social

situations by presenting the findings and results of a large-scale survey with 1054 university students. This survey identified various design factors and characteristics that should be taken into account when developing such intelligent agents.

- This work employs a user-centred and co-design approach in the development of a novel robotic mental well-being coach to support public speaking anxiety, one of the most common subtypes of social anxiety.

- To the best of our knowledge, this thesis presents the first study to explore the use of a fully autonomous social robot as a mental well-being coach to assist university students in managing public speaking anxiety by delivering strategies derived from evidence-based interventions for social anxiety such as mindfulness-based stress reduction (e.g., guided imagery, mindful deep breathing) and cognitive-behavioural therapy (e.g., relaxation techniques).

7.3 Ethical Considerations

This research on employing social robots as mental well-being coaches raises potential ethical considerations that will need careful examination in future research within this domain. As also confirmed by the findings of our first study (see Section 4.5.2), confidentiality is a critical aspect in the design of technology-based interventions, specifically if these interventions involve collecting, processing, and sharing client data through digital platforms. In these cases, it is essential to design these interventions with robust security and privacy features to ensure that client data remains confidential and protected from unauthorized access or disclosure. For example, to ensure client data confidentiality in technology-based mental health interventions, designers must implement strong security measures such as robust encryption algorithms, secure transmission protocols, and access controls [68, 515]. They should also develop clear privacy controls and limit data collection to only the necessary information for the intended intervention. In addition, it is essential to establish clear standards regarding confidentiality, information privacy, and secure management of data gathered by intelligent agents in the mental health domain [142].

Moreover, adaptation and privacy are two important concepts that need to be carefully balanced in the design of intelligent agents. Although adaptation can lead to a more personalized and satisfying user experience, it inherently necessitates the collection of user data. Thus, it must be implemented in a way that does not compromise user privacy and security. Besides, the researchers and designers must provide users with more transparency and education regarding the data collection and privacy policies to help alleviate

privacy concerns. For example, to mitigate privacy concerns related to data collection by intelligent agents, users should be informed about what data is collected and how it is used. It is important to effectively communicate this information to users since they may possess varying levels of technical knowledge and might not realize that their data is being recorded unless explicitly stated [23]. Moreover, obtaining informed consent is crucial for protecting privacy during data collection, particularly with commercially available agents in this context, as the meticulous implementation of informed consent may not be ensured as required in academic studies [68, 23]. Intelligent agents can also be equipped with customizable privacy settings similar to those available on social media platforms, enabling users to determine and manage the amount of personal information they wish to share. By adhering to these practices, we can ensure that intelligent agents provide value to users while respecting their rights and interests.

7.4 Limitations and Future Work

In this thesis, we presented three studies focusing on designing and evaluating a robot-based intervention for supporting university students' mental well-being. Nevertheless, there are some limitations to the research presented in this thesis. This section outlines the general limitations of this research, while specific limitations related to individual studies are discussed in each respective chapter. First, our studies did not examine the effectiveness and the long-term use of the developed robotic mental well-being coach. Future research should investigate the effectiveness of the robotic coach, as well as the users' experiences in the long term over multiple interaction sessions. Long-term research endeavours should encompass the examination of critical design elements that support sustained interactions, including long-term personalization, adaptability, and the integration of diverse functionalities (e.g., a variety of relaxation exercises). These recommendations, drawn from the findings of this study, are pivotal in meeting users' diverse needs, preventing monotony, and fostering enjoyable and engaging interactions over extended periods. Moreover, in this thesis, our primary focus was on providing mental health interventions to address public speaking anxiety. However, in future research, it could be beneficial to explore integrating presentation practice into this intervention, thereby introducing elements of exposure therapy to enhance the effectiveness of the intervention for addressing public speaking anxiety.

In addition, there are several aspects that could impact HRI that we have not addressed in this work and could be explored in future research. These aspects are outlined below.

- **Personalized and Adaptive Interventions:** Personalized care and support are other components of effective mental health interventions, as they ensure that the individual's unique needs and preferences are taken into account when developing a mental health intervention. Thus, future research can focus on a robot's ability to learn and adapt to the individual's needs and preferences, thereby offering personalized behaviours and interventions. This adaptation can be based on the user's personality, emotional and attentional states and memory of past interactions.

  For instance, social robots can help with providing personalized support by using algorithms and data analysis to track an individual's progress and adapt the interaction based on an individual's specific needs and therapies (e.g., [5]). A promising avenue for advancing robots aimed at supporting students' mental well-being involves the integration of specialized sensors designed to monitor emotional and physiological states. As indicated by our findings in the first study (see Section 4.5.2), many students express willingness and comfort in using wearable sensors and mobile/smartphone devices for gathering such information. Wearable sensors, including readily available devices such as Fitbits or Polar sensors, can be used to track emotional and physiological states to enhance the robot's capability to respond effectively to the emotional and attentional states of the student. By leveraging this information, the robot could offer appropriate psychological interventions, thereby ensuring that the interaction aligns with the intended mental health goals. Note that this is still a very active area of research in the field of robot-assisted interventions, and these objectives might not be immediately feasible in uncontrolled, real-world settings without sustained engagement and supervision from researchers. However, it remains a promising avenue for future research.

- **Improving Rapport:** When considering the effective collaboration of social robots with humans, it becomes essential to focus on their capacity to establish and sustain a positive social rapport through verbal and non-verbal behaviours, even if it is a perceived one [74]. Research suggests that the coordination of an agent's nonverbal cues with individuals would also help improve rapport [201]. Hence, beyond a robot's capacity to execute non-verbal cues for rapport-building, its ability to synchronize these cues with real-time interactions with people holds significant importance, which can be explored in future research in this context. This coordination of an agent's nonverbal behaviours with users has also proven beneficial in enhancing other facets of HRI, including trustworthiness [123], and engagement [434]. Providing adaptive empathetic responses is also an area shown to be beneficial in building rapport (e.g., [286]), which can be further investigated in robot-based interventions.

- **Cultural Diversity:** As recommended by MHPs during our co-design studies, taking into account users' cultural diversity and individual preferences would also be beneficial to make the robot more relatable and appealing to individual users. This approach would also contribute to encouraging usage and fostering sustained interactions with these robotic coaches. Studies in the field of HRI also discussed the significance of considering cultural diversity during human-robot interaction (e.g., see [219]). However, there is a limited body of work focusing on cross-cultural research in the HRI domain. Thus, conducting cross-cultural research can provide valuable insights into the specific requirements and preferences of individuals from various cultural backgrounds and ethnicities, particularly within the field of mental health and well-being.

- **Robotic Mental Well-being Coaches for Children, Adolescents and Older Adults**: In Chapter 3 of this thesis, we discussed the potential applications and roles of social robots (e.g., peer/interactive playmates, interactive social companion, coach or instructor, etc.) in robot-assisted interventions for individuals struggling with social anxiety across various age groups, including children, adolescents and adults. The third study in this thesis serves as a proof of concept, demonstrating promising results in the potential of employing robotic mental well-being coaches to assist university students in managing public speaking anxiety—a prevalent form of social anxiety. Future research could explore the potential of robotic mental well-being coaches to support various age groups, including children and adolescents with social anxiety or those who may not meet the diagnostic criteria for social anxiety but encounter challenges in navigating social situations. Using social robots in mental health interventions, particularly for children, could introduce an element of fun and excitement that promotes engagement and makes the therapy sessions more enjoyable [112]. In the scenarios that we presented in Chapter 3, Section 3.6, we proposed examples of how social robots could serve as coaches or instructors in delivering conventional interventions for social anxiety across a range of age groups, with a particular focus on children and adolescents. For example, social robots can actively engage in activities, such as role-playing exercises, to help participants rehearse simulated versions of feared social situations. Additionally, they can provide guidance in cognitive restructuring exercises and facilitate mindfulness practices to promote emotional well-being. Future work could also explore the possibility of utilizing robotic coaches to enhance the mental health and well-being of older adults.

- **Biofeedback for Managing Public Speaking Anxiety:** Future studies can also examine using biofeedback techniques to develop adaptive and personalized social

robots using physiological signals to address public speaking anxiety (e.g., see [90]). The aim of biofeedback for anxiety and stress management is to empower individuals with the ability to understand and control their physiological responses to stressors [517]. Biofeedback techniques monitor and interpret how individuals' body reacts to different stimuli and anxiety-provoking situations using wearable sensors to measure heart rate, muscle tension (Electromyography (EMG)), and electrodermal activity (Galvanic Skin Response (GSR)), etc. Therefore, in our research, the biofeedback technique can be used for real-time detection of anxiety during practising presentations with a robotic coach and help the robotic coach provide real-time and personalized feedback on practising relaxation techniques discussed in this thesis (e.g., progressive muscle relaxation, breathing techniques, mindfulness practise) and more to assist individuals in managing their physiological symptoms effectively. Incorporating biofeedback has the potential to enhance the results of interventions and increase their overall effectiveness. However, it is crucial to carefully assess its appropriateness when using it for individuals with certain physical health conditions.

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APPENDICES

Appendix A

Study 1

A.1 Ethics Clearance Certificate

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with Human Participants

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Principal Investigator: Kerstin Dautenhahn (Electrical and Computer Engineering)

Student investigator: Samira Rasouli (Electrical and Computer Engineering)

Co-Investigator: Moojan Ghafurian (Electrical and Computer Engineering)

File #: 42722

Title: Students' Preferences Towards the Use of Intelligent Agents to Promote Mental Well-being

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The Human Research Ethics Committee is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 03/28/21 (m/d/y)

University of Waterloo Research Ethics Committees are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Committees are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREC) and IRB00007409 (CREC).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Expiry Date: 03/29/22 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Committee

Heather Root, Senior Manager, Ethics, heather.root@uwaterloo.ca, 519-888-4567, ext. 30469

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: Consent_Form.docx

file: Social Anxiety questions.docx

file: Phobia-Inventory-SPIN Questionnaire.pdf

file: PRCA-24 Questionnaire.pdf

file: Fear of negative evaluation.pdf

file: Recruitment materials-Email.docx

file: Recruitment materials-Social Media.docx

file: Thank you page.docx

Approved Protocol Version 3 in Research Ethics System

This is an official document. Retain for your files.

You are responsible for obtaining any additional institutional approvals that might be required to complete this study.

A.2 Study 1.1: Pilot Study - Demographic Questionnaire

What is your MTurk ID?

→

Please specify your age: (Write NA if you prefer not to share)

Please specify your gender identity: (Write NA if you prefer not to share)

Which of the following describes your current status?

- I am an undergraduate student.
- I am a master's student.
- I am a Ph.D. student.
- I am no longer a student.
- Other? (Please Specify)
- Prefer not to answer

Please specify your primary college/faculty:

How long have you lived in the US?

- I have lived in the US all my life
- less than one year
- 1 year
- 2 years
- 3 years
- 4 years
- 5 years
- 6 years
- 7 years
- 8 years
- 9 years
- 10 years
- More than 10 years
- Prefer not to answer

Please specify your current year in your program:

- Year 1
- Year 2
- Year 3
- Year 4
- Year 5 or more
- Prefer not to answer

How familiar are you with any of these intelligent agents? *

Humanoid Robots

Not familiar at all — Very familiar

Animal-like Robots

Not familiar at all — Very familiar

Other types of robots that are not humanoid or animal-like

Not familiar at all — Very familiar

Conversational Agents (e.g., Siri, Bixby, Alexa)

Not familiar at all — Very familiar

Virtual Agents

Not familiar at all — Very familiar

Please specify if there are other intelligent agents? (Leave the answer blank if there are no other intelligent agents):

A.3 Study 1.2: Study at the University of Waterloo - Demographic Questionnaire

Please specify your age: (Write NA if you prefer not to share)

Please specify your gender identity: (Write NA if you prefer not to share)

Which of the following describes your current program?

- ○ I am an undergraduate student.
- ○ I am a master's student.
- ○ I am a Ph.D. student.
- ○ Other (Please Specify)
- ○ Prefer not to answer

Please specify your primary faculty:

- ○ Arts
- ○ Engineering
- ○ Environment
- ○ Health
- ○ Mathematics
- ○ Science
- ○ Other (Please Specify)
- ○ Prefer not to answer

Please specify your current year in your program:

- ○ Year 1
- ○ Year 2
- ○ Year 3
- ○ Year 4
- ○ Year 5 or more
- ○ Prefer not to answer

How long have you lived in Canada?

- ○ I have lived in Canada all my life
- ○ less than one year
- ○ 1 year
- ○ 2 years
- ○ 3 years
- ○ 4 years
- ○ 5 years
- ○ 6 years
- ○ 7 years
- ○ 8 years
- ○ 9 years
- ○ 10 years
- ○ More than 10 years
- ○ Prefer not to answer

Do you live alone?

- ○ Yes
- ○ No
- ○ Prefer not to answer

How familiar are you with any of these intelligent agents? *

Humanoid Robots

Not familiar at all — Very familiar

Animal-like Robots

Not familiar at all — Very familiar

Other types of robots that are not humanoid or animal-like

Not familiar at all — Very familiar

Conversational Agents (e.g., Siri, Bixby, Alexa)

Not familiar at all — Very familiar

Virtual Agents

Not familiar at all — Very familiar

Please specify if there are other intelligent agents? (Leave the answer blank if there are no other intelligent agents):

A.4 Survey Questions

To what extent do you feel the following characteristics are important in an intelligent agent for supporting mental well-being? *

Ability to recognize persons (e.g., recognizing the user)

Not important at all — Very important

Ability to perceive, understand, and express emotions

Not important at all — Very important

Ability to make eye contact

Not important at all — Very important

Ability to understand conversations

Not important at all — Very important

Ability to engage in conversations

Not important at all — Very important

Ability to play games

Not important at all — Very important

Ability to tell jokes

Not important at all — Very important

Ability to learn and adapt its behaviour according to your needs and preferences

Not important at all — Very important

Please specify if there are other characteristics? (Leave the answer blank if there are no other characteristics).

Do you ever experience anxiety or stress in social situations?*

- ○ Never
- ○ Rarely
- ○ Sometimes
- ○ Often
- ○ Very Often
- ○ Prefer not to answer

**Branching Questions: If "never" and "prefer not to answer" were not selected, the participant was asked to answer the following questions:*

What are the three (social) situations in which you experience the most anxiety and stress? *

You can select up to three choices.

- [ ] Participating in group discussion
- [ ] Participating in meetings or classes
- [ ] Meeting new people
- [ ] Expressing opinions
- [ ] Communicating at meetings
- [ ] Participating in conversations
- [ ] Engaging in a group discussion or conversation with new people
- [ ] Public speaking (e.g., giving a verbal report or presentation to a group)
- [ ] Asking questions in meetings or classes
- [ ] Answering questions in meeting or classes
- [ ] Reading out loud in meetings or classes
- [ ] Performing in front of other people (e.g., playing a sport, or acting on stage)
- [ ] Going to social events (e.g., parties, dinners or university activities)
- [ ] Joining a club or organization
- [ ] Working in a group (e.g. working on a project with other classmates)
- [ ] Having an interview
- [ ] Inviting others to do things
- [ ] Taking exams
- [ ] Other (social) situations? (Please specify)

Do you experience anxiety before you are actually in your most anxiety-provoking situation? (e.g., you start to feel anxious before you are scheduled to give a presentation)

- ○ Never
- ○ Rarely
- ○ Sometimes
- ○ Often
- ○ Very Often
- ○ Prefer not to answer

Have you ever sought help from a counselor, therapist, doctor, or any other healthcare professional to help you deal with the anxiety experienced during social situations?

- ○ Yes
- ○ No
- ○ Prefer not to answer

Which intelligent agent would you prefer to use for managing anxiety related to your most anxiety-provoking social situation? *

You can choose more than one option

- ☐ Humanoid Robots
- ☐ Animal-like Robots
- ☐ Other types of robots that are not humanoid or animal-like
- ☐ Conversational Agents (e.g., Siri, Bixby, Alexa)
- ☐ Virtual Agents
- ☐ Please specify if there are other intelligent agents?

Please specify to what extent each of the following factors would make you more inclined to use an intelligent agent for managing anxiety related to your most anxiety-provoking social situation? *

Accessibility: How easy it is for you to access it

Not important at all — Very important

Confidentiality: If it is able to maintain the confidentiality of your data

Not important at all — Very important

Adaptability: How well can the agent adjust its interactions based on your preferences and needs

Not important at all — Very important

Ease of use: How easy it is for you to use it

Not important at all — Very important

Engagement: How well you can engage with it

Not important at all — Very important

Enjoyment: How much you enjoy interacting with it

Not important at all — Very important

Companionship: If it is capable of acting as a companion for you (e.g., generates feelings of support or connection in a social and personalized manner)

Not important at all — Very important

Efficiency: How efficient the agent is in helping you in designated tasks

Not important at all — Very important

Intelligence: If the agent is able to show intelligent behaviour (e.g., having memory, capability to learn and make decisions)

Not important at all — Very important

Technical soundness: If the agent is robust to failures

Not important at all — Very important

Effectiveness: If there is evidence of effectiveness to improve mental well-being

Not important at all — Very important

Maintenance: If the agent is easy to maintain (e.g., long battery life, easy to upgrade)

Not important at all — Very important

Social intelligence: If the agent is able to interact socially and has awareness of social norms and conventions (e.g., engage in conversations, recognize the user, and remember the interaction with the user)

Not important at all — Very important

Cost: How affordable the agent is

Not important at all — Very important

Please specify if there are other factors? (Leave the answer blank if there are no other factors):

Which activities do you feel will be beneficial for managing anxiety related to your m anxiety-provoking social situation? *

You can choose more than one option.

- [ ] Receiving personalized psycho-education (e.g., providing education and information about the condition to those seeking or receiving mental health services for it)
- [ ] Receiving personalized coaching for activities and tasks that support mental well-being (e.g., meditation, yoga, journaling, healthy diet and sleeping behaviours)
- [ ] Receiving social skills training (e.g., how to communicate and engage with other people)
- [ ] Getting help with building confidence (e.g. through positive affirmations)
- [ ] Getting help with thinking calming or positive thoughts
- [ ] Practicing social skills via role plays (e.g., practicing public speaking)
- [ ] Monitoring and tracking of mood changes and providing feedback on my progress
- [ ] Receiving companionship (e.g., conversational partner)
- [ ] Receiving daily reminders to keep me on track with activities that support mental well-being
- [ ] Pleasurable activities to improve mental well-being (e.g., playing games, dancing)
- [ ] Receiving extrinsic motivation to achieve academic success
- [ ] Please specify if there are other activities?

**Options for the following question are based on the participant's selected choices for the previous question. We have also included a "none of them" option. The screenshot below illustrates a sample question presented to participants who chose "getting help with thinking calming or positive thoughts".*

Given the selections you made in previous question, for which of those activities would you be willing to use an intelligent agent? *

- ☐ None of them (why?)
- ☐ Getting help with thinking calming or positive thoughts

What types of data would you allow an intelligent agent to record to help address your most anxiety-provoking social situation?*

You can choose more than one option

- ☐ My voice, regardless of whether I am interacting with the intelligent agent or not.
- ☐ My video, regardless of whether I am interacting with the intelligent agent or not.
- ☐ My voice, only when I am interacting with the intelligent agent.
- ☐ My video, only when I am interacting with the intelligent agent.
- ☐ Text conversations with you
- ☐ Physiological data (e.g., heart rate, blood pressure)
- ☐ Physical activity (e.g., via pedometer)
- ☐ Medical information (e.g., allergies, medical conditions, health provider's contact information)

Please specify why you would not allow an intelligent agent to record the type(s) of the data not selected above?*

Would you like an intelligent agent to recognize and keep track of your emotional states and/or moods to help address your most anxiety-provoking social situation (e.g., using external sensors, wearable sensors, or mobile phones)?*

- Yes
- No (why?)
- Maybe (it depends)
- Prefer not to answer

How comfortable/uncomfortable would you be with an intelligent agent monitoring and tracking your emotional states and moods using *external sensors* (e.g., camera, microphone) *

Not comfortable at all — Very comfortable

How comfortable/uncomfortable would you be with an intelligent agent that records your physiological data (e.g., heart rate) *using wearable sensors* to monitor and track your emotional states and moods?*

Not comfortable at all — Very comfortable

How comfortable/ uncomfortable would you be with an intelligent agent that monitors and tracks your emotional states and moods *using a mobile/smartphone* ?*

Not comfortable at all — Very comfortable

Appendix B

Study 2

B.1 Interview Questions with Mental Health Professionals

This is an example of questions posed during the semi-structured interviews with mental health professionals. The interviews were modified based on the mental health professionals' backgrounds and expertise.

1. If a student experiences public speaking anxiety, what techniques would you suggest to the student to help him/her manage it?
2. What specific stress management or coping skills do you think a robot could be used to provide to students to help them manage their public speaking anxiety?
3. What do you think about the robot's interaction style?
4. What do you think about the Furhat robot? What do you think about its advantages and disadvantages in this context? What type of behaviour or capabilities do you expect to see?
5. If you could design any robot in the world, what type of robot would you design to address anxiety and stress among university students?
6. Do you have any concerns about social robots in this application area?
7. Do you have any additional comments or concerns?

B.2 Ethics Clearance Certificate

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with Human Participants

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Principal Investigator: Kerstin Dautenhahn (Electrical and Computer Engineering)

Student investigator: Samira Rasouli (Electrical and Computer Engineering)

Co-Investigator: Moojan Ghafurian (Electrical and Computer Engineering)

File #: 45060

Title: Opinions about a robotic coach to help manage public speaking anxiety

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The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 02/15/23 (m/d/y)

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Expiry Date: 02/16/24 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board

Heather Dekker, Ethics Advisor, hdekker@uwaterloo.ca, 519-888-4567, ext. 41506

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: FurhatUserManual_V1_202301.pdf

file: Procedure_v2_202302.pdf

file: Study_SetUp.jpg

file: Script_v1_202302.pdf

file: Online_ConsentForm_v3_202302.pdf

file: Information Form_v3_202302.pdf

file: AppreciationLetter_v1_202301.pdf

file: RecruitmentMaterial_v1_202301.pdf

Approved Protocol Version 3 in Research Ethics System

This is an official document. Retain for your files.

You are responsible for obtaining any additional institutional approvals that might be required to complete this study.

B.3 Participatory Study - Pre-Study Questionnaire

Please enter the participant's ID you received via an email with the link to the study:

Please specify your age: (Write NA if you prefer not to share)

Please specify your gender identity: (Write NA if you prefer not to share)

Which of the following describes your current program?

- ○ I am an undergraduate student.
- ○ I am a master's student.
- ○ I am a Ph.D. student.
- ○ Other (Please Specify)
- ○ Prefer not to answer

Please specify your primary faculty:

- ○ Arts
- ○ Engineering
- ○ Environment
- ○ Health
- ○ Mathematics
- ○ Science
- ○ Other (Please Specify)
- ○ Prefer not to answer

Have you ever interacted with a robot?

- ○ Yes
- ○ No

What did the robot look like?

- ☐ Human-like robot
- ☐ Animal-like robot
- ☐ Other types of robots that are not human-like or animal-like
- ☐ Other robots
- ☐ Prefer not to answer

How comfortable are you with giving a presentation or speech in front of other people?

- ○ Very uncomfortable
- ○ Uncomfortable
- ○ Neutral
- ○ Comfortable
- ○ Very comfortable

How many presentations or speeches have you given in front of a group of other people during the past year? (Please estimate, e.g., presentations in classes, talking about a topic in a class, etc.)

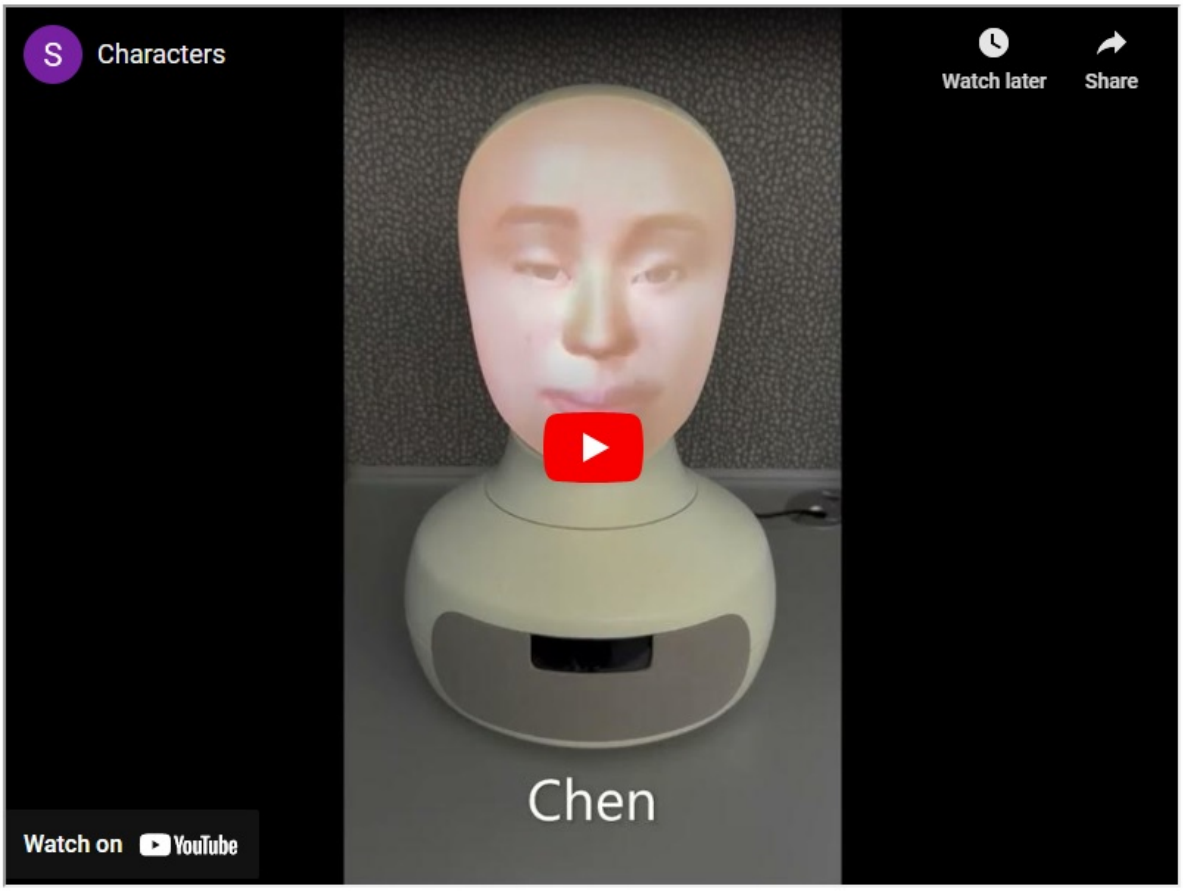
B.3.1 Public Speaking Anxiety (PRCA-PS) Questionnaire

Please indicate the degree to which each statement applies to you: (There are no right or wrong answers. Work quickly; just record your first impressions)

	Strongly agree	Agree	Are undecided	Disagree	Strongly disagree
I have no fear of giving a speech.	○	○	○	○	○
Certain parts of my body feel very tense and rigid while I am giving a speech.	○	○	○	○	○
I feel relaxed while giving a speech.	○	○	○	○	○
My thoughts become confused and jumbled when I am giving a speech.	○	○	○	○	○
I face the prospect of giving a speech with confidence.	○	○	○	○	○
While giving a speech, I get so nervous I forget facts I really know.	○	○	○	○	○

Please watch a short video of the Furhat robot as a robotic mental well-being coach with different appearances (e.g., different skin colours, eye colours, genders, male and female voices).
Once you have watched the video, you will be asked to provide the name of the one you prefer to interact with during the study in the designated textbox.

Please note that you need to *listen to the audio* in the video to select the character with a male or female voice.



Please enter the name of the character you prefer to interact with.

B.4 Participatory Study - Post-Study Interview Questionnaire

1. How was your interaction with the robotic coach?
2. What did you like about your interactions with the robotic coach?
3. What did you dislike about your interactions with the robotic coach? What would you change?
4. What did you think of the robotic coach's personality and talking style?
5. What do you think about the length of the session and the amount of content?
6. Did you encounter any technical problems during the session with the robotic coach?
7. How appropriate do you think the robotic coach was for practising relaxation techniques?
8. What do you think about the robotic coach's appearance?
9. What do you think about the robotic coach's behaviour?
10. What do you think about the robotic coach's speech? Was it understandable?
11. What do you think about the robotic coach's speech rate?
12. What do you think about the robotic coach's making eye contact? Were you comfortable with it or not?
13. Is there anything else you would like to change or add to the robotic coach?
14. Imagine you have various resources available to help you manage stress and anxiety related to verbal presentations, such as self-help books, a robotic coach such as the one you interacted with, or a voice assistant such as Google Nest; which delivery method would you prefer to use?
15. How would you feel about having such a robotic coach on campus all the time?
16. Do you have any additional comments about your interaction with the robotic coach?

B.5 Handout

Handout*: Alleviating Stress and Anxiety*

Stress and anxiety management Techniques:

- ***Relaxation Techniques:***

Thoughts, feelings, and behaviours interact to form an "anxiety cycle." This cycle can be an endless loop that perpetuates anxiety. Relaxation techniques *are our best strategies for slowing down the anxiety cycle at the point of feelings.* There are several types of relaxation strategies. Over the next several weeks, pick a relaxation technique and practice *daily*. Once you have practiced, you will be able to use it more effectively to help cope with anxiety when it arises. With practice when you are not particularly anxious, you will be better able to use the strategy when you need it.

Deep breathing

Deep breathing is one of the best techniques for relieving stress. When you are under stress, your muscles tense and your breathing gets shallow and rapid as you breathe higher in the chest. You can stop this stress response by breathing deeply and slowly from the diaphragm or abdomen. It sounds simple and IT IS!

Progressive muscle relaxation

Progressive muscle relaxation (PMR) increases your awareness of body tension versus relaxation and is a tool to induce a relaxed state. During PMR you tense and then relax targeted muscle groups. The tensing and relaxing over 3-5 repetitions slowly forces the muscles into a state of relaxation.

Guided Imagery (Visualization)

Close your eyes and visualize a serene, comforting place, e.g., a beach or a forest. Use all your senses to savour this place: what do you see, smell, hear, taste, and feel? Prepared scripts are fine, but it is more powerful to use your own imagery which has meaning to you.

Stretching

Graduate students tend to sit a great deal during the day, reading and writing. Muscles, especially the neck, shoulders, and lower back can take a beating. Combine stress with this sedentary picture and you have a recipe for muscle tension. It's good to take many mini power breaks of 5-10 minutes throughout the day to stretch out.

- ***Mindfulness exercises:***

Practice focusing every day. It will help you learn to stay in the moment in your everyday life.

Body Scan: Lie down with your eyes closed. Slowly scan up and down your body for tightness or soreness. If you find a tight spot, stop and breathe into it until it relaxes. You might also imagine healing, white light radiating into the spot.

Object Meditation: Choose a favourite or interesting object, e.g., a stone or a flower. Spend some time observing the object: its shape, hues, textures, smells, and tastes. Go for details.

Mindful Eating: Eating slowly, mindfully. Be aware of all the sensations of the food: taste, texture, sounds, and weight.

Walking Meditation: While you walk, focus on the sensations of the body moving. Soften your eyes and look at the ground a few paces ahead of you. Pay attention to how you walk. Aim to walk with no tension: relax into it, letting your hips and shoulders swing easily. Breathe with your footsteps. It can help to scan your body as you walk, allowing the movement to free up tensions. You may also consider saying a mantra or affirmation in time with the steps.

Resources:

1. The Relaxation and Stress Reduction Workbook by M. Davis, E. Eshelman, & M. McKay. Now in its 5th edition (2000) this is still one of the best self-help books around.
2. Stress Less: Break the Power of Worry, Fear and Other Unhealthy Habits by Don Colbert, MD (2008). Latest information on the effects of stress on your body and ways to help you de-stress.
3. The Mindfulness and Acceptance Workbook for Anxiety: A Guide to Breaking Free from Anxiety, Phobias, and Worry Using Acceptance and Commitment Therapy by Forsyth, John P., and Georg H. Eifert, G.H. (2016). A great self-directed book filled with practical exercises and a CD with scripted meditations.
4. Website: sass.queensu.ca/learningstrategies/

Get mental health support when you need it

Counselling Services:

On-campus contact: 519-888-4096 (8:30 a.m. – 4:30 p.m.)

- Individual appointments and group therapy
- Seminars, workshops, and training sessions for students, faculty and staff
- Crisis intervention
- Walk in and booked appointments for primary medical care

Address: Needles Hall addition, 2nd floor
https://uwaterloo.ca/campus-wellness/

After-hours contacts:

Region of Waterloo

Non-emergency Waterloo Regional Police Services - 519-653-7700
Grand River Hospital - 519-749-4300
St. Mary's Hospital - 519-744-3311
Kitchener-Waterloo Sexual Assault Support Centre - 519-741-8633

Other resources

- Here 24/7 talk line: 1-844-437-3247
- Good2Talk talk line: 1-866-925-5454
- Empower Me: 1-833-628-5589

Appendix C

Study 3

C.1 Ethics Clearance Certificate

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with Human Participants

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Principal Investigator: Kerstin Dautenhahn

Student investigator: Samira Rasouli

Co-Principal Investigator: Moojan Ghafurian

File #: 45372

Title: Evaluating a robotic coach for managing public speaking anxiety

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The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 05/29/23 (m/d/y)

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Expiry Date: 05/30/24 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board

Heather Dekker, Ethics Advisor, hdekker@uwaterloo.ca, 519-888-4567, ext. 41506

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Documents reviewed and received ethics clearance for use in the study and/or received for information:

file: Handout_V1_202305.pdf

file: FurhatUserManual_V1_202304.pdf

file: Flyer1_v1_202305.pdf

file: AppreciationLetter-v2-202305.docx

file: Online_ConsentForm_v2_202305.docx

file: Information Form_v2_202305.docx

file: Procedure_Study-v2-202305.docx

file: Script_v1_202305.pdf

file: Pre-studyemail_v1_202305.docx

Approved Protocol Version 2 in Research Ethics System

This is an official document. Retain for your files.

You are responsible for obtaining any additional institutional approvals that might be required to complete this study.

C.2 Pre-Experiment Questionnaire

C.2.1 Demographic Questionnaire

Please enter the participant's ID you received via an email with the link to the study:

Please specify your age: (Write NA if you prefer not to share)

Please specify your gender identity: (Write NA if you prefer not to share)

Which of the following describes your current program?

- ○ I am an undergraduate student.
- ○ I am a master's student.
- ○ I am a Ph.D. student.
- ○ Other (Please Specify)

Please specify your primary faculty:

- ○ Arts
- ○ Engineering
- ○ Environment
- ○ Health
- ○ Mathematics
- ○ Science
- ○ Other (Please Specify)

Please specify your current year in your program:

- ○ Year 1
- ○ Year 2
- ○ Year 3
- ○ Year 4
- ○ Year 5+

Have you ever programmed or interacted with a robot?

- ○ Yes
- ○ No

What did the robot look like?

- ☐ Human-like robot
- ☐ Animal-like robot
- ☐ Other types of robots that are not human-like or animal-like
- ☐ Other robots (Please specify) _____

How comfortable are you with giving a presentation in front of other people?

Very Uncomfortable ——●—— Very Comfortable

How many presentations have you given in front of a group of other people during the past year? (Please estimate, e.g., number of presentations in classes, conferences, etc.)

C.2.2 Public Speaking Anxiety (PRCA-PS) Questionnaire

Please indicate the degree to which each statement applies to you: (There are no right or wrong answers. Work quickly; just record your first impressions)

	Strongly agree	Agree	Are undecided	Disagree	Strongly disagree
I have no fear of giving a speech.	○	○	○	○	○
Certain parts of my body feel very tense and rigid while I am giving a speech.	○	○	○	○	○
I feel relaxed while giving a speech.	○	○	○	○	○
My thoughts become confused and jumbled when I am giving a speech.	○	○	○	○	○
I face the prospect of giving a speech with confidence.	○	○	○	○	○
While giving a speech, I get so nervous I forget facts I really know.	○	○	○	○	○

C.2.3 Personality Traits (TIPI) Questionnaire

Please indicate the extent to which you agree or disagree with the following statements. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other. ***I see myself as:***

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

C.2.4 Readiness Ruler Questionnaire (Pre-study)

At this moment, how important is it for you to make behaviour changes to manage your stress and anxiety before/during verbal presentations?



How ready are you to make behaviour changes to manage your stress and anxiety before/during verbal presentations?

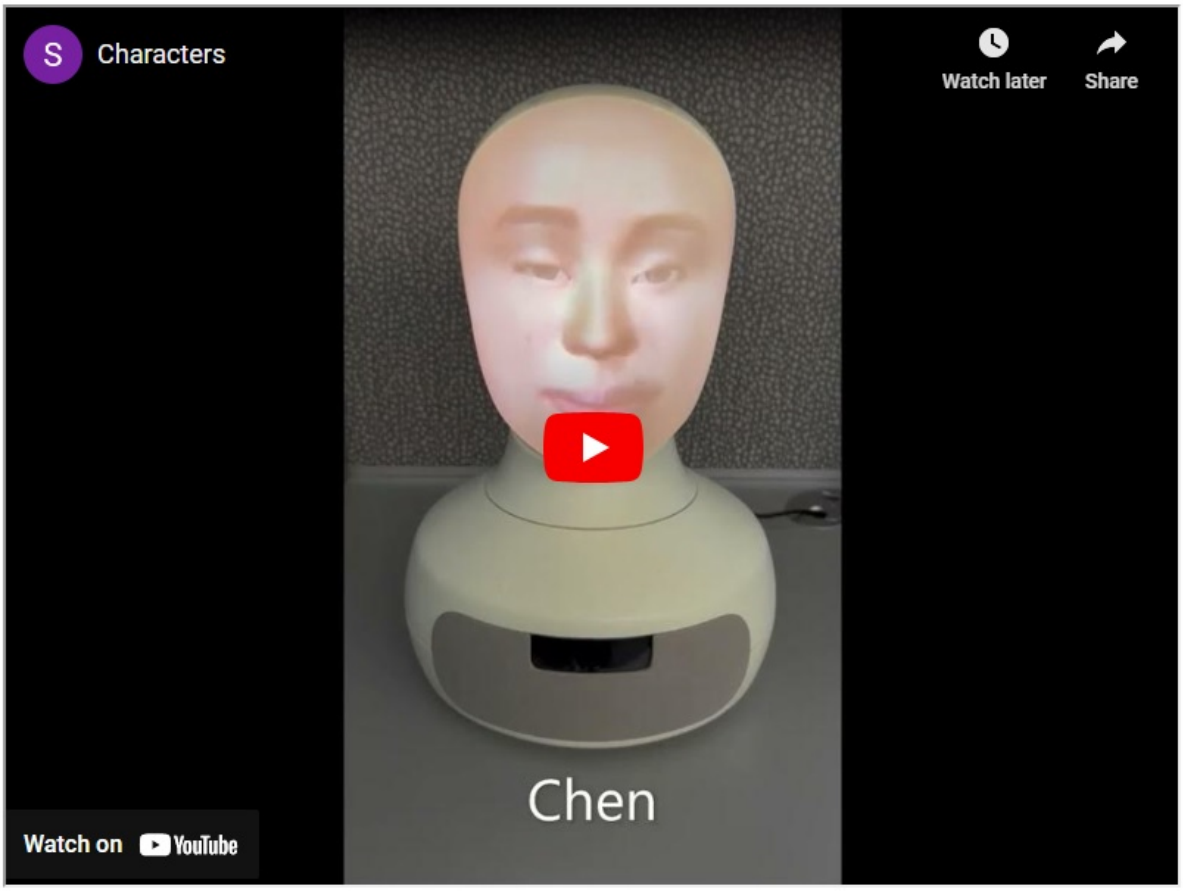


How confident are you in your ability to make behaviour changes to manage your stress and anxiety before/during verbal presentations?



Please watch a short video of the Furhat robot as a robotic mental well-being coach with different appearances (e.g., different skin colours, eye colours, genders, male and female voices).
Once you have watched the video, you will be asked to provide the name of the one you prefer to interact with during the study in the designated textbox.

Please note that you need to *listen to the audio* in the video to select the character with a male or female voice.



Please enter the name of the character you prefer to interact with.

C.3 Post-Experiment Questionnaire

Please enter the participant's ID you received via an email:

C.3.1 System Usability Score (SUS) Questionnaire

Please rank each statement based on how much you agree with it:

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I think that I would like to use this robotic coach frequently.	○	○	○	○	○
I found the robotic coach unnecessarily complex.	○	○	○	○	○
I thought the robotic coach was easy to use.	○	○	○	○	○
I think that I would need the support of a technical person to be able to use this robotic coach.	○	○	○	○	○

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I found the various functions in this robotic coach were well integrated.	○	○	○	○	○
I thought there was too much inconsistency in this robotic coach.	○	○	○	○	○
I would imagine that most people would learn to use this robotic coach very quickly.	○	○	○	○	○
I found the robotic coach very awkward to use.	○	○	○	○	○

	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I felt very confident using the robotic coach.	○	○	○	○	○
I needed to learn a lot of things before I could get going with this robotic coach.	○	○	○	○	○

C.3.2 Acceptability Questionnaire (Part 1)

Please rank each statement based on how much you agree with it:

	Totally disagree	Disagree	Don't know	Agree	Totally agree
I think I'll use the robot in future.	○	○	○	○	○
I'm certain to use the robot in future.	○	○	○	○	○
I plan to use the robot in future.	○	○	○	○	○
I enjoy the robot talking to me.	○	○	○	○	○
I enjoy doing things with the robot.	○	○	○	○	○
I find the robot enjoyable.	○	○	○	○	○
I find the robot fascinating.	○	○	○	○	○

	Totally disagree	Disagree	Don't know	Agree	Totally agree
I find the robot boring.	○	○	○	○	○
I consider the robot a pleasant conversational partner.	○	○	○	○	○
I find the robot pleasant to interact with.	○	○	○	○	○
I feel the robot understands me.	○	○	○	○	○
I think the robot is nice.	○	○	○	○	○
I think the robot is useful to me.	○	○	○	○	○
It would be convenient for me to have the robot.	○	○	○	○	○

	Totally disagree	Disagree	Don't know	Agree	Totally agree
When interacting with the robot I felt like I'm talking to a real person.	○	○	○	○	○
It sometimes felt as if the robot was really looking at me.	○	○	○	○	○
I can imagine the robot to be a living creature.	○	○	○	○	○
I often think the robot is not a real person.	○	○	○	○	○
Sometimes the robot seems to have real feelings.	○	○	○	○	○
I would trust the robot if it gave me advice.	○	○	○	○	○
I would follow the advice the robot gives me.	○	○	○	○	○

	Totally disagree	Disagree	Don't know	Agree	Totally agree
My interaction with the robot is clear and understandable.	○	○	○	○	○
Interacting with the robot does not require a lot of mental effort.	○	○	○	○	○
The robot provides helpful guidance in performing tasks.	○	○	○	○	○
Overall, I find the robot easy to use.	○	○	○	○	○

C.3.3 Readiness Ruler Questionnaire (Post-study)

At this moment, how important is it for you to make behaviour changes to manage your stress and anxiety before/during verbal presentations?



How ready are you to make behaviour changes to manage your stress and anxiety before/during verbal presentations?



How confident are you in your ability to make behaviour changes to manage your stress and anxiety before/during verbal presentations?



C.3.4 Working Alliance Inventory-Short Revised Questionnaire (Task Scale)

Below is a list of statements and questions about experiences people might have with their session or the robotic coach. Think about your experience in the session, and decide which category best describes your own experience.

	Never	Rarely	Occasionally	Sometimes	Often	VeryOften	Always
What I am doing in the session gives me new ways of looking at how to manage stress and anxiety related to verbal presentations.	○	○	○	○	○	○	○
I feel that the things I do in the session will help me to accomplish the changes that I want.	○	○	○	○	○	○	○
As a result of this session, I am clearer as to how I might be able to change.	○	○	○	○	○	○	○
I believe the way we are working to manage stress and anxiety related to verbal presentations is correct.	○	○	○	○	○	○	○

C.3.5 The Robotic Social Attributes Scale (RoSAS) Questionnaire

Using the scale provided, how closely are the following attributes associated with the robotic coach?

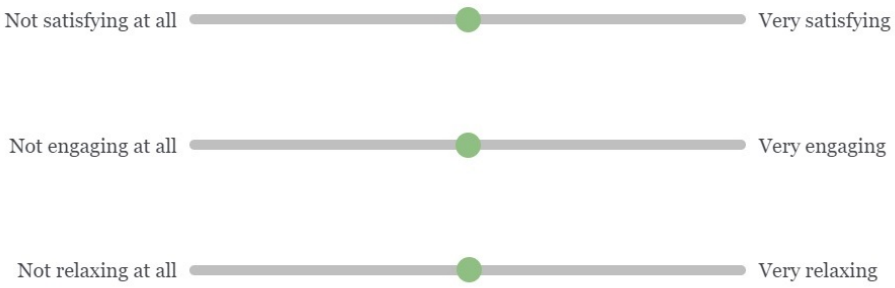
	Definitely Not Associated	Strongly Not Associated	Moderately Not Associated	Slightly Not Associated	Neutral	Slightly Associated	Moderately Associated	Strongly Associated	Definitely Associated
Reliable	○	○	○	○	○	○	○	○	○
Competent	○	○	○	○	○	○	○	○	○
Knowledgeable	○	○	○	○	○	○	○	○	○
Interactive	○	○	○	○	○	○	○	○	○
Responsive	○	○	○	○	○	○	○	○	○
Capable	○	○	○	○	○	○	○	○	○

	Definitely Not Associated	Strongly Not Associated	Moderately Not Associated	Slightly Not Associated	Neutral	Slightly Associated	Moderately Associated	Strongly Associated	Definitely Associated
Organic	○	○	○	○	○	○	○	○	○
Sociable	○	○	○	○	○	○	○	○	○
Emotional	○	○	○	○	○	○	○	○	○
Compassionate	○	○	○	○	○	○	○	○	○
Happy	○	○	○	○	○	○	○	○	○
Feeling	○	○	○	○	○	○	○	○	○

	Definitely Not Associated	Strongly Not Associated	Moderately Not Associated	Slightly Not Associated	Neutral	Slightly Associated	Moderately Associated	Strongly Associated	Definitely Associated
Awkward	○	○	○	○	○	○	○	○	○
Scary	○	○	○	○	○	○	○	○	○
Strange	○	○	○	○	○	○	○	○	○
Awful	○	○	○	○	○	○	○	○	○
Dangerous	○	○	○	○	○	○	○	○	○
Aggressive	○	○	○	○	○	○	○	○	○

C.3.6 User Experience Questionnaire

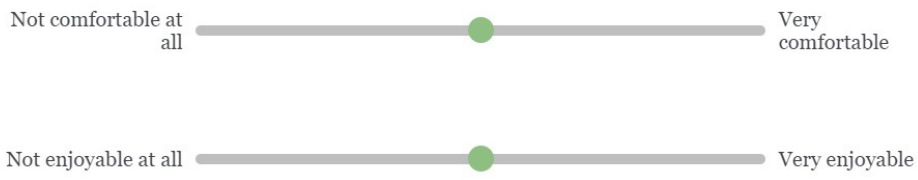
Please describe your interaction with the robotic coach:



I found the behaviour of the robotic coach:



I found practicing relaxation exercises with the robotic coach:



I found the information provided by the robotic coach:

Not useful at all — Very useful

Would you want to continue further sessions with the robotic coach?

Not at all — Very much

Will you continue to practice techniques you learned from the robotic coach?

Not likely at all — Very likely

Have you ever practiced any of the relaxation techniques before being introduced to them today?

- ○ Yes
- ○ No

**Branching question: If "yes" is selected:*

Which one(s) you were already familiar with? (You can choose more than one option)

- [ ] Mindful deep breathing
- [ ] Progressive muscle relaxation
- [ ] Guided imagery

**Branching question: If any of the relaxation techniques are selected:*

How often do you practice Mindful Deep Breathing?

- ○ Rarely
- ○ Somtimes
- ○ Often
- ○ Very Often

How often do you practice Progressive Muscle Relaxation?

- ○ Rarely
- ○ Somtimes
- ○ Often
- ○ Very Often

How often do you practice Guided Imagery?

- ○ Rarely
- ○ Sometimes
- ○ Often
- ○ Very Often

Please answer this question and explain why you chose this answer.

Among the option provided below, which of the following intervention delivery methods would you prefer to use to help manage stress and anxiety related to verbal presentations?

- ○ Bibliotherapy (self-help books or resources)
- ○ A robot coach like the one you interacted with
- ○ A robot coach different from the one you interacted with
- ○ An agent different from a robot, for example, a voice assistant agent, such as Google Nest
- ○ None of them

**Branching question: If any of the above options are selected:*

Could you briefly explain why you chose this option?

**Branching question: If the third option (i.e., a robot coach different from the one you interacted with) is selected:*

Since you chose a different robot coach than the one you previously interacted with, could you please indicate what would you prefer to change or add? (you can choose more than one option)

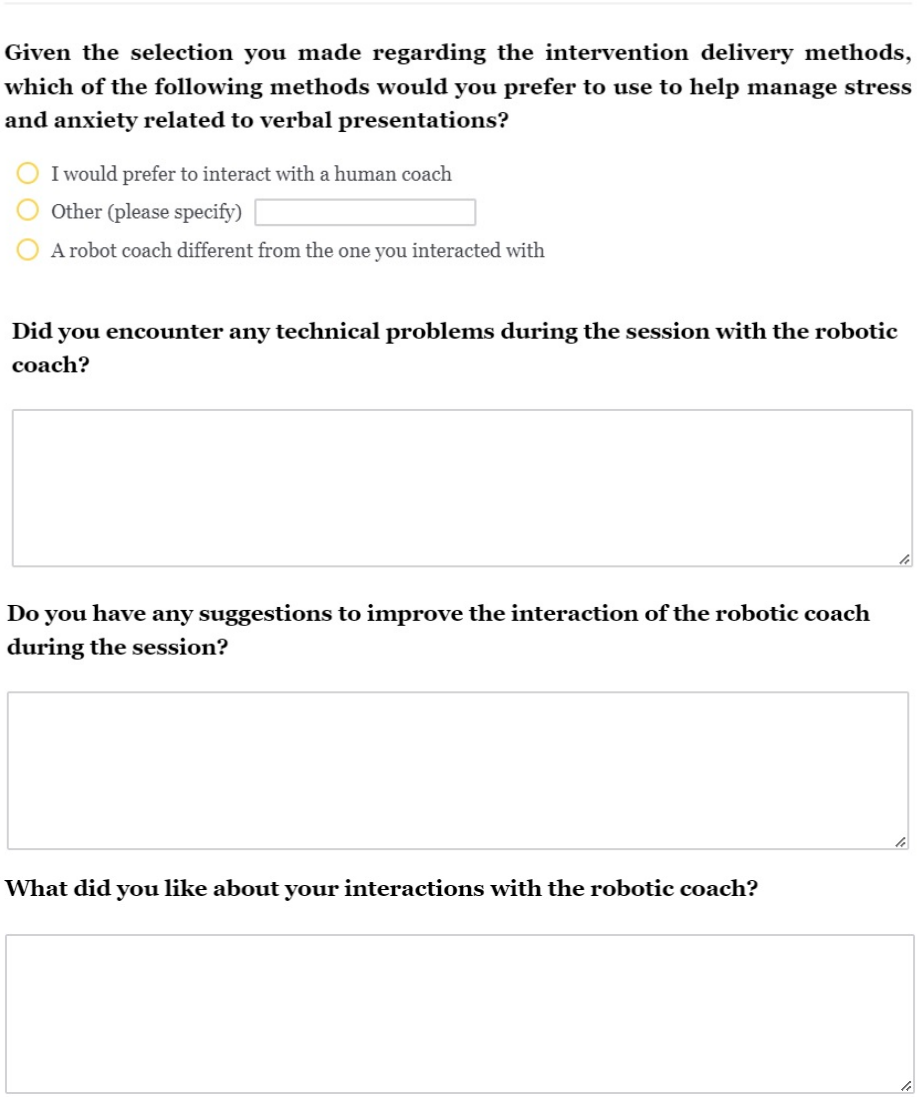
- ☐ Appearance
- ☐ Behaviour
- ☐ Speech
- ☐ Other (please specify)

How would you prefer its appearance to be changed?

How would you prefer its behaviour to be changed?

How would you prefer its speech to be changed?

**Participants were asked whether they preferred a human coach or if they maintained their original choice of intervention delivery method based on their earlier selections. The following screenshot is an example of a question shown to participants who selected "a robot coach different from the one you interacted with".*



Given the selection you made regarding the intervention delivery methods, which of the following methods would you prefer to use to help manage stress and anxiety related to verbal presentations?

- ○ I would prefer to interact with a human coach
- ○ Other (please specify)
- ○ A robot coach different from the one you interacted with

Did you encounter any technical problems during the session with the robotic coach?

Do you have any suggestions to improve the interaction of the robotic coach during the session?

What did you like about your interactions with the robotic coach?

What did you dislike about your interactions with the robotic coach? What would you change?

What did you think of the robot's personality and talking style? (e.g., being too formal or too casual)

How do you feel about making such a robotic coach available at the university along with current resources to assist students in managing their stress and anxiety related to verbal presentations?



Would you use the robotic coach if it were available at your university?



C.3.7 Acceptability Questionnaire (Part 2)

Please rank each statement based on how much you agree with it:

	Totally disagree	Disagree	Don't know	Agree	Totally agree
I think it's a good idea to use the robot.	○	○	○	○	○
The robot would make life more interesting.	○	○	○	○	○
It's good to make use of the robot.	○	○	○	○	○
If I should use the robot, I would be afraid to make mistakes with it.	○	○	○	○	○
If I should use the robot, I would be afraid to break something.	○	○	○	○	○
I find the robot scary.	○	○	○	○	○
I find the robot intimidating.	○	○	○	○	○